## Effects of the Commercial Revolution

In the third and the second millennia B.C. long-distance trade supposedly had the character of an expedition. By the start of the last millennium B.C., however, a new approach to engaging in such trade emerged. Based on the principle of colorization, it was pioneered by the Phoenicians and Greeks, who established colonies along the Mediterranean Sea. The new approach to long-distance trade, known as the commercial revolution, led to changes in a number of political and economic patterns.

For the first time, the planting of colonies in distant lands became possible. The Phoenician settlements in the central and western Mediterranean, such as Carthage, and the slightly later establishment of Greek colonies are early examples, while the settlement of south Arabians in Eritrea around the middle of the last millennium marks the subsequent spread of this sort of commercial consequence to the Horn of Africa. In the third or second millennia B. C., a state such as Egypt might colonize areas outside its heartland, such as Nubia. But this colonization comprised military outposts and ethnic settlements that were planted to hold the contiguous territories of a land empire, not distant localities far separated from the home country.

The commercial revolution constructed the economic basis as well for a new kind of town or city, an urban center that above all serviced trade and was home to the crafts and occupational specializations that went along with commercial development. The urban locations of earlier times commonly drew trade simply because their populations had included a privileged elite of potential consumers. Such towns had arisen in the first place as political and religious centers of the society, they attracted population because power and influence resides there and access to position and wealth could be gained through service to the royal or priestly leadership.

Wherever the effects of the commercial revolution penetrated over the last millennium B. C., kings and emperors increasingly lost their ability to treat trade as a royalty sponsored activity, intended to preserve the commodities of trade as the privileges of immemorial power and position. Instead, their policies shifted toward controlling geographical accessibility to the products of commerce and to ensuring security and other conditions that attracted and enhanced the movement of goods. No longer could kings rely on agriculturally supported and religiously based claims to an ability to protect their lands and people; now they also had to overtly support the material prosperity of their people compared to other societies. And rather than exerting a monopoly over prestige commodities, as had Egyptian kings of the third and second millennia, and redistributing such commodities in ways designed to reinforce the allegiance of their subjects and enhance the awesomeness of their position, rulers turned to the taxation of trade and to the creation and control of currency, more and more relying on duties and other revenues to support the apparatus of the state. It was no historical accident that the first metal coinage in the world began to be made in eighth-century Anatolia (modern Turkey) and that the use of coins rapidly spread with the expanding commercial revolution. The material bases and the legitimizations of state authority as we know them today had begun to take shape.

The commercial revolution tended also to spread a particular pattern of exchange. The early commercial centers of the Mediterranean most characteristically offered manufactured goods— purple dye, metal goods, wine, olive oil, and so forth—for the raw materials or the partially processed natural products of other regions. As the commercial revolution spread, this kind of exchange tended to spread with it, with the recently added areas of commerce providing new kinds of raw materials or new sources for familiar products of the natural world, and the longer established commercial centers— which might themselves have lain at the margins of this transformation—producing, or acting as the intermediaries in the transmission of, manufactured commodities. India, for instance, had developed by the tum of the ear into a major exporter of its own cotton textiles, as well as naturally occurring materials, such as gems of various kinds, and at the same time its merchants were the intermediaries of the silk trade.

## Colonial America and the Navigation Acts

In the seventeenth and eighteenth centuries, the British parliament enacted a number of laws, called Navigation Acts, governing commerce between Britain and its overseas colonies. For example, the Navigation Acts of 1660 and 1663 barred the empire's colonial merchants from exporting such commodities as sugar and tobacco anywhere except to England and from importing goods in non-English ships. Similarly, the Molasses Act of 1733 taxed all foreign molasses (a thick liquid drained from sugarcane and used to make rum) entering the mainland American colonies at sixpence per gallon. This act was intended less to raise revenue than to serve as a protective tariff (tax) that would benefit British West Indian sugar producers at the expense of their French rivals. By 1750 a long series of Navigation Acts were in force, with several effects on the North American colonial economy.

For one thing, the laws limited all imperial trade to British ships, defined as those with British ownership and crews that were three-quarters British. For purposes of the legislation, Parliament classified all colonists as British. This restriction not only contributed to Great Britain's rise as Europe's foremost shipping nation but also laid the foundations for an American shipbuilding industry and merchant marine. By the 1750s one-third of all imperial vessels were American- owned, mostly by merchants in the northeast and in mid-Atlantic colonies. The swift growth of this merchant marine diversified the northern colonial economy and made it more self-sufficient. The expansion of colonial shipping in turn accelerated urbanization by creating a need for centralized docks, warehouses, and repair shops in the colonies. By 1770 Philadelphia and New York City had emerged as two of the British Empire's busiest ports.

The Navigation Acts also barred the export of certain "enumerated goods" to foreign nations unless those items first passed through England or Scotland. The American mainland's chief items of this sort were tobacco, rice, furs, indigo (a Carolina plant that produced a blue dye), and naval supplies (such as masts and tar). Parliament never restricted grain, livestock, fish, lumber, or rum, which altogether made up 60 percent of American colonial exports. Furthermore, Anglo-American exporters of tobacco and rice—the chief commodities affected by enumeration—had their burdens reduced by two significant concessions. First, Parliament gave tobacco growers a monopoly over the British market by excluding foreign tobacco, even though this hurt British consumers. (Rice planters enjoyed a natural monopoly because they had no competitors.) Second, Parliament tried to minimize the added cost of landing tobacco and rice in Britain (where customs officials collected duties on both) by refunding the duties on all tobacco and rice that the colonists later shipped to other countries.

The navigation system's impact on the colonies encouraged economic diversification as well. Parliament used British tax money to pay modest incentives to Americans producing such items as silk, iron, dyes, hemp, and lumber, which Britain would otherwise have had to import from other countries, and it raised the price of commercial rivals' imports by imposing protective tariffs on them. The trade laws did prohibit Anglo-Americans from competing with large-scale British manufacturing of certain products, most notably clothing. However, colonial tailors, hatters, and other small clothes manufacturers could continue to make any item of dress in their households or small shops. Manufactured by low- paid labor, British clothing imports generally undersold whatever the colonists could have produced given their higher labor costs. The colonists were also free to produce iron and built numerous ironworks.

Finally, the Navigation Acts made the colonies a protected market for low-priced consumer goods and other exports from Britain. Steady overseas demand for colonial products created a prosperity that enabled colonists to consume ever-larger amounts not only of clothing but of dishware, home furnishings, tea, and a range of other items both produced in Britain and imported by British and colonial merchants from elsewhere. Consequently, the share of British exports sold to the colonies rapidly increased from just 5 percent in 1700 to almost 40 percent by 1760. Cheap imported goods enabled many colonists to adopt a lifestyle similar to that of middle-class Britons.

## Mass Production: Method and Impact

The technological and managerial innovations of Thomas Alva Edison (the inventor of electricity) and the industrial leaders Andrew Carnegie (iron and steel) and John D. Rockefeller (oil) proved readily adaptable throughout United States industry, spurring marvels of productivity. Late-nineteenth-century industrialists often discovered that their factories produced more goods than the market could absorb. This was particular true in two kinds of businesses: those that manufactured devices for individual use, such as sewing machines and farm implements, and those that mass-produced consumer goods, such as matches, flour, soap, canned foods, and processed meats. Not surprisingly, these industries were trailblazers in developing advertising and marketing techniques. Strategies for encouraging consumer demand and for differentiating one product from another were an important component of the American post-Civil War industrial transformation.

The growth of the flour industry illustrates both the spread of mass production and the emergence of new marketing concepts. In the 1870s the nation's flour mills adopted the most advanced European manufacturing technologies and installed continuous-process machines that graded, cleaned, hulled, and packaged their product in one rapid operation. These companies, however, soon produced more flour than they could see. To sell this excess, the mills thought up new product lines, such as cake flours and breakfast cereals, and sold them using easy-to-remember brand names.

Through brand names, trademarks, guarantees, and slogans, manufacturers built demand for their products and won remarkable consumer loyalty. Americans in large numbers bought a brand of soap first made in 1897 in Cincinnati, Ohio,  because of the absurd overly precise but impressive pledge that it was "99 and 44/100ths percent pure." In the photographic field, George Eastman in the 1880s developed a paper-based photographic film as an alternate to the bulky, fragile glass plates then in use. Manufacturing a cheap camera for the masses and devising a catchy slogan ("you just press the button, we do the rest"). Eastman introduced a system whereby customers returned the 100-exposure film and the camera to the Rochester, New York, factory. There the film was developed, the camera reloaded, and everything shipped back to the customer—for a charge of ten dollars. In marketing a new technology, Eastman had revolutionized an industry and democratized a visual medium previously confined to a few.

By 1900 the chaos of early industrial competition, when thousands of small companies had struggled to enter a national market, had given way to an economy dominated by a few enormous films. An industrial transformation that originated in railroading and expanded to steel and petroleum had spread to every area of United States business, and for those who could not compete in the era's unforgiving economic environment, the cost could be measured in ruined fortunes, bankrupted companies, and shattered dreams. John D. Rockefeller, talking about businesses he wanted to acquire, said he wanted "only the big ones, one those who have already proved they can do a big business. As for the others, unfortunately they will have to die."

The cost was high, too, for millions of American workers, immigrant and native born alike. The new industrial order was built on the backs of an army of laborers who were paid subsistence wages and who could be fired on a moment's notice when hard times or new technologies made them expendable. Moreover, industrialization often devastated the environment with pollution in the relentless drive for efficiency and profit.

To be sure, this industrial revolution brought social benefits as well, in the form of labor-saving products, lower prices, and advances in transportation and communications. The benefits and liabilities were inextricably interconnected. The sewing machine, for example, created thousands of new factory jobs, made available a wider variety of clothing, and eased the lives of millions of consumers. At the same time, it encouraged greedy entrepreneurs to operate factories in which the poor worked long hours in unhealthy conditions pitifully low wages. Whatever the final balance sheet of social gains and costs, one thing was clear: the United States had forced its way onto the world stage as an industrial nation, and the groundwork had been laid for a new social and economic order in the twentieth century.

## Alaska and Bark Beetles

Over the twentieth century, global temperatures increased by an average of about 0.7 degrees Celsius, but some places have warmed a lot more than this, and other places have warmed less. These temperature increases have been enough to trigger changes in ecosystems all over the world, especially in places where the warming has been the greatest. In some places, the changes have been subtle, perhaps a slight shift in vegetation that only a careful observer would notice. In other cases, small changes in climate have sparked a chain of larger effects, leading to massive changes.

The biggest climate-caused ecosystem shifts today are happening at the world's most northern latitudes, where the temperature over the last century has been rising about two times faster than the global average. In the northernmost state of the United States, Alaska, for example, warming has paved the way for a spike in the numbers of spruce bark beetles. Bark beetles have been a pest to Alaskan white spruce trees for thousands of years, but their numbers were held in check by the cold climate, which forced the insects to hide in the bark of individual trees for most of the year. As the length of the warm season increased over the 1980s and 1990s, however, bark beetles had more time to fly from one tree to the next, burrow, and lay their eggs between the bark and the wood. The beetles had another thing going for them, too: a multi-year drought had weakened many of the spruce trees, leaving them vulnerable to attack. In the mid-1990s, the bark beetle population exploded, and over the next few years the pests wiped out white spruce forests over an area the size of the U.S. state of Connecticut. In the years since, the combined forces of a longer insect-breeding season and forest management practices that left forests overcrowded gave way to similar epidemics farther south. Large swaths of pine and spruce have been destroyed by insects in several other parts of the United States.

In the late 1990s, the effects of the bark beetle epidemic rippled throughout Alaska's white spruce ecosystem and affected virtually every population of living organisms, but not all of the impacts were negative. Fewer spruce trees meant a sunnier area in the forest below the treetops, which allowed grasses to move in and take hold. The grasses, in turn, changed the soil temperature, making the environment more friendly for some other types of vegetation. Animals that feed on grasses, including moose, elk, and some birds, also benefited. But the beetle infestation was bad news for organisms that rely on white spruce for their habitat, like hawks, owls, red squirrels, and voles. Volesa type of small, mouselike rodentare an especially vital part of the ecosystem because they help spread mycorrhizal fungi, which attach to the roots of plants and help them take in water and nutrients. Voles are also an important food for a number of predators.

Ecosystem changes always hurt some living creatures and help others. It's hard to say, therefore, whether a change is good or bad overall. Instead, ecologists (people who study ecosystems) often focus on the impacts on a single species: for instance, us. In the short term, the Alaskan spruce beetle epidemic supplied a lot of people with firewood, but only by destroying tons of otherwise valuable timber and threatening the livelihoods of loggers. And no one knows for sure what the long-term impacts on the forest will be. Ecosystems tend to return to their previous states after disturbances like pest outbreaks, fires, or major storm events, but if the Alaskan spruce ecosystem is disturbed too often or too much, it might shift to a different type of forest, a woodland, or a grassland instead.

In extreme cases, major assaults on ecosystems can lead to a total collapse in which the ecosystem doesn't bounce back to the way it was or transition to a new, healthy state. The result is an area with very little life; in the oceans, biologists refer to these areas as dead zones. One such example is the coral reef die-off that happened in the Indian Ocean in the late 1990s.

## Earthquake Prediction

Accurate prediction of earthquakes is not currently possible, although intensive research is proceeding in many areas. Two types of earthquake prediction are theoretically possible. The first type is long-term forecasting, in which the probability of an earthquake along a particular segment of a within a certain time interval is calculated by studying seismic gaps and historical records of earthquakes that have occurred along that fault segment. By plotting the number of earthquakes within specific time intervals against their magnitudes, diagrams can be constructed for a local area. From this plot it is possible to determine the recurrence interval, or the average time interval between earthquakes of a specific magnitude. Predictions can then be made that an earthquake of that magnitude has a high probability of occurrence within a specified time interval, if the date of the last earthquake is known.

Research leading to short-term forecasting, which involves a shorter time interval, has been focused on precursors observed prior to previous earthquakes. Precursors are physical or chemical phenomena that occur in a typical pattern before an earthquake. These phenomena include changes in the velocity of seismic waves, the electrical resistance of rocks, the frequency of the usually minor preliminary earthquakes (foreshocks), the deformation of the land surface, and the water level or water chemistry of wells in the area. Many of these precursors can be explained by a theory called the dilatancy model. Under this hypothesis, rocks in the process of strain along a fault show significant dilation or swelling before rupture. This volume increase is caused by the opening of microcracks, which are minute failure zones in weaker mineral grains in the rock and along grain boundaries. Groundwater flows into the highly stressed areas during the formation of microcracks. These changes in density and water content affect the ability of the rock to transmit seismic waves and conduct electricity. Therefore, seismic-wave velocity and electrical resistance progressively change as the overall rupture along the fault draws near. Localized changes in land-surface elevation are also related to volume changes at depth. An area of recent uplift along the San Andreas Fault near Los Angeles, which has been named the Palmdale Bulge, is being monitored in great detail as a possible indicator of a future earthquake.

Volume changes and groundwater movement may be reflected by changes in water levels in wells and also by changes in the chemical composition of groundwater. Radon gas has been observed to increase in wells prior to earthquakes. These increases are perhaps related to the release of radon gas from rocks during the formation of microcracks. The pattern of seismic activity is also significant in the vicinity of a fault area where rupture is imminent. This pattern consists of an initial rise in the number of small events, followed by a decline in foreshocks just prior to the major earthquake. The decline may represent a temporary increase in rock strength before the newly formed microcracks are filled with water.

The precursor phenomena can be grouped into stages according to the dilatancy model. Stage I consists of a gradual stress buildup along the fault. Stages II and III are correlated with dilatancy and water influx. Stage IV is the major earthquake, and stage V is the aftermath of the event. If every earthquake followed the sequence with uniform stage duration, earthquake prediction would be a simple matter. Instead of following the same patterns, each earthquake is unique in terms of specific precursor behavior patterns and length of precursor stages. A magnitude 6.9 North American earthquake in 1989 was preceded by a substantially smaller magnitude 5 earthquake fifteen months before the event. Another foreshock of similar size occurred two months before the event. In each case, a public advisory was issued stating that those smaller earthquakes could be foreshocks to a stronger earthquake within five days. However, the fault did not cooperate, and those predictions were not successful. Continued research and study of future earthquakes will certainly lead to refinement of the dilatancy model or to a replacement model with more accurate predictive capabilities.

## Soil Fertilization

Fertilizers partially restore plant nutrients lost by erosion, crop harvesting, and leaching. Farmers can use either organic fertilizer from plant and animal materials or commercial inorganic fertilizer produced from various minerals. Three basic types of organic fertilizer are animal manure, green manure, and compost. Animal manure includes the waste matter of cattle, horses, poultry, and other farm animals. It improves soil structure, adds organic nitrogen, and stimulates beneficial soil bacteria and fungi. Despite its effectiveness, the use of animal manure in the United States has decreased. There are three reasons for this: the replacement of most mixed animal-raising and crop-farming operations with separate operations for growing crops and raising animals, the high costs of transporting animal manure from feedlots near urban areas to distant rural crop-growing areas, and the replacement of horses and other draft animals that added manure to the soil with tractors and other motorized farm machinery.

Green manure is fresh or growing green vegetation plowed into the soil to increase the organic matter and humus (degraded organic matter) available to the next crop. Compost is a sweet-smelling, dark-brown, humuslike material that is rich in organic matter and soil nutrients. It is produced when microorganisms in soil (mostly fungi and aerobic bacteria) break down organic matter such as leaves, food wastes, paper, and wood in the presence of oxygen. Compost is a rich natural fertilizer and soil conditioner that aerates soil, improves its ability to retain water and nutrients, helps prevent erosion, and prevents nutrients from being wasted by being dumped in landfills. Compost is produced by piling up alternating layers of nitrogen-rich wastes (such as grass clippings, weeds, animal manure, and vegetable kitchen scraps), carbon-rich plant wastes (dead leaves, hay, straw, sawdust), and topsoil. Compost provides a home for microorganisms that help decompose plant and manure layers and reduces the amount of plant wastes taken to landfills and incinerators.

Another form of organic fertilizer is the spores of mushrooms, puffballs, and truffles. Rapidly growing and spreading mycorrhizae fungi in the spores attach to plant roots and help them take in moisture and nutrients from the soil. Unlike typical fertilizers that must be applied every few weeks, one application of mushroom fungi lasts all year and costs just pennies per plant. The fungi also produce a bigger root system, which makes plants more disease resistant.

Corn, tobacco, and cotton can deplete the topsoil of nutrients, especially nitrogen, if planted on the same land several years in a row. One way to reduce such losses is crop rotation. Farmers plant areas or strips with nutrient-depleting crops one year. In the next year they plant the same areas with legumes, whose root nodules add nitrogen to the soil. In addition to helping restore soil nutrients, this method reduces erosion by keeping the soil covered with vegetation and helps reduce crop losses to insects by presenting them with a changing target.

Today, many farmers rely on commercial inorganic fertilizers containing nitrogen (as ammonium ions, nitrate ions, or urea), phosphorus (as phosphate ions), and potassium (as potassium ions). Inorganic commercial fertilizers are easily transported, stored, and applied. Worldwide, their use increased about tenfold between 1950 and 1989 but declined by 12% between 1990 and 1999. Today, the additional food they help produce feeds one of every three people in the world, without them, world food output, would drop an estimated 40%. Commercial inorganic fertilizers have some disadvantages, however. These include (1) not adding humus to the soil, (2) reducing the soil's content of organic matter and thus its ability to hold water (unless animal manure and green manure are also added to the soil), (3) lowering the oxygen content of soil and keeping fertilizer from being taken up as efficiently, (4) typically supplying only two or three of the twenty or so nutrients needed by plants, and (5) releasing nitrous oxide, a greenhouse gas that can enhance global warming. The widespread use of commercial inorganic fertilizers, especially on sloped land near streams and lakes, also causes water pollution as nitrate and phosphate fertilizer nutrients are washed into nearby bodies of water. The resulting plant nutrient enrichment causes algae blooms that use up oxygen dissolved in the water, thereby killing fish.

## Early Modern Industrialization

Industrial output increased smartly across nearly all of Europe between 1450 and 1575. Although trade with the Americas had something to do with this, the main determinants of this industrial advance lay within Europe itself. Population grew from 61 million in 1500 to 78 million a century later, and the proportion of Europeans living in cities of 10,000 or more—and thus dependent on the market for what they consumed—expanded from less than 6 percent to nearly 8 percent during the same period. More important than sheer numbers, many Europeans' incomes rose. This was especially true among more fully employed urban groups, farmers who benefited from higher prices and the intensifying commercialization and specialization in agriculture (which also led them to shed much non-agricultural production in favor of purchased goods), and landlords and other property owners who collected mounting rents. Government activities to build and strengthen the state were a stimulus to numerous industries, notably shipbuilding, textiles, and metallurgy. To cite just one example, France hastened to develop its own iron industry when the Hapsburgs—the family that governed much of Europe, and whom France fought repeatedly in the sixteenth century—came to dominate the manufacture of weapons in Germany and the cities of Liege and Milan, which boasted Europe's most advanced technology.

The supply of goods was also significantly modified. Migration had long been critical for the diffusion of knowledge that spawned new trades or revived others. Now thousands of workers, and sizeable amounts of capital, moved from one region to another. At the same time, new commodities appeared on the market, often broadening and deepening demand. Most were inexpensive items destined for individual consumers. Knitted stockings, ribbon and lace, buttons, starch, soap, vinegar brewed from beer, knives and tools, pots and ovens, and many more goods, formerly made only for local sale, now entered into channels of national or international trade. The best-known and most widely adopted new industry was printing with movable type, which spread swiftly throughout Europe after Johannes Gutenberg perfected his innovation in 1453. Despite isolated cases of resistance—the scribes' guild (an association of book copiers) delayed printing's

introduction into Paris for twenty years, for example—more than 380 working presses had sprung up by 1480, and 1,000 (in nearly 250 towns) by 1500. Between 1453 and 1500, all the presses of Europe together turned out some 40,000 editions (known as incunabula), but from 1501 to 1600, that same quantity was produced in Lyon and Paris alone.

In metals and mining, technical improvements were available that saved substantially on raw materials and fuel, causing prices to drop. The construction of ever-larger furnaces capable of higher temperatures culminated in the blast furnace, which used cheaper ores and economized on scarce and expensive wood, cutting costs per ton by 20 percent while boosting output substantially. A new technique for separating silver from copper allowed formerly worthless ores to be exploited. Better drainage channels, pumps, and other devices made it possible to tunnel more deeply into the earth as surface deposits began to be exhausted. In most established industries, however, technological change played little role, as in the past, new customers were sought by developing novel products based on existing technologies, such as a new type of woolen cloth with the texture of silk.

Sharply declining transaction costs (the direct and indirect expenses associated with transporting, distributing, and marketing goods and services) were more influential. On a general level, the decrease was due to greater security thanks to the lessening of wartime disruptions and to the economies of scale achieved when selling to large, concentrated urban populations. More specifically, it can be traced to transport innovations such as the carrack, a large ship that reduced rates for ocean borne freight by up to 25 percent, and big four-wheeled Hesse carts for overland routes. The spread of efficient organizational forms further contributed to declining costs, as did falling interest rates, which dropped from 20 percent or 25 percent in the mid fifteenth century to 10 percent 100 years later.

## Cereals and Legumes: A Partnership

Cereals are flowering grasses that sprout, flower, seed, and die in the space of a year, which is why gardeners refer to them as annuals. Grown for their seeds or kernels, cereals are excellent sources of energy: although they lack some amino acids, as well as calcium, vitamin A, and vitamin C, they provide starch and oil, and in some cases, considerable amounts of protein. Once ripe, the kernels are relatively easy to store, and they retain their nutrients for a long time. Even the stalks of cereals are useful as animal food, as bedding in stables and barns, and as a building material. A major drawback with cereals is that they depend on the soil for nitrogen. Without fertilization they eventually exhaust the fields they are growing in, but despite this, two cereals (wheat and barley) were the very first plants to be domesticated (grown for human use); and a third (rye) may have been cultivated, or even domesticated, at about the same time. Today, cereal crops including wheat, rice, maize, sorghum, millet, and oats provide most of the calories in the human diet.

Like cereals, legumes are annuals. Some legumes are grown for animal fodder. Many other legumes, however, are cultivated for their seeds, which ripen in pods. The seeds are rich in B vitamins and iron, contain on average two times the protein but less starch than cereals, and can be eaten, sometimes pods and all, while they're still green. (Snow peas and green beans are familiar examples.) Legumes are characterized by a long period of sequential ripening, during which a single plant may have ripe pods, green pods, and flowers, all at the same time, which means that a stand of legumes can be harvested again and again over several weeks. Like cereals, legumes can be dried and stored for later use (the pods open easily when dry), and again like cereals, legumes provide food for both people and animals. However, legume plants add nitrogen to the soil, so when they are grown in the same fields as cereals, they can replace much of the nitrogen the cereals have depleted.

Growing cereals and legumes together is good for the fields, and eating them together is good for the farmers. In order to build and maintain body tissue, people need protein or more specifically, the amino acids in protein. Some amino acids are synthesized in the adult human body, but eight essential ones cannot be and have to come from food. Although all eight are present in animal protein, plant proteins are usually missing one or two. When cereals and legumes are eaten together, they provide all eight of the essential amino acids, a fact that the ancestors of early agriculturalists undoubtedly understood at least on a practical level and their descendants took advantage of that knowledge. In Asia, rice, wheat, and barley were grown along with soybeans; in India rice was paired with hyacinth bean, black gram, and green gram; in the African savanna, pear millet and sorghum were domesticated along with cow pea and Bambara groundnut; and in the New World, maize and Phaseolus beans in Central America and maize and groundnuts in South America were the bases for agriculture. Cereals and legumes are technically dry fruits (they have a hard dry layer around their seeds).

Early agriculturalists also experimented with growing succulent fruits like apples, olives, grapes, and melons, but most of these were brought into domestication much later than cereals and legumes, and in most cultures they've always been supplementary foods rather than staples. Many of them are propagated vegetatively asexually by using a plant part such as a bulb or cutting rather than sexually through seeds, so they are more complicated to grow than cereals and legumes, and this may account for their typically late addition to agricultural assemblages. It should be noted, however, that recent research in Israel suggests that figs may have been domesticated at a site near Jericho in the Jordan Valley at about the same time as the first experiments with cereals and legumes, and some archaeologists believe that in New Guinea, tubers may have been domesticated long before other crops were imported.

## Evolution of the Flowering Plants

Many aspects of the history of flowering plants (angiosperms) remain mysterious. Evidence of the earliest angiospermscomes from fossilized leaves, stems, fruits, pollen, and, very rarely, flowers. In addition, there has been much study of modern plant morphology (structure) and genetics in order to determine which living species might be most closely related to the ancient ancestors of angiosperms. Despite intensive efforts for over 200 years, scientists have still not reached consensus on which type of plant was the ancestor to the angiosperms, and when and where the angiosperms first evolved. Indeed, Charles Darwin himself called the origin of the flowering plants an abominable mystery

What type of plant was the ancestor to the angiosperms? Most botanists now agree that the flowering plants are monophyletic in origin, meaning that they evolved from a common ancestor. Some paleontologists have suggested that the common ancestor may have been a type of cycad (palmlike tropical plants). Other paleontologists maintain that the angiosperms may have evolved from seed-bearing ferns. Finally, analysis of the morphological traits of some primitive living plants suggests that the ancestor may have been related to the modern pines. The question of angiosperm ancestry remains unresolved.

The time and place of the first appearance of flowering plants have long been a topic of great interest. There is good fossil evidence that early angiosperms, including a number resembling modern magnolias, were present in the Early Cretaceous geologic period (more than 100 million years ago). Angiosperms became increasingly abundant during this period.  Between 100 million and 65 million years ago, a period known as the Late Cretaceous, angiosperms increased from less than 1 percent of flora (plant life) to well over 50 percent. Many of the modern plant families appeared during this time period. In the Early Tertiary period which followed, angiosperms increased to comprise 90 percent or more of Earth’s total flora. Where did these successful plants first originate and spread from?

Analysis of the fossil leaf structure and geographic distribution of the earliest Cretaceous angiosperms has led many biogeographers to conclude that they evolved in the tropics and then migrated poleward. It is known that angiosperms did not become dominant in the high latitudes until the Late Cretaceous. Paleontologists have recovered fossil angiosperm leaves, sterns, and pollen from Early Cretaceous deposits in eastern South America and western Africa. These two continents were joined together as part of Gondwanaland, one of two supercontinents that existed at that time. The locations of these early angiosperm finds would have been close to the equator during the Early Cretaceous and are comfortable with a model by which angiosperms spread from the tropics poleward.

Not all botanists agree with an African-South American center for the evolution and dispersal of the angiosperms, pointing out that many of the most primitive forms of flowering plants are found in the South Pacific, including portions of Fiji, New Caledonia, New Guinea, eastern Australia, and the Malay Archipelago. Recent genetic research has identified the rare tropical shrub Amborella as being the living plant most closely related to the ancient ancestor of all the angiosperms. This small shrub, which has tiny yellow-white flowers and red fruit, is found only on New Caledonia, a group of islands in the South Pacific. Many botanists conclude that the best explanation for the large numbers of primitive living angiosperms in the South Pacific region is that this is where the flowering plants first evolved and these modern species are relics of this early evolution. Comparisons of the DNA of Amborella and many hundreds of species of flowering plants suggest that the first angiosperm arose and the development of separate species occurred about 135 million years ago.

Recently discovered fossils complicate our understanding of the origin of the angiosperms even further. Paleontologists from China have found beautifully preserved fossils of an angiosperm plant, including flowers and seeds, in Jurassic period deposits from China. The site, which is about 130 million years old, is near modern Beijing. The new fossil plant found at the site is now the oldest known angiosperm. The age of the fossils and the very primitive features of the flowers have led the discoverers to suggest that the earliest flowering plants may have evolved in northern Asia.

## Pest Control

Many pest species that are native to North America, such as white-footed mice and ground moles, are more nuisance pests and are usually regulated by native predators and parasites. This situation is not true for nonindigenous pests in North America, such as brown rats and cockroaches. After centuries, it is evident that these pests cannot be eradicated. The best that can be done is to introduce pest control measures that will control their numbers.

And ancient and popular means of pest control is chemical. For example, the Sumerians used sulfur to combat crop pests, and by the early 1800s such chemicals as arsenic were used to combat insect and fungal pests.

However, chemical control has its dark side. Chemical pesticides have many unintended consequences through their effects not just on the target species but on a wide array of non-target species as well, often eliminating them and thereby upsetting the existing food webs, especially through the suppression of native predator species. The surviving pests then rebound in greater numbers than ever.

Perhaps more insidious is that a pesticide loses its effectiveness because the target species evolves resistance to it. As one pesticide replaces another, the pests acquire a resistance to them all. Some species, notably certain mosquitoes, have overcome the toxic effects of every pesticide to which they have been exposed. Insect pests need not only about five years to evolve pesticide resistance, their predators do so much more slowly. So after the pest develops resistance, pest outbreaks become even more disastrous.

Farmer long ago observed that enemies of pests act as controls. As early as 300 C.E., the Chinese were introducing predatory ants into their citrus orchards to control leaf-eating caterpillars. Insect pests have their own array of enemies in their native habitats. When an animal or plant is introduced, intentionally or unintentionally, into a new habitat outside of its natural range, it may adapt to the new environment and leave its enemies behind. Freed from predation and finding and abundance of resources, the species quickly becomes a pest or a weed. This fact had led to the search for natural enemies to introduce into populations of pests to reduce their populations. Because the serious pest is usually a nonnative species, biological control involves the introduction of a nonindigenous predator or parasite to control the pest. The introduction of the cactus-eating moth, a native of Argentina, into Australia effectively reduced and controlled the rapidly spreading prickly pear, which had been introduced into Australia in 1901.

But biological control, like chemical control, can backfire. The success of the cactus-feeding moth in controlling prickly pear in Australia encouraged its introduction to several West Indies islands to control prickly pear there. In time the moth made its way to Florida, where it now threatens the existence of several native prickly pear species. The moral is that although using nonindigenous predators as biological controls can be effective, these species possess their own inherent dangers that must be assessed before they are released. They, too, can become alien invaders. Because chemical, biological, and other methods used individually are obviously not the solution to pest control, entomologists have developed a holistic approach to pest control, called integrated pest management (IPM). IPM considers the biological, ecological, economic, social, and even aesthetic aspects of pest control and employs a variety of techniques. The objective of IPM is to control the pest not at the time a major outbreak but at an earlier time, when the size of the population is easier to control. The approach is to rely first on natural mortality caused by weather and natural enemies, with as little disruption of the natural system as possible, and to use other methods only if they are needed to hold the pest below the economic injury level.

Successful IPM requires the knowledge of the population ecology of each pest and its associated species and the dynamics of the host species. It involves considerable field work monitoring the pest species and its natural enemies by such techniques as egg counts and the trapping of adults to acquire information to determine the necessity, timing, and intensity of control measures. These control measures must be adjusted to the situation, which may vary from one location to another. The intensity of control or no control is based on the degree of pest damage that can be tolerated, the costs of control, and the benefits to be derived.

## How Animals in Rain Forests Make Themselves Heard

Scientists have discovered that animals are experts at exploiting weather conditions and the physical conditions of their environments so that they are heard or not heard, and seen or not seen. The species living in rain forests must engineer their calls to accommodate all of the obstacles, such as leaf cover, that can deflect and degrade the sounds intended for a potential receiver. Over, short, loud bursts of sound tend to be more effective than longer calls at cutting through the dense foliage. There is no natural environment on Earth noisier than a virgin rain forest. In the Peruvian rain forest, every species has developed clever or remarkably sophisticated strategies to ensure that its voice is heard. The noise creates a real challenge for the smaller residents, such as male tree crickets, which need to get the attention of females, often from a relatively long distance. Some species of crickets maximize the volume of their calls by chewing a hole in the middle of a leaf to create a sound baffle, similar to a stereo speaker. The leaf functions as a speaker cabinet, with the cricket in the center acting as the speaker.

A species of tree frog in Borneo has an inventive approach to getting its mating call heard over the noise. Mataphrenella sudana, which is only an inch long, has learned to exploit the sound properties of a water-filled hole in a tree in the same way that a person uses resonance, the intensification and enrichment of a sound by added vibration, in the shower to sing like a professional performer. The frog searches for a suitable hole and then partially submerges itself in the water. Its forte is the ability to adjust the frequency of its call to the size of the hole and play the tree like a musical instrument. As it sits in the hole, it begins vocalizing at different frequencies until it hits the one note that makes the hole and tree resonate.

The time of day affects how sound travels in any environment, and this fact is not lost on animals and insects. Early morning and late evening produce conditions that allow sound to travel greater distances than during the middle parts of the day. Sound travels best at night, which is why the rain forest is so wonderfully noisy between dusk and dawn. For species that sleep at night, dusk and dawn are their windows of opportunity to get the best resonance and distance out of a signal. This is why animals, especially birds, tend to be more active and noisy in the early morning and late evening. The British call the phenomenon of birds singing in the early morning the dawn chorus. Because of the superior sound conditions, dusk and dawn are the times to conduct the serious business of attracting mates and defending territory. For predators, it is the best time to track down their noisy prey.

Another way animals and insects ensure that their calls connect with the intended receivers is by developing their own specialized frequencies, which are determined primarily by the size of their bodies. Recently, a scientist visiting the Peruvian rain forest made an audiotape of a little of the night's music. When he took the tape back to his lab and analyzed it, he discovered that this seemingly chaotic banquet of sound was actually highly ordered. Each animal and insect is tuned to and calling on its own species-specific frequency, in the same way that radio stations use different signals so that many stations can broadcast at the same time.

Bernard Krause, a professor at the University of Oregon in Eugene, has found that in older tropical rain forests some species, such as the Asian paradise flycatcher, have become so specialized that their voices occupy several niches of the sound spectrum at the same time, thus laying territorial claim to several audio channels. His recordings from undisturbed rain forests around the world demonstrate a remarkable stability in the combined voices of the residents from year to year. The stability of the ambient sound gives each region a unique sound signature, or fingerprint.

## The Extinction of the Dinosaurs

Geologists define the boundary between sediment layers of the Cretaceous period (144.C65 million years ago) and the Paleocene period (65.C55 million years ago) in part by the types and amounts of rocks and fossils they contain or lack.  Before the limit of 65 million years ago, marine strata are rich in calcium carbonate due to accumulations of fossils of microscopic algae deposited on the sea floor. Above the 65-million-year limit, sea-floor sediments contain much less calcium carbonate, and fossils of several families of mollusks are no longer found. In continental sediments, dinosaur fossils, though frequent before 65 million years ago, are totally absent. By contrast, new families of mammals appear, including large mammals for the first time.

Scientists wondered for many years about what could have caused the dinosaurs' rapid disappearance at the end of the Cretaceous period, coming up with a great variety of theories and scenarios. For some, it could have been due to unfavorable genetic changes triggered by a dramatic increase by a factor of 10, 100, 1000in cosmic-ray particles reaching the Earth after a supernova explosion somewhere in the neighborhood of the solar system. For these high-energy particles to affect life, they would have to get through the protective barrier of the Earth's magnetosphere, the region of the upper atmosphere controlled by Earth's magnetic field. That could have happened if the cloud of particles from the supernova explosion reached the Earth during a period when the magnetosphere was weakened, something that may happen when the Earth's magnetic field changes direction. And we know that the magnetic north and south poles of the Earth switch on the average twice every million years. However, this is not the only possible explanation for dinosaur destruction.

Other theories have raised the possibility of strong climate changes in the tropics (but they then must be explained). Certainly, if climate changes, the changed distributions of temperature and rainfall modify the conditions that favor one ecosystem over another. The extinction of a particular family, genus, or species may result from a complicated chain of indirect causes and effects. Over thirty years ago, scientist Carl Sagan quoted one suggestion that the demise of the dinosaurs resulted from the disappearance of a species of fern plant that was important for dinosaur digestion. Other theories involved a worldwide cold wave following the spread of a layer of cold but not very salty water in the world's oceans, which floated on the surface because, with its low salinity, the water was less dense.

Proponents of another theory that remains under consideration today postulate that the extinction of the dinosaurs corresponds to a period of intense volcanic activity. It's not a question of just one or even of a thousand eruptions comparable to the explosion of Krakatoa in 1883, one of the largest volcanic events in modern times, but rather of a prolonged period of activity. On the Deccan plateau in India, basalt (volcanic) rocks cover more than 500,000 square kilometers (nearly 200,000 square miles),and correspond to massive lava outflows occurring precisely at the end of the  Cretaceous. This sort of outflow could correspond to volcanic activity similar to the activity that drives sea-floor spreading, with lava emerging from elongated fractures in the crust rather than from craters.

The volcanic convulsion that buried the Deccan plateau in lava must also have changed the composition of the atmosphere and severely affected climate. Initially, there must have been strong sudden cooling resulting from the blocking of sunlight by sulfate aerosol veils in the stratosphere (part of the Earth's atmosphere). If strong cooling lasted a year after the formation of the aerosols, it would have been the death of tropical species unable to adapt to such a volcanic winter. However, a long period of strong volcanic activity (again, remember thousands of Krakatoas) would at the same time have added a substantial amount of carbon dioxide to the atmosphere, reinforcing the greenhouse effect. This would gradually warm things up, ending the extended cold snap and producing global warming together with geographic shifts of humid and arid (dry) zones. Certainly things would change to upset living conditions, leading to the extinction of some species while others would profit, if only from the disappearance of predators.

## Agriculture in the Late Ottoman Empire

Throughout its history, agriculture was the economic mainstay of the Ottoman Empire, which dominated North Africa, the Middle East, Turkey, and southeastern Europe for over 600 years until the early twentieth century. Most cultivators possessed small landholdings, engaging in a host of tasks, with their crops and animal products mainly dedicated to self- consumption. But enormous changes over time prevailed in the agrarian sector. Beginning in the late eighteenth century, agriculture became more and more commercialized, with increasing amounts of produce going to sale to domestic and international consumers.

At least three major engines increased this agricultural production devoted to the market, the first being rising demand, both international and domestic. Abroad, especially after 1840, the living standards and buying power of many Europeans improved substantially, permitting them to buy a wider choice and quantity of goods. Rising domestic markets within the empire were also important, thanks to increased urbanization as well as mounting personal consumption. In the late nineteenth century, newly opened railroad districts brought a flow of domestic wheat and other cereals to major coastal cities. Railroads also attracted market gardeners who now could grow and ship fruits and vegetables to the expanding and newly accessible markets of these cities.

The second engine driving agricultural output concerns cultivators' increasing payment of their taxes in cash rather than in kind (that is, in agricultural or other products). Some historians have asserted that the increasing commitment to market agriculture was a product both of a mounting per capita tax burden and the state's growing preference for tax payments in  cash rather than in kind. In this view, such government decisions forced cultivators to grow crops for sale in order to pay their taxes. Thus, state policy is seen as the most important factor influencing the cultivators' shift from subsistence farming to market agriculture.

However, cultivators' rising involvement in the market was not simply a reactive response to the state's demands for cash taxes; other factors were at work. There was a third engine driving increased agricultural production cultivators' own desires for consumer goods. Among Ottoman consumers, increasingly frequent changes in taste, along with the rising availability of cheap imported goods, stimulated a rising consumption of goods. This pattern of rising consumption began in the eighteenth century, as seen by the urban phenomenon of the Tulip Period (1718 to 1730) a time of urban revival and orientation toward the West and accelerated subsequently. Wanting more consumer goods, cultivators needed more cash.  Thus, rural families worked harder than they had previously, not merely because of cash taxes. In such circumstances, leisure time diminished, cash incomes rose, and the flow of consumer goods into the countryside accelerated.

Increases in agricultural production both promoted and accompanied a vast expansion of the area of land under cultivation. At the beginning of the eighteenth century and indeed until the end of the empire, there remained vast stretches of uncultivated, sometimes nearly empty, land on every side. These spaces began to fill in, a process finally completed only in the 1950s in most areas of the former empire. Many factors were involved. In many cases, families increased the amount of time at work, bringing into cultivation uncultivated land already under their control. They also engaged in sharecropping agreeing to work another's land and paying that person a share of the output. Often such acreage had been pastureland for animals but now was given over to crop production. The extraordinarily fertile lands of Moldavia  and Wallachia (modern Romania), for example, had been among the least populated lands of the Ottoman empire in the eighteenth century, but now saw large amounts of land brought under the plow. Significant concentrations of commercial agriculture first formed in areas easily accessible by water, such as the Danube River basin. During the nineteenth century, expansion in such areas continued, and interior regions joined the list as well. There were also some increases in productivity. Irrigation projects, one form of intensive agriculture, developed in some areas, and the use of modern agricultural tools increased. But more intensive exploitation of existing resources remained comparatively unusual, and most increases in production derived from placing additional land under cultivation.

## Comets

Comets are among the most interesting and unpredictable bodies in the solar system. They are made of frozen gases (water vapor, ammonia, methane, carbon dioxide, and carbon monoxide) that hold together small pieces of rocky and metallic materials. Many comets travel in very elongated orbits that carry them far beyond Pluto. These long-period comets take hundreds of thousands of years to complete a single orbit around the Sun. However, a few short-period comets (those having an orbital period of less than 200 years), such as Halley's Comet, make a regular encounters with the inner solar system.

When a comet first becomes visible from Earth, it appears very small, but as it approaches the Sun, solar energy begins to vaporize the frozen gases, producing a glowing head called the coma. The size of the coma varies greatly from one comet to another. Extremely rare ones exceed the size of the Sun, but most approximate the size of Jupiter. Within the coma, a small glowing nucleus with a diameter of only a few kilometers can sometimes be detected. As comets approach the Sun, some develop a tail that extends for millions of kilometers. Despite the enormous size of their tails and comas, comets are relatively small members of the solar system.

The observation that the tail of a comet points away from the Sun in a slightly curved manner led early astronomers to propose that the Sun has a repulsive force that pushes the particles of the coma away, thereby forming the tail. Today, two solar forces are known to contribute to this formation. One, radiation pressure, pushes dust particles away from the coma. The second, known as solar wind, is responsible for moving the ionized gases, particularly carbon monoxide. Sometimes a single tail composed of both dust and ionized gases is produced, but often two tails—one of dust, the other, a blue streak of ionized gases—are observed.

As a comet moves away from the Sun, the gases forming the coma recondense, the tail disappears, and the comet returns to distant space. Material that was blown from the coma to form the tail is lost from the comet forever. Consequently, it is believed that most comets cannot survive more than a few hundred close orbits of the Sun. Once all the gases are expelled, the remaining material—a swarm of tiny metallic and stony particles—continues the orbit without a coma or a tail.

Comets apparently originate in two regions of the outer solar system. Most short-period comets are thought to orbit beyond Neptune in a region called the Kuiper belt, in honor of the astronomer Gerald Kuiper. During the past decade over a hundred of these icy bodies have been discovered. Most Kuiper belt comets move in nearly circular orbits that lie roughly in the same plane as the planets. A chance collision between two comets, or the gravitational influence of one of the Jovian planets—Jupiter, Saturn, Uranus, and Neptune—may occasionally alter the orbit of a comet in these regions enough to send it to the inner solar system and into our view.

Unlike short-period comets, long-period comets have elliptical orbits that are not confined to the plane of the solar system. These comets appear to be distributed in all directions from the Sun, forming a spherical shell around the solar system, called the Oort cloud, after the Dutch astronomer Jan Oort. Millions of comets are believed to orbit the Sun at distances greater than 10,000 times the Earth-Sun distance. The gravitational effect of a distant passing star is thought to send an occasional Oort cloud comet into a highly eccentric orbit that carries it toward the Sun. However, only a tiny portion of the Oort cloud comets have orbits that bring them into the inner solar system.

The most famous short-period comet is Halley's Comet, named after English astronomer Edmond Halley. Its orbital period averages 76 years, and every one of its 30 appearances since 240 B.C. has been recorded by Chinese astronomers. When seen in 1910, Halley's Comet had developed a tail nearly 1.6 million kilometers (1 million miles) long and was visible during daylight hours. Its most recent approach occurred in 1986.

## Mexican Mural Art

The first major modern art movement in Latin America was Mexican muralism, which featured large-scale murals painted on the wall surfaces of public buildings. One of the most persistent strands in Latin American art in the last 80 years has been an engagement with political and social issues, including the struggle for social justice. This in turn has been accompanied by a desire for authentic forms of self-expression and freedom from cultural dependency. Although these preoccupations have taken many different forms, Mexican muralism was the first, and its influence was the most far-reaching. Muralism flourished in Mexico in the years immediately following the Mexican Revolution (1910-1920) as a result of a combination of circumstances: a climate of revolutionary optimism and cultural experimentation that challenged traditional Eurocentrism, a small but strong group of relatively mature artists of energy, ideas, and ability, and a visionary minister of education, Jose Vasconcelos. Vasconcelos believed that Mexico was destined to play a central role on the international stage. He understood that ideas could be more quickly assimilated through images than through any other medium, and he had the courage to allocate the funds, and the walls of public buildings, to the artists to do with as they liked.

The muralists shared a belief in the power of art to transform society for the better, to challenge social, political, economic, and cultural stereotypes, and to enrich the intellectual life of their country. During the 1920s and 1930s, they covered miles of wall with paintings representing aspects of Mexico's past and present and the future to which all aspired. Although Mexican muralism is representational and often narrative in form, it should be recognized as a modern movement, it was modernizing in intent, in that it challenged the old order—culturally, socially, and politically. By definition, it was a public, accessible form of art—not a commodity that could be bought and sold by the wealthy elite. Its purpose was to educate, inform, enlighten, politicize and thus empower the general public, in particular the working classes.

The muralist movement was not a unified force, however. The painters who were its leaders took different directions and did not always see eye to eye. Diego Rivera (1886-1957) sought to promote a pluralistic vision of Mexican society by drawing on the rich heritage of the pre-Columbian past (before Christopher Columbus arrived in the Americas in 1492) and contemporary popular culture, and he investigated pre-Columbian styles and techniques in an effort to create an aesthetic language that was new and Mexican. He was deeply influenced by native pictographic traditions of communication in which pictures represent written words and ideas, and he sought to develop a modern equivalent, a visual language that could be read like a book. The art of Jose Clemente Orozco (1883-1949) is less optimistic: he saw both the pre-Columbian past and the revolutionary present in a more negative light, the former as barbarous, the latter often tarnished by corruption and cruelty. He offers no comforting narratives and his expressive, aggressive technique serves as a metaphor of Mexico's harsh, contradictory reality. David Alfaro Siqueiros (1898-1976) was the most politically active of the three and was an internationalist both ideologically and artistically. In his art he deliberately avoided traditional materials and methods, preferring to use modern industrial paints and spray guns. His works look forward to a fully socialist future where the workers will have won the right to the benefits of the modern industrial era, and his often fragmented, complex imagery does not patronize or make concessions to his audience.

The Mexican muralist movement is undoubtedly one of the most important manifestations of twentieth-century Mexican culture. Its impact elsewhere in the region, as well as in the United States and Europe, has been enormous. The work of Rivera, Orozco, and Siqueiros triggered a homegrown muralist movement in the United States in cities like New York City, Detroit, Los Angeles, and San Francisco. The influence of the Mexicans on the modern Spanish painter Picasso's first mural and almost his only major explicitly propagandist work of art— his famous Guemica of 1937—is unmistakable even though the artist himself would have derived it. In Latin America, Mexican-influenced muralism has recurred whenever artists have felt the need to make a clear, public statement in a language that has not been borrowed from outside.

## Temperature Regulation in Marine Organisms

There are two extremes of temperature regulation in organisms. Homeotherms are organisms that regulate body temperature to a constant level, usually above that of the ambient (surrounding) environment. A constant and relatively high body temperature enables biochemical reactions to occur in a relatively constant internal environment and at a relatively high rate. Most birds have a body temperature of about 40℃, whereas the temperature of most marine mammals is about 38℃. Because such temperatures are much higher than that of most seawater, marine homeotherms lose heat rapidly to the surrounding environment.

There is another completely different style of living. Poikilotherms are organisms whose body temperature conforms to that of the ambient environment. All subtidal marine invertebrates and most fishes fit into this category. There is an interesting intermediate status in which body temperature is usually somewhat higher than ambient temperature. Strong- swimming fishes, such as skipjack tuna and yellowfin tuna, have this intermediate status. Their rise in temperature above ambient conditions stems from metabolic heat generated by muscular activity (swimming) combined with a heat retention mechanism. The temperature rise is probably necessary to generate the increased biochemical reaction rates that are needed for sustained activity. In contrast, some intertidal animals are not true Poikilotherms, they maintain themselves at lower-than-ambient body temperature, using both evaporation and circulation of body fluids to avoid being heated at low tide by the Sun. Their body temperatures, therefore, differ from that of an inanimate object of the same size and shape that might be placed on the shore. Intertidal organisms absorb and lose heat directly to the air. Darker-colored forms can absorb more heat than can light-colored forms, therefore, variation in color can reflect differences in adaptation to the capture of solar energy at different latitudes. Ocean temperatures are usually less than 27℃ and may be less than 0℃ in some locations and during some seasons. Therefore, most homeothermic mammals and birds must lose heat continuously to the environment. Their skin is the main pathway of heat loss, especially by direct conduct of heat from the skin to the contacting colder water. Because animals have a circulatory system, heat loss from the body surface also occurs as warm interior blood is transferred and moves into contact with the periphery of the body. Their bodies also radiate heat, usually in the infrared part of the spectrum. Finally, as animals exhale, the resulting evaporation of water involves a considerable loss of heat.

The first line of defense against heat loss is a well-insulated body surface. Marine birds deal with this problem by means of specially adapted feathers. A series of interlocking contour feathers encloses a thick layer of down feathers that traps stationary air, which in turn acts as an insulating layer. Whales, porpoises, and seals are insulated against the lower sea temperatures by a thick layer of subcutaneous fat. Sea otters lack such a layer, but they constantly preen and fluff up a relatively thick layer of fur. Such mechanisms are only partly successful, however, and to generate more body heat to maintain a constant temperature, marine mammals usually must have a higher metabolic rate than similarly sized terrestrial (land) animals.

In marine mammals that have limbs, the limbs are the principal sources of heat loss because they expose a relatively greater amount of body surface area per unit volume to cold water. However, warm arterial blood must be supplied to limbs, such as the flipper of a porpoise. Heat loss in porpoises is minimized by a countercurrent heat exchanger. The arteries are surrounded by veins, within which blood is returning to the core of the animal. At any contact point, the artery, which is on the inside, is warmer than a surrounding vein, so heat is lost to the returning venous blood flow. Heat is thus reabsorbed and returned to the porpoise’s body core. This spatial relationship of circulatory vessels minimizes heat loss to the flipper and thence to the water. Although the anatomical details are quite different, fishes such as skipjack tuna have a circulatory anatomy based on the same overall design. Arteries and veins in the near-surface musculature are in contact, and in arteries and veins, respectively, blood flows in opposite directions.

## The Identification of the Genetic Material

The history of biology is filled with incidents in which research on one specific topic has contributed richly to another, apparently unrelated area. Such a case is the work of Frederick Griffith, an English physician whose attempts to prevent the disease pneumonia led to the identification of the material in cells that contains genetic information the information that determines an organism's characteristic structure. In the 1920s, Griffith was studying the bacterium Streptococcus pneumonia, or pneumococcus, one of the organisms that cause pneumonia in humans. He was trying to develop a vaccine against this devastating illness. He was working with two strains of the bacteria pneumococcus. A bacterial strain is a population of cells descended from a single parent cell; strains differ in one or more inherited characteristics. Griffith's strains were designated S and R because, when grown in the laboratory, one produced shiny, smooth (S) colonies or groups of bacteria, and the other produced colonies that look rough (R).

When the S strain was injected into mice, the mice became diseased. When the R strain was injected, the mice did not become diseased. Bacteria of the S strain are virulent (able to cause disease) because they are surrounded by a protective jelly-like coating that prevents the mouse's immune defense mechanisms from destroying the bacteria before they can multiply. The R strain lacks this coating.

With the hope of developing a vaccine against pneumonia, Griffith injected some mice with heat-killed S pneumococci. These heat-killed bacteria did not produce infection. Griffith assumed the mice would produce antibodies to the bacteria that would allow them to fight the virulent form if they were exposed to it. However, when Griffith inoculated other mice with a mixture of living R bacteria and heat-killed S bacteria, to his astonishment, the mice became ill with pneumonia. When he examined blood from these mice, he found it full of living bacteria many with characteristics of the virulent S strain. Griffith concluded that, in the presence of the dead S pneumococci, some of the living R pneumococci had been transformed into virulent S-strain organisms.

Did this transformation of the bacteria depend on something the mouse did to the bacteria? No. It was shown that simply putting living R and heat-killed S bacteria together in a test tube yielded the same transformation. Next it was discovered that a cell-free extract of heat-killed S cells also transformed R cells. (A cell-free extract contains all the contents of cells, but no intact cells.) This result demonstrated that some substance called at the time a chemical transforming principle from the extract of S pneumococci could cause a heritable change (a change that could be passed on to future generations) in the affected R cells.

From these observations, some scientists concluded that this transforming material carried heritable information, and thus was the genetic material that scientists had been searching for. The identification of the transforming material was a crucial step in the history of biology, accomplished over a period of several years by Oswald Avery and his colleagues at what is now Rockefeller University. They treated samples of the transforming extract in a variety of ways to destroy different types of substances proteins, nucleic acids, carbohydrates, and lipids and tested the treated samples to see if they had retained transforming activity. The answer was always the same: If the DNA (deoxyribonucleic acid) in the extract was destroyed, transforming activity was lost; everything else could be eliminated without removing the transforming ability of the extract. As a final step, Avery, with Colin MacLeod and Maclyn McCarty, isolated virtually pure DNA from a sample of pneumococcal transforming extract and showed that it caused bacterial transformation.

In retrospect, the work of Avery, MacLeod, and McCarty, published in 1944, was a milestone in establishing that DNA is the genetic material. However, at the time, it had little impact on scientists' view about the physical basis of inheritance. The genetic material had to encode all the information needed to specify an organism, and the chemical complexity and diversity of proteins were known to be impressive. So during the first half of the twentieth century, the hereditary material was generally assumed to be a protein. Nucleic acids, by contrast, were known to have only a few components and seemed too simple to carry such complex information.

## Mesolithic Complexity in Scandinavia

The European Mesolithic (roughly the period from 8000 B.C to 2700 B.C) testifies to a continuity in human culture from the times of the Ice Age. This continuity, however, was based on continuous adjustment to environmental changes following the end of the last glacial period (about 12,500 years ago). Three broad subdivisions within the northern Mesolithic are known in Scandinavia. The Maglemose Period (7500-5700 B.C.) was a time of seasonal exploitation of rivers and lakes, combined with terrestrial hunting and foraging. The sites from the Kongemose Period (5700-4600 B.C.) are mainly on the Baltic Sea coasts, along bays and near lagoons, where the people exploited both marine and terrestrial resources. Many Kongemose sites are somewhat larger than Maglemose ones. The Ertebolle Period (4600-3200 B.C) was the culmination of Mesolithic culture in southern Scandinavia.

By the Ertebolle Period, the Scandinavia were occupying coastal settlements year-round and subsisting off a very wide range of food sources. These included forest game and waterfowl, shellfish, sea mammals, and both shallow-water and deep water fish. There were smaller, seasonal coastal sites, too, for specific activities such as deep water fishing, sealing, or hunting of migratory birds. One such site, the Aggersund site in Denmark, was occupied for short periods of time in the autumn, when the inhabitants collected oysters and hunted some game, especially migratory swans. Ertebolle technology was far more elaborate than that of its Mesolithic predecessors, a wide variety of antler, bone, and wood tools for socialized purposes such as fowling and sea-mammal hunting were developed, including dugout canoes up to ten meters long. With sedentary settlement comes evidence of greater social complexity in the use of cemeteries for burials and changes in burial practices. The trend toward more sedentary settlement, the cemeteries, and the occasional social differentiation revealed by elaborate burials are all reflections of an intensified use of resources among these relatively affluent hunter- gatherers of 3000 B.C Mesolithic societies intensified the food quest by exploiting many more species, making productive use of migratory waterfowl and their breeding grounds, and collecting shellfish in enormous numbers. This intensification is also reflected in a much more elaborate and diverse technology, more exchange of goods and materials between neighbors, greater variety in settlement types, and a slowly rising population throughout southern Scandinavia. These phenomena may, in part, be a reflection of rising sea levels throughout the Mesolithic that flooded many cherished territories. There are signs, too, of regional variations in artifact forms and styles, indicative of culture differences between people living in well-delineated territories and competing for resources.

Mesolithic cultures are much less well-defined elsewhere in Europe, partly because the climatic changes were less extreme than in southern Scandinavia and because there were fewer opportunities for coastal adaptation. In much of central Europe, settlement was confined to lakeside and riverside locations, widely separated from one another by dense forests. Marry Mesolithic lakeside sites were located in transitional zones between different environments so that the inhabitants could return to a central base location, where for much of the year they lived close to predictable resources such as lake fish. However, they would exploit both forest game and other seasonal resources from satellite camps. For example, the archaeologist Michael Jochim believes that some groups lived during most of the year in camps along the Danube River in central Europe, moving to summer encampments on the shores of neighboring lakes. In areas like Spain, there appears to have been intensified exploitation of marine and forest resources. There was a trend nearly everywhere toward greater variety in the diet, with more attention being paid to less obvious foods and to those that require more complex processing methods than do game and other such resources. Thus, in part of Europe, there was a long-term trend among hunter-gatherer societies toward a more extensive exploitation of food resources, often within the context of a strategy that sought ways to minimize the impact of environmental uncertainty. In more favored southern Scandinavia, such societies achieved a new level of social complexity that was to become commonplace among later farming peoples, and this preadaptation proved an important catalyst for rapid economic and social change when farming did come to Europe.

## Forest Succession

Succession is a continuous change in the species composition, structure, and function of a forest through time following disturbance. Each stage of succession is referred to as a successional sere. The final stage of succession, which is generally self-replacing, is referred to as the climax sere. There are two major types of succession: primary and secondary. Primary succession is the establishment of vegetation on bare rocks or radically disturbed soil. Secondary succession is the reestablishment of vegetation following a disturbance that killed or removed the vegetation but did not greatly affect the soil. Volcanic eruptions, retreating glaciers, and bare sand dunes are examples of sites subject to primary succession, while clear-cutting of forests, wild fires, and hurricanes are examples of sites subject to secondary succession. Hundreds to thousands of years are required for primary succession to reach the climax sere, compared to decades to hundreds of years for it to occur in secondary succession. A longer time is needed to reach the climax sere for primary than secondary succession because soil development must first take place in primary succession. The rate of succession is dependent upon the extent of the disturbance and the availability of appropriate seeds for recolonization.

What morphological (structural) and ecophysiological characteristics determine the species composition and abundance in succession? In general, nitrogen fixing plants (plants that can make use of atmospheric nitrogen) are important early succession species in primary succession because nitrogen is not derived from the weathering of rock and little or no organic matter is present in the soil. Weedy plants are common early successional species because of their rapid growth and high reproductive rates, while stress-tolerant species are common late successional species.

The structure of a forest changes as well in secondary succession. Depending on the type and the severity of the disturbance, a moderate to large amount of dead organic matter from the previous forest remains on the site immediately from the disturbance. The leaf area of the forest is at a minimum and slowly increases as new vegetation occupies the site. Following a disturbance, such as a fire, the new canopy (the uppermost spreading and branching layer of a forest) is largely composed of similar-aged, or even-aged, trees. Light, nutrient, and water availability are highest during the early successional sere because the vegetation has not completely occupied the site. Canopy closure, or maximum leaf area, can occur within several years after disturbance in some tropical forests, but may take three to fifty years in evergreen forests.

In the second stage of forest development there is tree mortality caused by competition for light, nutrients and water. The intense intraspecies (within a species) and interspecies (between species) competition for light, nutrients and water induces the mortality of plants that are shaded or have one or more life-history characteristics that are not well adapted to the changing environment. The third stage of forest development is characterized by openings in the overstory canopy, caused by tree mortality, and the renewed growth of understory in response to increased light reaching the forest floor. Consequently, the forest canopy becomes more complex, or multilayered. The final stage of forest development, the climax or old growth stage, is characterized by a species composition that in theory can continue to replace itself unless a catastrophic disturbance occurs. Unique characteristics of old growth forests include large accumulation of standing and fallen dead trees-- referred to as coarse woody debris. Also, the annual input of forest litter is dominated by coarse woody debris compared to the earlier stages of forest development, when leaf and fine root debris were the dominant sources of nutrients and organic matter input into the soil.

Some ecosystems may never reach the latter stages of succession if natural disturbances (fire, flooding, hurricanes, etc) are frequent. A pyric climax refers to an ecosystem that never reaches the potential climax vegetation defined by climate because of frequent fires. The ecotone, a boundary, between grassland and forest is a pyric climax, and only with fire suppression have woodlands and forests began to advance into these regions.

## The Cambrian Explosion

The earliest fossil evidence for eukaryotes complex organisms whose cells contain a distinct nucleus dates to only about 1.2 billion years ago. The fossil record suggests that animal evolution progressed slowly, with relatively little change seen between fossils from 1.2 billion years ago and those from a half-billion years later. But then something quite dramatic happened as can be judged by the many different animal groups that suddenly appear in the fossil record.

Biologists classify animals according to their basic body plans. For example, the basic body plan shared by mammals and reptiles is fundamentally different from that of insects. Animals are grouped by body plan into what biologists call phyla. Mammals and reptiles both belong to the single phylum Chordata, which includes animals with internal skeletons. Insects, crabs, and spiders belong to the phylum Arthropoda, which contains animals with body features such as jointed legs, an external skeleton, and segmented bodies. Classifying animals into phyla is an ongoing project for biologists, but modern animals appear to comprise about 30 different phyla, each representing a different body plan.

Remarkably, nearly all of these different body plans, plus a few others that have gone extinct, make their first known appearance in the geological record during a period spanning only about 40 million years less than about 1 percent of Earth's history. This remarkable flowering of animal diversity appears to have begun about 545 million years ago, which corresponds to the start of the Cambrian period. Hence it is called the Cambrian explosion.

The fact that the Cambrian explosion marks the only major diversification of body plans in the geological record presents us with two important and related questions: Why, so long after the origin of eukaryotes, did the pace of evolution suddenly accelerate dramatically at the beginning of the Cambrian, and why hasn't there been another period of similarly explosive diversification since then we can identify at least four factors that might have contributed to the Cambrian explosion. First, the oxygen level in our atmosphere may have remained well below its present level until about the time of the Cambrian explosion. Thus, the rapid diversification in animal life may have occurred at least in part because oxygen reached a critical level for the survival of larger and more energy-intensive life forms. A second factor that may have been important was the evolution of genetic complexity. As eukaryotes evolved, they developed more and more genetic variation in their DNA. Some scientists believe that the Cambrian explosion marks the point at which organisms developed certain kinds of genes (homeobox genes) that control body form and that could be combined in different ways, allowing the evolution of a great diversity of forms over time. A third factor may have been climate change. Geological evidence points to a series of episodes in which Earth froze over before the Cambrian began. The extreme climate conditions of these episodes eliminated many species, leaving a wide array of ecological niches available into which new species could rapidly evolve when climate conditions eased at the beginning of the Cambrian.

A fourth factor may have been the absence of efficient predators. Early predatory animals were probably not very sophisticated, so some evolving animals that later might have been eliminated by predation were given a chance to survive, making the beginning of the Cambrian period a window of opportunity for many different adaptations to establish themselves in the environment. This last idea may partly explain why no similar explosion of diversity has taken place since the Cambrian: once predators were efficient and widespread, it may have been virtually impossible for animals with entirely new body forms to find an environmental niche in which they could escape predation. Or it may be that while more body plans may have been possible at some early point in evolution, it was not possible to evolve into those other body plans from the body plans that evolved in the Cambrian. Or perhaps the various body forms that arose during the Cambrian explosion represent the full range of forms possible given the basic genetic resources that characterize all Earth's organisms. In any case, no fundamentally new body forms have emerged since the Cambrian explosion.

## Tree Species Identification in Tropical Rain Forests

Identifying tree species in tropical rain forests may be harder than you think. Plant species identification can be difficult for all kinds of reasons even identification of trees, which are big and conspicuous. For example, for some willow trees, both leaves and flowers may be needed for identification, but the two may not be present at the same time. Yet whatever problems may confront us in temperate climates, we can be sure that the tropics will pose far worse difficulties.

In tropical rain forests, the flowers of a given tree species are typically not in bloom and so cannot be observed. In seasonal rain forests (with a distinct wet season and a distinct dry season), many trees adjust their flowering to the rains, so flowering is to some extent predictable. But much rain forest (as in much of the Amazon region) is no seasonal, and trees may flower at any time. To be sure, different trees of the same species generally flower simultaneously, for if they did not, they could not pollinate each other. 80 they must be responding to signals from the environment at large, or else (or in addition) they must be communicating with one another. But what those signals are is unknown, at least to us. To the human observer, the flowering seems random. In any case ,in a tropical forest (at least in a secondary forest ,which is  forest that is regrowing after previous harvesting or clearance) , the trees grow very close together, and most are remarkably thin, like poles, and grow straight up and disappear into the gloom, twenty meters overhead . Even if there are flowers, you would not necessarily see them.

The leaves may not be accommodating either, at least when viewed from the ground. Rain-forest trees all face the same kinds of conditions and have adapted in the same general kinds of way. Rain forests are wet by definition. But in some there is a dry season, and even when there is not, it doesn't rain all the time. Thus the forest floor may be moist, but the topmost leaves of the canopy are far above it and are exposed to the fiercest sun. 80 the uppermost leaves must resist desiccation (drying out). Yet from time to time, and in due season every day, they must also endure tremendous downpours. Leaves that can cope with such contrasts tend to be thick and leathery (to resist drought), oval in shape, and have a prection at the end known as a drip tip to let surplus rain run off the leaf. Many hundreds of trees from dozens of only distantly related families have leaves of this general type. But even if you can distinguish individual leaves, it is hard to be certain if they belong to the tree you are interested in or to the one next to it or to some epiphyte (a plant that grows on other plants) or liana (vine) slung over its branches. Often, in short, researchers must base their identification of a tree on the bark of its trunk. The trunks of tropical trees are sometimes highly characteristic, being deeply furrowed or twisted, but in most species the bark is simply smooth and gray, dappled with lichen and moss.

In a temperate forest you can be fairly sure that any one tree is the same species as the one next to it or, at least, it will be one of a list that is unlikely to exceed more than half a dozen (oak with ash in much of Britain; lodge pole pine with aspen in the northernmost reaches of North America; alder, scotch pine, and spruce in the Baltic; and so on). But in the Amazon in particular, you can be fairly sure that any one tree is not the same species as the one next to it. Often there is a third of a mile between any two trees of the same species, and there can be up to 120 different species of trees in any one acre. So the task , often, is to identify an individual tree that may be not much thicker than your arm from the appearance of its bark, out of a total list of several hundred (or thousand) possibilities which may well include some that have not been described before, so that there is nothing to refer back to.

## Models of Egg Development

Several different theories have been put forward to explain how the hard-shelled eggs of land-dwelling reptiles (e.g. lizards) evolved from the soft eggs that amphibians (e.g. frogs and toads) lay in water. The Romer model of egg development is named after the late Alfred Romer, a paleontologist who also became director of the Harvard University Museum of Comparative Zoology. His specialty was early reptiles because, he felt, they were the key to understanding the great reptile diversification seen in the Late Paleozoic and Mesozoic Eras (around 230 million years ago). Romer's hypothesis was that some aquatic amphibians that is, amphibians living in water called anthracosaurs began to lay their eggs on land at about the time that they were evolving reptile-like skeletal features. Indeed, some of these early amphibians and earliest reptiles are so similar in their skeletons that the exact transition point from one to the other is still difficult to determine. Eventually, though, the transition was made, but these early reptiles remained aquatic. The advantage for laying eggs on land was primarily to avoid the aquatic larval (pre-adult) stage during which immature amphibians live exclusively in water with its inherent risk of predators and drying of ponds. However, the land has its own set of dangers, not least of which is the drying effect of the atmosphere. To cope with these problems, a series of protective membranes developed around the egg, including a hard shell. Only later did the reptiles completely abandon an aquatic lifestyle.

Another hypothesis was proposed by German paleontologist Rolf Kohring, whose specialty is fossil eggs. In Kohring's model, amphibians during the Mississippian epoch (360¨C320 million years ago) spread into nutrient-poor or cooler water. Because of the harsher conditions, eggs were produced with larger yolks, that is, more nutrients for the embryo. With larger yolks, the eggs were bigger, and fewer of them could be produced by the female hundreds rather than thousands. To keep the larger egg intact, one or more membranes were developed, including one that surrounded and protected the egg. This outer membrane provided a place to safely store calcium ions, which are poisonous. Accumulating the calcium in a hard shell then made it possible for the egg to be laid on land (it was pre-adapted to be laid there.)

One other model we should consider is the anti-predator hypothesis proposed by Gary and Mary Packard to explain the evolution of the hard-shelled egg. Their model was not concerned with the development of membranes surrounding the egg but continues the story after these membranes appeared. The Packards assume that the earliest reptiles laid leathery shelled eggs on very wet ground where they could absorb water during the embryos' growth. But life on the ground is not without hazards, based on studies of modern reptiles with leathery shelled eggs. Predatory insects and microbes can be a major cause of egg mortality. To counter this loss of eggs, some of the early reptiles began secreting a thin calcareous (containing calcium carbonate) layer. This hard layer gave the embryos a better chance of surviving until hatching. And these survivors in turn would probably leave more progeny once a few of them reached reproductive age. In time, a thicker, more resistant shell developed. However, a thicker eggshell meant that less water could be absorbed for the needs of the embryo. To compensate, larger eggs were produced, containing a great deal more albumen (egg white, a water-soluble protein). At this point, the rigid eggshell had reached the bird egg level of complexity.

Mary Packard presented yet another model with her colleague Roger Seymour. They note that amphibian eggs can never get very large because the gelatin coat surrounding the developing larva is not very good at transmitting oxygen. Because of this restriction, we will never see frog eggs the size of a chicken's. For Packard and Seymour, the major evolutionary breakthrough in reptile eggs was the elimination of the thick gelatin coat and replacing part of it with a fibrous membrane. This change allowed larger eggs to be developed.

## Elements of Life

The creation of life requires a set of chemical elements for making the components of cells. Life on Earth uses about 25 of the 92 naturally occurring chemical elements, although just 4 of these elements oxygen, carbon, hydrogen, and nitrogen make up about 96 percent of the mass of living organisms. Thus, a first requirement for life might be the presence of most or all of the elements used by life.

Interestingly, this requirement can probably be met by almost any world. Scientists have determined that all chemical elements in the universe besides hydrogen and helium (and a trace amount of lithium) were produced by stars. These are known as heavy elements because they are heavier than hydrogen and helium. Although all of these heavy elements are quite rare compared to hydrogen and helium, they are found just about everywhere.

Heavy elements are continually being manufactured by stars and released into space by stellar deaths, so their amount compared to hydrogen and helium gradually rises with time. Heavy elements make up about 2 percent of the chemical content (by mass) of our solar system; the other 98 percent is hydrogen and helium. In some very old star systems, which formed before many heavy elements were produced, the heavy-element share may be less than 0.1 percent. Nevertheless, every star system studied has at least some amount of all the elements used by life. Moreover, when planetesimals small, solid objects formed in the early solar system that may accumulate to become planets condense within a forming star system, they are inevitably made from heavy elements because the more common hydrogen and helium remain gaseous. Thus, planetesimals everywhere should contain the elements needed for life, which means that objects built from planetesimals planets, moons, asteroids, and comets also contain these elements. The nature of solar-system formation explains why Earth contains all the elements needed for life, and it is why we expect these elements to be present on other worlds throughout our solar system, galaxy, and universe.

Note that this argument does not change, even if we allow for life very different from life on Earth. Life on Earth is carbon based, and most biologists believe that life elsewhere is likely to be carbon based as well. However, we cannot absolutely rule out the possibility of life with another chemical basis, such as silicon or nitrogen. The set of elements (or their relative proportions) used by life based on some other element might be somewhat different from that used by carbon-based life on Earth. But the elements are still products of stars and would still be present in planetesimals everywhere. No matter what kinds of life we are looking for, we are likely to find the necessary elements on almost every planet, moon, asteroid, and comet in the universe.

A somewhat stricter requirement is the presence of these elements in molecules that can be used as ready-made building blocks for life, just as early Earth probably had an organic soup of amino acids and other complex molecules. Earth's organic molecules likely came from some combination of three sources: chemical reactions in the atmosphere, chemical reactions near deep-sea vents in the oceans, and molecules carried to Earth by asteroids and comets. The first two sources can occur only on worlds with atmospheres or oceans, respectively. But the third source should have brought similar molecules to nearly all worlds in our solar system.

Studies of meteorites and comets suggest that organic molecules are widespread among both asteroids and comets. Because each body in the solar system was repeatedly struck by asteroids and comets during the period known as the heavy bombardment (about 4 billion years ago), each body should have received at least some organic molecules. However, these molecules tend to be destroyed by solar radiation on surfaces unprotected by atmospheres. Moreover, while these molecules might stay intact beneath the surface (as they evidently do on asteroids and comets), they probably cannot react with each other unless some kind of liquid or gas is available to move them about. Thus, if we limit our search to worlds on which organic molecules are likely to be involved in chemical reactions, we can probably rule out any world that lacks both an atmosphere and a surface or subsurface liquid medium, such as water.

## Preventing Overgrowth among Tree Branches

One way trees prevent themselves from having too many braches is simply by shedding (dropping off) branches once they have fulfilled their purpose. This happens as the tree gets bigger and grows new outer layers of foliage that shade the inner and lower branches. In most large trees, the center of the canopy contains only large branches, small branches and fine twigs are found only at the canopy's edge. In the shaded center, the small branches that would once have occupied that space are long gone. Trees like the true cypresses regularly shed small twigs complete with leaves toward the end of summer. Most other trees shed only branches that prove unproductive. If a branch is not producing enough carbohydrate to cover its own running costs—i.e., it needs to be subsidized by other branches because, for example, it is being shaded and receives little light—it will usually be got rid of. This prevents unproductive branches from being a drain on the tree and removes the wind drag (the force of air resistance) from useless branches.

Branches are shed for reasons other than lack of light. In dry parts of the world, it is common for trees and shrubs to lose smaller branches to save water. Small branches have the thinnest bark (the protective outer covering of a tree) and greatest surface area and thus are the source of most water loss once the leaves have been lost. The creosote bush of United States deserts self-prunes, or removes parts of itself, in the face of extreme heat or drought, starting from the highest and most exposed twigs and working downward to bigger and bigger branches, it's a desperate act because if the creosote bush loses too much food, it dies. Shedding branches can also be useful for self-propagation. Most poplar trees and willow trees characteristic of waterways will readily drop branches, which take root when washed up on muddy banks further downstream.

How are branches shed? In the simplest cases, dead branches rot and fall off, or healthy branches are snapped off by wind, snow, and animals. Some willows have a brittle zone at the base of small branches that encourages breaking in the wind, seemingly for propagation. Other cases of"natural pruning" are more startling: elm trees, and to a certain extent others, such as oaks, have a reputation for dropping large branches (up to half a meter in diameter) with no warning on calm, hot afternoons. Such dramatic shedding appears to be due to a combination of internal water stress coupled with heat expansion affecting cracks and decayed wood.

Many trees, however, shed branches deliberately. In this situation, branches are shed in the same way as foliage in autumn by the prior formation of a corky layer that leaves the wound sealed over with cork, which in turn is undergrown with wood the following year. In hardwoods, branches up to a meter in length and several centimeters in diameter can be shed normally after the leaves have fallen in the autumn (maples are unusual in casting branches mainly in spring and early summer). Oaks tend to shed small twigs up to the thickness of a pencil, beech may shed larger ones, and birches dump whole branches of dead twigs. Pine trees shed their clusters of needles (which really are short branches), and members of the redwood family shed their small branchlets with leaves. Typically in hardwood trees, something around 10 percent of terminal branches are lost each year through a mixture of deliberate shedding and being broken off.

Another way of reducing potential congestion is to make some branches smaller than others. Branches in the shade grow smaller than those in the sun. But trees can also regulate branch length from within. In many trees there is a clear distinction between long and short branches or shoots. The long shoots build the framework of the tree, making it bigger. The job of the short shoots (called spur shoots by horticulturalists) is to produce leaves, and commonly flowers, at more or less the same position every year. To maintain flexibility, any one shoot can switch from long to short or vice versa depending on internal factors, light levels, and damage.

## Grassland Environment

As opposed to forests, grasslands receive markedly less precipitation. This is one of the reasons why trees, which usually require a significant amount of moisture, are spaced relatively sparsely in grasslands. Due to the facts that most grasslands are situated in the center of continental landmasses, and that costal mountain ranges can block west-to-east winds as is the case with the Great Plains in North America, air masses from the north and south are highly influential on grasslands. The Great Plains receive cold Arctic air in winter and hot tropical air in summer. A typical grassland climate includes hot summers with long periods of desiccation and cold winters with erratic snow cover. Consequently, plants in these grassland areas experience low soil moisture and, additionally, are exposed to fixll sun, strong dry winds, and extreme summer heat and winter cold. Grassland plants must adapt to these conditions.

To support research on various types of ecosystems, during the 1970s, The National Science Foundation started what is known as the Long-Term Ecological Research (LTER) program. With the LTER program, scientists working at far-away sites can share data and collaborate to identify and understand large scale ecological patterns. At one LTER site in the Flint Hills of Northeastern Kansas, scientists made an important discovery about the influence of precipitation on plant productivity, the fuel on which ecosystems run. It was found that grasslands respond more strongly to pulses in rainfall than any other ecosystem. Dramatic bursts of plant growth and significant increases in primary productivity result from intermittent rainfall in grasslands. This pattern indicates that grasslands have a high underlying growth potential that surfaces when enough water is suddenly available. Because of these findings, LTER scientists have proposed that grassland annual primary productivity can be a useful indicator of global climate change. Similar to the canaries that miners used to carry into mines to warn of poisonous gases, grasslands may be able to serve as a warning of climate change and how it is affecting plants and humans. ?

When maintaining grasslands, fire plays an essential role. In the summer, dry grasses and their dead remains which have accumulated over previous years on the upper layer of soil (known as mulch) make a highly combustible fuel for fires started by people or lightning. When there is an absence of rain, dry lightning is a common occurrence in grassland areas, as is the accidental escape of campfires or other human-related fires. These fires in grasslands can bum for many kilometers before being stopped by rain or wet areas. Studying charcoal buried in soil layers have suggested that under natural (pre-European settlement) conditions, at least a hectare of North American prairie may have burned once every 5 to 30 years.

Plants in the grasslands are adapted to survive fire in many ways, but, just as importantly, fire is an essential component of grassland ecosystems. The invasion of both fire-sensitive plants and most trees are prevented by fire, and fire clears away dead plant material, thereby releasing necessary nutrients that facilitate new growth. Since the development of new grass was favored by Native Americans' horses and was also attractive to the buffalo they hunted, they often set grassland fires to stimulate it. These fires on grasslands was also helpful in increasing productivity of the Native Americans' wild food plants, improving visibility (which brings security), and helping control pests such as ticks. Nowadays, people use fire as an important tool in restoring and preserving grasslands.

Eaters create a disturbance to which grassland plants are adapted in many ways. In grasslands, grazing is more significant than in other types of ecological communities. Up to 60 percent of energy and grassland materials flows through primary and other consumers. In other terrestrial ecosystems, on the other hand, less than 5 percent of the ecosystem's material and energy usually flows through consumer food webs. This difference coordinates with the relatively large herbivore populations that grasslands support.

Benefits brought about from grazing include helping lower-growing plants by preventing shading by tall species, and providing a rich source of nutrients from grazer excrement. Grazing and fire both prevent just a few plants from dominating grasslands and help maintain the high natural plant diversity. Researchers at the University of Minnesota have found that high plant diversity has been pivotal in establishing and maintaining the high fertility in natural grassland soils.

## Population Revolution in Eighteenth-Century Europe

In late seventeenth-century Europe, what had been evolution in population followed by stabilization changed to population revolution? Increasing contacts with the Americas brought more sophisticated knowledge of the advantages of new foods, particularly the potato. Originally a cool-weather mountain crop in the Americas, potatoes did well in the Pyrenees, Alps, and Scottish Highlands. They also grew well in the long, damp springtime of the northwest European plain. Whatever hesitancy peasants may have felt about eating potatoes quickly passed when famine threatened; after all, people who in famines desperately consumed grass, weeds, and the bark of trees hardly would have hesitated to eat a potato. By the later eighteenth and the nineteenth century, American foods had become the principal foodstuffs of many rural folk. Various agricultural publicists promoted adoption of these foods, and peasants found that potatoes could allow subsistence on smaller plots of land. Fried potatoes soon began to be sold on the streets of Paris in the 1680sthe original French fries. Governments, eager to promote population growth as a source of military and economic strength, also backed the potato.

Along with new foods, some landowners began to introduce other innovations. The nutritional base for a population revolution combined regional changes with the use of American foods. Dutch and English farmers drained more swamps and so increased cultivable land. Agricultural reformers further promoted the use of crops such as the turnip that return valuable nitrogen to the soil. Improvements in available tools, such as growing use of the scythe instead of the sickle for harvesting, and better methods of raising livestock also spread. All this took shape from the late seventeenth century onward, building on earlier agricultural changes. At the same time, rates of epidemic disease declined, in part because of more effective government controls over the passage of people and animals along traditional plague routes from the Middle East. It was the change in foods that really counted, however.

These developments provided a framework for an unprecedented surge. In virtually every area of Europe, the population increased by 50 to 100 percent in the eighteenth century, with the greatest growth coming after 1750. The Hapsburg Empire grew from 20 million to 27 million people; Spain rose from 5 million to 10 million, and Prussia rose from 3 million to 6 million. Growth would continue throughout the nineteenth century. In Europe as a whole, population rose from 188 million in 1800 to 401 million in 1900. This was an upheaval of truly impressive proportions.

The population explosion resulted from a break in the traditional, if approximate, balance between births and deaths in European society. In England between 1700 and 1750, approximately 32.8 people were born annually for every 1,000 inhabitants, and 31.5 people died. Similarly, in Lombardy in the eighteenth century, 39 people were born and 37 people died for every 1,000 inhabitants. Clearly, a major alteration had to occur in either the birth or the mortality rate before the expansion of population could begin. In fact, both rates changed: families began to have more children, and a lower percentage of the population died each year. Lower infant death rates meant more people living to produce children of their own, though falling adult death rates also increased the number of older Europeans.

While historians continue to debate the precise balance of causes involved in these dramatic changes, basic outlines are clear. Better food and a reduction in the epidemic-disease cycle allowed more children to live to adulthood, which increased the population directly and also provided more parents for the next generation a double impact. Rapidly increasing populations provided a new labor force for manufacturing. In the eighteenth century, this mainly involved hundreds of thousands of people, mostly rural, producing thread, cloth, and other products for market sale. This manufacturing expansion helped sustain the growing population, but it could also encourage a higher birth rate. Some people, able to earn money by their late teens, began to produce children earlier; the rate of illegitimate births went up.  Others realized that having an extra child or two might help the family economy by providing additional worker- assistants. While death-rate decline was the most important source of Europe's population explosion, various changes on the birth rate side, though quite short-lived, pushed the population up as well.

## The Western Roman Empire in the Fifth Century

Shortly after the death of emperor Theodosius in 395 A.D., the Roman Empire was permanently divided into Eastern and Western empires. By the fifth century A.D., the power of the Western Roman Empire had declined considerably, though the Eastern Roman Empire centered in Byzantium continued to flourish. Various problems contributed to this undermining of the West. The accessions of Arcadius and Honorius, sons of Theodosius, as emperors in the East and West, respectively, illustrate the unfortunate pattern of child heirs that had unfavorable effects for both empires. When Arcadius died in 408, he was succeeded by his seven-year-old son, Theodosius II. Reigning until 423, Honorius was succeeded by his nephew Valentinian III, who was only five.

Because of their young ages, Theodosius' sons and grandsons could not rule without older advisors and supervising regents upon whom they naturally became dependent and from whom they were unable to break away after reaching maturity. As powerful individuals vied for influence and dominance at court, the general welfare was often sacrificed to private rivalries and ambitions. Moreover, it was the women of the dynasty who were the more capable and interesting characters. Holding the keys to succession through birth and inheritance, they became active players in the political arena.

Compared with the East, however, the West faced a greater number of external threats along more permeable frontiers. Whereas the East could pursue war and diplomacy more effectively with their enemies on the long eastern frontier, the West was exposed to the more volatile tribal Germanic peoples on a frontier that stretched along the Rhine and Danube rivers for 1,000 miles. The East, however, only had to guard the last 500 miles of the Danube. In addition, the East had many more human and material resources with which to pursue its military and diplomatic objectives. The East also had a more deeply rooted unity in the Greek culture of the numerous Greek and Near Eastern cities that Rome had inherited from earlier Grecian empires. Latin culture had not achieved comparable penetration of the less urbanized West outside of Italy. The penetration of Germanic culture from the north had been so extensive along the permeable Rhine-Danube frontier that it was often difficult to distinguish between barbarians (speakers of German and other languages unrelated to Latin) and Romans in those regions by the fifth century anyway.

One of the most outstanding features at the beginning of this period was the prominence of Germanic generals in the high command of the Roman Imperial army. The trend became significant, and several practical reasons can explain it. The foremost probably was the sheer need for military manpower that made it attractive to recruit bands of Germanic peoples for the armies, which, in turn, gave able chieftains and warlords the opportunity to gain Imperial favor and advance in rank. Second, one way to turn Germanic chieftains from potential enemies into loyal supporters was to offer them a good position in the Roman military. Third, although Theodosius had risen to power as a military leader, he was also a cultured aristocrat and preferred to emphasize the civilian role of the emperor and to rely for protection on Germanic generals whose loyalties were primarily to him, their patron.

Unfortunately, the high positions achieved by Germanic officers often aroused the jealousy and hostility of high-ranking Roman military and civilian officials. Such positions also gave their Germanic holders a chance to act on both personal and tribal animosities in the arena of Imperial politics. Internal Roman rivalries and power struggles aggravated the situation.

Rival factional leaders often granted Imperial titles and conceded territory to one Germanic leader or another in return for help against fellow Romans. While the Romans were thus distracted by internal conflict, other tribes seized the opportunity to cross into Roman territory unopposed. When the Romans could not dislodge them, peace was bought with further titles and territorial concessions as allies. In the midst of it all, alliances and coalitions between Roman emperors or powerful commanders and various tribes or tribal kings were made, unmade, and remade so often that it is nearly impossible to follow their course. Accordingly, all of these situations proved dangerous to the peace and safety of the West.

# Motor Development in Children

Control over one's motor behavior ranks among the infant's greatest achievements. Psychologists who study the acquisition of motor skills in children find it useful to distinguish between gross motor development, that is, motor skills which help children to get around in their environment such as crawling and walking, and fine motor development, which refers to smaller movement sequences like reaching and grasping.

The development of motor skills has implications beyond simply learning how to perform new actions: motor skills can have profound effects on other areas of development. For example, researchers have shown that infants with locomotor experience (experience moving around their environment) were less likely to make errors while searching for hidden objects. The ability to initiate movement around one's environment stimulates the development of making hidden object tasks easier to solve. Psychology professor Carolyn Rovee-Collier argues that the onset of independent locomotion at around nine months old marks an important transition in memory development. Children who can move about the environment develop an understanding of locations such as here and there. Because infant memory is initially highly dependent on context that is, the similarity between the situation where information is encoded (stored in memory) and where it is recalled infants who have experience moving about the environment and who learn to spatially encode information become less dependent on context for successful recall. These examples show that gross motor development has implications beyond the immediately apparent benefits of crawling and walking.

Renowned psychologist Jean Piaget argued that the development of reaching and grasping was a key aspect of development because it formed an important link between biological adaptation and intellectual adaptation. Reaching and grasping are voluntary actions under the infant's control, and as such, they open up exciting new possibilities in their ability to explore the environment. An infant who reaches for and grasps an object so as to explore it pushes his development forward as he engages in processes such as adapting his grip to the size and shape of the object. Piaget argued that these early processes drive cognitive development in the first two years of an infant's life.

The development of reaching begins early on in life. Newborn infants seated in an upright position will swipe and reach towards an object placed in front of them, a behavior labeled "prereaching." These poorly coordinated behaviors start to decline around two months of age and are replaced by "directed reaching" which begins at about three months of age. At this time reaching becomes more coordinated and efficient, and improves in accuracy. According to research conducted by Clifton et al., the infant's reaching does not depend simply on the guidance of the hand and arm by the visual system but is controlled by proprioception, the sensation of movement and location based on the stimulation arising from bodily  sources such as muscle contractions. By about nine months old, infants can adjust their reaching to take into account a moving object. However, nine month olds are far from expert reachers. A good deal of skill must still develop.

Once infants begin reaching they also begin to grasp the objects that are the target of their reaches. The ulnar grasp is seen when infants first engage in directed reaching. The ulnar grasp is a primitive form of grasping in which the infant's fingers close against its palm. The fingers seem to act as a whole, requiring the use of the palm in order to hold an object. Shortly after this accomplishment, when infants can sit upright on their own, they can acquire the ability to transfer objects from hand to hand. Around the end of the first year, infants will have graduated to using the pincer grasp where they use their index finger and thumb in an opposable manner (placing them opposite each other), resulting in a more coordinated and finely tuned grip which allows for the exploration of very small objects or those objects which demand specific actions for their operation, such as the knobs on a stereo system which require turning to the left or right to adjust volume.

## The Plow and the Horse in Medieval Europe

One of the most important factors driving Europe's slow emergence from the economic stagnation of the Early Middle Ages (circa 500-1000 B.C.E.) was the improvement of agricultural technology. One innovation was a new plow, with a curved attachment (moldboard) to turn over wet, heavy soils, and a knife (or coulter) in front of the blade to allow a deeper and easier cut. This more complex plow replaced the simpler "scratch" plow that merely made a shallow, straight furrow in the ground. In the lands around the Mediterranean, with light rains and mild winters, this had been find, but in the wetter terrain north and west of the Danube and the Alps, such a plow left much to be desired, and it is to be wondered  if it was used at all. Cleared lands would more likely have been worked by hand tilling, with little direct help from animals, and the vast forests natural to Northern Europe remained either untouched, or perhaps cleared in small sections by fire, and the land probably used only so long as the ash-enriched soil yielded good crops and then abandoned for some  others similarly cleared field. Such a pattern of agriculture and settlement was no basis for sustained cultural or economic life.

With the new heavy plow, however, fields could be cleared, sowed, and maintained with little more difficulty than in the long-settled lands of Southern Europe, while the richness of the new soils, the reliability of the rains, and the variety of crops now possible made for an extremely productive agriculture. The new tool, however, imposed new demands, technical, economic, and social. The heavy plow was a substantial piece of capital, unlike a simple hand hoe, and this had the same sorts of implications that capitalization always has—it favored the concentration of wealth and control. Moreover, making full use of it required more animal power, and this had a host of implications of its own. The full importance of this was even more apparent in the centuries after 1000, when oxen began to give way in certain parts of Western Europe to horses.

The powerful, rugged farm horse was itself a product of improvement during the Middle Ages, and it was part of a complex set of technical changes and capabilities. The introduction of new forms of equipment for horses transformed this animal into the single most important assist to human labor and travel. Instead of the old harness used by the ancient Greeks and Romans, there appeared from Central Asia the rigid, padded horse collar. Now, when the horse pulled against a load, no longer did the load pull back against its neck and windpipe but rather rode on the sturdy shoulders. When this innovation was combined with the iron horseshoe, the greater speed and stamina of the horse displaced oxen wherever it could be afforded. The larger importance of this lay not only in more efficient farm work, but in swifter and surer transportation between town and countryside. The farmer with horses could move products to market more frequently and at greater distances than with only oxen, and the urban development that was to transform the European economic and social landscape after the eleventh century was propelled in large part by these new horse-centered transport capabilities.

Another indicator of how compelling and important was the new horse agriculture was its sheer cost. Unlike oxen and other cattle, horses cannot be supported exclusively on hay and pasturage, they require, particularly in northern climates where pasturing seasons are short, cropped food, such as oats and alfalfa. Unlike grass and hay, these are grown with much of the same effort and resources applied to human nourishment, and thus their acquisition represents a sacrifice, in a real sense, of human food. The importance of this in a world that usually lived at the margins of sufficient diet is hard to overstate. The increased resources that went into making the horse central to both the medieval economy and, in a separate but related development, medieval warfare, are the surest signs of the great utility the animal now assumed.

## Art and Culture of Pacific Northwest Communities

The 1,600-kilometer stretch of the northwestern Pacific coast of North America (from southern Alaska to Washington State) provided an ideal environment for the growth of stable communities. Despite the northerly latitude, the climate is temperate. Natural resources were originally so rich that the inhabitants could subsist by fishing and hunting and gathering, without the need to domesticate stock or cultivate the land. Forests yielded an abundance of wood for buildings, for boats, and for sculpture. Beyond them the Rocky Mountains were an impenetrable barrier against raids. The area appears to have been settled around 500 A.D. by tribes of diverse origins speaking mutually unintelligible languages: from north to south they include the Tlingit, the Haida, the Tsimshian, the Bella Coola, the Kwakiutl, and the Nootka. The culture to which they contributed has, nevertheless, an underlying homogeneity and a distinct visual character.

The peoples of the Northwest engaged in trade as well as warfare with one another, and this may account for the diffusion of cultural traits and artistic motifs throughout the area. Much of their art was concerned with religious ritual objects. But the rest is secular and springs from a preoccupation with the hereditary basis of their complex social structures.

The Tlingit and other nations or language groups were collections of autonomous village communities composed of one or more families, each with its own chief, who inherited his position through matrilineal descent. They had no centralized political or religious organization, but cohesion was given by extensive kinship networks established through marriage, and men and women were obliged to many outside the larger divisions of clans and moieties (tribal subdivisions) into which they were born and into which the social group was divided by matrilineal or patrilineal descent. Thus families built up riches by marriage without any one family acquiring a dominant position

Totem poles (see figure below), the most distinctive artistic product of the Northwest, were conspicuous declarations of prestige and of the genealogy (family history) by which it had been attained. These magnificent sculptures that probably originated as funerary monuments were first described by travelers in the late eighteenth century. Each one was carved from a single trunk of cedar, and the increasing availability of metal tools both permitted and encouraged more complex compositions and greater height—up to 27.4 meters. Their superimposed figures—eagles, beavers, whales, and so on— were crests (symbols of identity) that a chief inherited from his lineage, his clan, and his moiety. They were not objects of worship, though the animals carved on them might represent guardian spirits. Poles were designed according to a governing principle of bilateral symmetry, with their various elements interlocked so that they seem to grow organically out of one another, creating a unity of symbolism, form, and surface.

Masks (see figure above) are the most varied of the carvings from the Northwest, where they were an essential part of communal life. In style they range from an almost abstract symbolism to combinations of human and animal features and to a lifelike naturalism sometimes bordering on caricature (a style that strongly exaggerates features or characteristics), taken to its extreme in Tlingit war helmets. Some differences must have been due to those among the cultures in which they were created, but their place of origin cannot always be ascertained as they seem to have passed from one contiguous nation to another in the course of trade or warfare. Although carvers worked according to established conventions, no two masks are identical and those with basic similarities reveal varying degrees of skill.

The major differences between masks were determined by their purpose. Some were representations of chiefs and their ancestors and made to be displayed and treasured as heirlooms. Although they appear to record the styles of facial tattooing customary in different groups, it is difficult to say how far they were intended to be portraits rather than generalized images. Many masks, sometimes quite large, were carved to be worn in dance-dramas that re-enacted and kept alive the cohesive myths of a culture. Often, Tlingit masks were made for religious leaders and incorporated the animals that were believed to be their spirit helpers. Conjuring up forces of nature from the ocean, the forests, or the sky, they mediated between life on Earth and the inscrutable powers around and above.

## Architectural Change in Eighth-Century Japan

Japanese construction techniques and architectural styles changed in the eighth century C.E. from more traditional Japanese models to imported continental (especially Chinese) models. Several factors contributed to this, in particular with respect to the creation of two new capital cities. In essence, changes then occurring in Japanese political life were rendering past arrangements for the rulers' headquarters obsolete, and continental models offered an alternative.

To elaborate, before the eighth century, the elite marriage practice, which was an important instrument of political alliance making, had encouraged rulers to maintain multiple palaces: that of their own family and those of their spouses, who commonly remained at or near their native family headquarters, at least for some years after marriage. These arrangements had the effect of encouraging frequent changes in royal residence as children matured and marriage alliances changed. The customs of multiple palaces and a moveable court were feasible as long as a ruling group was modest in size and its architectural practices relatively simple.

Moreover, because buildings using the traditional construction of thatched roofs and wooden poles placed directly in the ground rotted away in two decades or so, periodic replacement of palaces, shrines, warehouses, gate towers, and fortress walls was essential. The custom of residential mobility was thus not especially wasteful of labor and material resources: when the time came, one simply erected a new building at a new site—reusing valuable timbers as appropriate—and burned the rest. The practical necessity of replacement was given religious sanction because the regular replacement of buildings was regarded as necessary to provide spiritual cleansing of the site.

As rulers of the sixth and seventh centuries expanded their realm, however, they acquired more and more underlings, administrative paraphernalia, weaponry, and tribute goods, and they needed more and more buildings to house them. As the scale of government grew, moreover, it became more important to have these people and resources close at hand where they could be more easily controlled and utilized. Under these circumstances, frequent moves by the court or replacement of buildings became more costly, even prohibitive.

A solution to the problem was advocated by experts from the continent. This was the use of continental principles of urban design and techniques of construction. These produced geometrically laid out capital cities whose major gates and buildings employed stone foundations, mortise-and-tenon framing (a technique for attaching timbers), and tile roofs that largely eliminated the problem of rot and the consequent need for replacement.

One the other hand, to construct cities and buildings of that sort required so much labor and material that their use effectively precluded periodic replacement or the transfer of a royal headquarters from site to site. Nevertheless, the notion of grand buildings and capital cities became immensely attractive to Japanese rulers during the seventh and eighth centuries. Continental regimes, the glorious new Chinese dynasties most notably, had them: they constituted an expression of political triumph, a legitimizing symbol of the first order. Moreover, the architecture was an integral part of Buddhism, and acceptance of this religion in Japan at this time fostered adoption of its building style.

These several conflicting factors—the need to modify palace and capital arrangements but the difficulty of doing so, the wish to enjoy grandeur but the reluctance to settle for a single, immobile court—all became evident by the mid-seventh century. Change did come, but slowly, and in the end a compromise system was devised. Traditional shrines of Shinto, the native religion of Japan, and many residential buildings continued to be built in the rottable, replaceable style that accommodated religious concerns and taboos, while city gates, major government buildings, and Buddhist temples were built in the continental fashion that met the need for permanence and grandeur. Moreover, the wish of rulers to maintain multiple palaces fit with the custom of certain continental regimes that maintained summer palaces or other regional capitals where rulers could periodically reside on a temporary basis.

## Coral Reef Communities

Coral reefs are massive underwater structures made from the hard limestone exoskeletons of thousands of tiny living organisms (coral polyps) produced one on top of another in warm, clear, shallow ocean waters. Living polyps extend upward and outward from the coral colony center and live on top of the old dead exoskeletons. Coral reef communities are crowded with other animals representing virtually every major animal phylum. Space is at a premium on reefs, corals, seaweeds (various forms of algae), sponges, or other organisms cover virtually every surface. Because both corals and algae require light to survive, access to light, like space, is also a resource subject to competition. Fast-growing, branching corals can grow over slower-growing, encrusting, or massive corals and deny them light. In response, the slower-growing forms can extend stinging filaments from their digestive cavity and kill their competitor's polyps. Undamaged polyps on the faster-growing, branching coral, however, may grow very long sweeper tentacles, containing powerful nematocysts (stingers) that kill polyps on the slower-growing form. The faster-growing form repairs the damage and continues to overgrow its competitor. In addition to sweeper tentacles and stinging filaments, corals have several other mechanisms available for attack or defense.

In general, slower-growing corals are more aggressive than fast-growing species. In cases where a competitor cannot be overcome, however, corals may survive by taking advantage of differences in local habitats. Massive corals are generally more shade tolerant and able to survive at greater depths. Therefore, on many reefs it is the fast-growing, branching corals that ultimately dominate at the upper, shallower portion of the reef, whereas more massive forms dominate in deeper areas.

Corals also must compete with other reef organisms, each with its own strategies for survival. Sponges, soft corals, and seaweeds (algae) can overgrow stony corals and smother them. Algae are competitively superior to corals in shallow water but less so at depth. Survival of coral in shallow water, therefore, may depend on grazing by plant-eating echinoderms (starfish and sea urchins) and fishes. In Jamaica, overfishing removed most of the plant-eating fish from coral reefs. Initially, algal growth was kept in check by grazing sea urchins, but in 1982, a pathogen reduced the population by 99 percent. Without grazers, the algae were able to completely overgrow the coral. Competition may occur among other reef communities. Grazing by urchins and fishes is important in preventing seaweeds from overgrowing the reef. The dominant algae on a healthy reef are usually fast-growing filamentous forms or coralline algae, well protected by calcification (hardening) and the production of noxious chemicals. These algae are inferior competitors to larger, fleshier seaweeds, so grazing by urchins and fishes on the larger seaweeds allows these algae to persist. Grazing on plants is greatest in the shallow reef areas but decreases with depth, where lower temperatures and light reduce algal growth. The reef is, therefore, a mosaic of microhabitats with different levels of grazing and different algal communities.

An additional complexity arises from the activity of damselfish. Because they are territorial, many damselfish species exclude grazers and other species from certain areas of the reef. Algae grow rapidly in these territories, providing habitat for many small invertebrates but overgrowing the corals. Branching corals tend to dominate in damselfish territories because they are upright and faster growing than the more massive or encrusting forms.

Although less studied than on rocky shores, predation almost certainly has a significant influence on the community structure of coral reefs. Fish and other predators may preferentially prey on such competitors of corals as sponges and gorgonians, giving competitively inferior reef corals an advantage in securing space. Many species of fish, mollusks, and crustaceans also feed directly on coral polyps. Several surgeonfish and parrotfish may actually pass coral skeletons through their digestive tracts and add sediment to the reef. Both fish and invertebrate corallivores (coral-feeding organisms) seem to attack faster-growing, branching species preferentially, perhaps preventing slower-growing forms from being overgrown. Corallivores, however, rarely ever completely destroy a coral colony except in cases where tropical storms or humans have already done severe damage. The fact that almost all small invertebrates on reefs are so well hidden or highly camouflaged is another indicator of how prevalent predation is on reefs and its importance in determining reef structure.

## How Birds Acquire Their Songs

Most songbirds hatch in the spring and then merely listen to the songs of adult male birds until sometime in late summer or autumn, when the adults stop singing, not to resume until the end of winter the following year. It is usually male birds that are doing the singing in northern latitudes, though female singing is common in the tropics. Many young songbirds do no singing of their own until nearly a year after their birth. With the coming of their second spring, their testosterone levels rise and this in turn prompts them to begin singing, with their song development following a predictable pattern over a period of weeks. At first, their songs may be a quiet, jumbled series of chirps and whistles. Over time, young birds begin to use the syllables of their species' songs, though the order in which these syllables appear will vary. Finally, their songs crystallize (take form) into the clear, orderly song of their species.

There is a songbird, called the white-crowned sparrow, whose song development follows this general script while providing some variations that are instructive about the interplay of internal influences and learning in birdsong. White- crowned sparrows raised in captivity will follow the pattern of song acquisition just described: they listen to songs in their first spring and summer but do not themselves begin singing until they are perhaps six months old. In nature, however, things are different. For example, the white-crown found year-round in the San Francisco area sings a particular regional variant or dialect of the basic white-crown song and begins singing within six weeks or so of birth and may progress to fully crystallized song as early as three months after birth, meaning about September.

Why would there be a difference between singing in nature and singing in the laboratory? The pressures of nature. As year-round residents, the San Francisco white-crowns do not fly into an area in spring and then establish territories. Rather, they establish territories as early as their first autumn. One function of birdsong is to announce, I have a territory here. Young white-crowns, like many species, will extend this practice by counter singing, meaning a male, upon hearing the song of a nearby male of its species, will repeat the exact song he has heard, thus setting off a back-and-forth duel, like two children in an argument, each of them saying, I'm still here.

Internal influences and learning are also on display in white-crowns in the way they acquire their songs. We know that there is often a so-called sensitive period for animal learning a kind of window in which an animal is able to acquire certain skills or information. In laboratory-raised white-crowns, the sensitive period starts at about ten days after birth and extends until about fifty days after birth. A white-crown that became deaf prior to the opening of the sensitive period eventually will sing individual notes, but it will never learn to sing its species' song. Meanwhile, white-crowns that are raised in nature through part of their sensitive period and then taken to the laboratory will begin singing the following winter in the dialect of the area in which they were hatched. Two points are worth observing about this. First, note that these birds are learning the white-crown song months before they ever start practicing it themselves. Indeed, the learning window will be closed completely (in their first summer) before these lab-reared birds ever sing a note (the following winter). Second, learning is important enough in song acquisition that white-crowns learn not just their species' song but local or regional variants of it, which they are able to recall months after last hearing them.

But what about internal influences interestingly, all white-crowns that are reared in isolation from birth eventually sing nearly identical versions of a kind of standard white-crown song. In other words, there seems to be a built-in version of the white-crown song that becomes modified with local dialects only when birds are raised in the wild. Beyond this, isolated white-crowns that are exposed to tapes of other species' songs will ignore the other birds' songs entirely and go on to sing the basic white-crown song. White-crowns are thus genetically disposed to learn their own song while ignoring the songs of others.

## Isolation and diversification in the Tropical

The dense vegetation of the tropical rain forest preventing living organisms from moving easily. This in the way the rain forest limits human movement. For example, each valley in New Guinea, a large tropical rain forests, has its own tribe— each with language manner of dress, and child-rearing tendency. This diversification is so great that New Guineans have developed about 1000 different languages in contrast to the fifty that occur throughout all of Europe. Often people born in these isolated tribes never venture further than 10 miles from their birthplace.

It is not unreasonable to surmise that the same cause of the great diversity of tribes and languages in the rainforests of New Guinea—the extreme hindrance to movement caused by ecological congestion—may also have contributed to the great diversity in plants and animals in rainforests worldwide. In open continental regions, over grasslands or dry stretches, birds or insects may travel many miles before they come upon a new likely residence. But beneath the rainforest canopy, dispersal potential becomes drastically severed, and no bird, animal or insect could move very far before encountering a wealth of edible opportunities and available habitats. Jungle populations that become separated from each other by just hundreds or even tens of miles may be as effectively and permanently isolated from each other as if they were on opposite sides of the globe. Indeed, this is one of the evolutionary reasons for the very bright colors and loud calls of many rain forest plants and animals. Consider the vocalizations and vibrancy of parrots and toucans (tropical birds with typically brightly covered feathers) or consider the howler monkey, the world's loudest land animal. These noisy or highly visible shows help the animals discover the whereabouts of other members of the same species within the lavish display of green.

Thus for many jungle organisms, new species can begin to occur at very short distances, and like a wildfire, this great diversity led to spread and fuel itself, for the different plants and animals would provide great variations in the survival benefits and drawbacks within all the small neighboring micro-territories. These extreme isolating effects of course would only occur below or at the level of the canopy, which is that upper, oceanic layer of leaves situated some 45—50 meters above the ground that forms the unbroken living roof of the rain forest.

But there is another less crowed layer, the emergent layer. The emergent layer made up of the occasional enormous tree that grows 60-70 meters high, like the giant kapok, or silk cotton, tree, which often breaks through the darkness of the canopy and extends upward into the open sunshine. In South America, these more sparsely situated leafy treetops have become the nesting sites of the harpy eagle, the largest eagle in the world, with a wing span reaching 2 meters. The happy eagle uses its advantageous position and view to prey upon the monkeys resulting through the meadow of canopy leaves below—a hunting system that is similar to that of North American birds of prey that sit in tress looking down for animals moving about the fields and grasslands. In the rain forest, thought this system begins at 50 meters off the ground.

Unlike the more than 40 species of toucans that inhabit the Amazon rainforest, the range of the harpy eagle extends from Central America and all across the South American jungles, yet it has not diversified. Clearly, the freedom of movement offered above the canopy has allowed a continuous flow of genes and has not encouraged diversification of the species. The giant kapok trees, in which these eagles so often build their nests are similarity unconfined by their neighboring trees and have retained their powers of dispersal. Their seeds, surrounded by fluffy cotton fibers.

## Why did Nonavian dinosaurs become extinct?

Data from diverse sources, indicates that the Late Cretaceous climate was milder than today's because of shallow seas covering the continents. At the end of the Cretaceous, the geological record shows that these seaways retreated from the continents back into the major ocean basins. No one knows why. Over a period of about 100,000 years, while the seas pulled back, climates around the world became dramatically more extreme: warmer days, cooler nights: hotter summers, colder winters. Perhaps Nonavian dinosaurs (that is , all the dinosaurs except those belonging to the Ave, or bird family) could not tolerate these extreme temperature changes and become extinct.

If true though, why did 'cold-blooded' animals, such as snakes, lizards, turtles, and crocodiles survive the freezing winters and torrid summers? These animals are at the mercy of the climate to maintain a livable body temperature. It's hard to understand why they would not be affected, whereas Nonavian dinosaurs were left too crippled to cope, especially if some dinosaurs were 'warm-blooded'. Critics also point out that the shallow seaways had retreated from and advanced not the continents numerous times during the Mesozoic, so why did the nonavian dinosaurs survive the climatic changes associated with the earlier fluctuations but not with this one? Although initially appealing, the hypothesis of a simple climatic change related to sea levels is insufficient to explain all the data. Volcanism, has also been implicated in dinosaur extinction. The end of the Cretaceous coincided with a great increase in volcanic activity throughout the world. Lava flooded areas of India, and explosive eruptions in the South Atlantic and the midwestern United States hurled ash over much of the globe. These eruptions could have spewed great quantities of poisonous gases into the atmosphere causing acid rain and more-acidic waters in the surface layers of the ocean. Over the short term, a cooling would result from the airborne volcanic ash, which would cut off sunlight. Over a longer term, warming could have resulted from the greenhouse effect. Climatic changes from increased volcanism may have caused the extinction of many nonavian dinosaurs, but they do not satisfactorily explain the selective patterns of extinction in the fossil record.

Dissatisfaction with conventional explanations for nonavian dinosaur extinctions eventually led to a key observation that, in turn, has fueled a decade of vigorous and often vitriolic debate. Many plants and animals that become extinct at the end of the Mesozoic disappear abruptly as one moves from older layers of rock documenting the end of the Cretaceous up into younger rocks representing the beginning of the Cenozoic. Between the last layer representing the end of the Cretaceous and the first layer representing the start of the Cainozoic, there is often a thin bed of clay. Scientists felt that they could get an idea of how long it took to deposit this 1 centimeter of clay by looking at the concentration of the element iridium in it.

Iridium is no longer common at Earth's surface. Because it usually exists in a metallic state, it was preferentially incorporated into Earth's core as the planet cooled and consolidated. Iridium is found in high concentrations in some meteorites in which the solar system's original chemical composition is preserved. Even today, microscopic meteorites continually bombard Earth, falling on both land and sea. By measuring how many of these meteorites fall to Earth over a given period of time, scientists can estimate how long it might have taken to deposit the observed amount of iridium in the boundary clay. These calculations suggest that a period of about 1 million years would have venn required. On the basis of other evidence related to Earth's magnetic field at the time of the extinction, however, it was believed that nonavian dinosaurs and other animals had to have gone extinct within a period of half a million years. If so, the deposition of the boundary clay could not have lasted 1 million years, and the unusually high concentration of iridium seemed to require a special explanation.

Consequently, scientists hypothesized that a single large asteroid, about 10 to 15 kilometers across, collided with Earth, and the resulting fallout created the boundary clay. Their calculations show that the impact kicked up a dust cloud that cut off light for several months, inciting photosynthesis in plants; decreased surface temperatures on continents to below freezing; caused extreme episodes of acid rain; and significantly raised long-term global temperatures through the 'greenhouse effect,' This disruption of the food chain an climate would have eradicated the nonavian dinosaurs and other organisms in less than 50 years.

## Origin of the Solar System

The orderly nature of our solar system leads most astronomers to conclude that the planets formed at essentially the same time and from the same primordial (original) material as the Sun. This material formed a vast cloud of dust and gases called a nebula. The nebular hypothesis suggests that all bodes of the solar system formed from an enormous nebular cloud consisting mostly of hydrogen and helium as well as a small percent of all the other heavier elements known to exist. The heavier substances in this frigid cloud of dust and gases consisted mostly of such elements as silicon, aluminum, iron, and calcium—the substances of today's common rocky materials. Also prevalent were other familiar elements, including oxygen, carbon, and nitrogen.

Nearly five billion years ago, some external influence, such as a shock wave traveling from a catastrophic explosion (supernova), may have triggered the collapse of this huge cloud of gases and minute grains of heavier elements, causing the cloud to begin to slowly contract due to the gravitational interactions among its particles. As this slowly spiraling nebula contracted, it rotated faster and faster for the same reason ice-skaters do when they draw their arms toward their bodies. Eventually, the inward pull of gravity came into balance with the outward force caused by the rotational motion of the nebula. By this time the once vast cloud had assumed a flat disk shape with a large concentration of material at its center, called the protosun (pre-Sun). Astronomers are fairly confident that the nebular cloud formed a disk because similar structures have been detected around other stars.

During the collapse, gravitational energy was converted to thermal energy (heat), causing the temperature of the inner portion of the nebula to dramatically rise. At such high temperatures, the dust grains broke up into molecules and energized atomic particles. However, at distances beyond the orbit of Mars, the temperatures probably remained quite low. At -200℃, the tiny particles in the outer portion of the nebula were likely covered with a thick layer of ices made of frozen water, carbon dioxide, ammonia, and methane. Some of this material still resides in the outermost reaches of the solar system in a region called the Oort cloud.

The formation of the Sun marked the end of the period of contraction and thus the end of gravitational heating. Temperatures in the region where the inner planets now reside began to decline. The decrease in temperature caused those substances with high melting points to condense into tiny particles that began to coalesce (join together). Such materials as iron and nickel and the elements of which the rock-forming minerals are composed—silicon, calcium, sodium, and so forth—formed metallic and rocky clumps that orbited the Sun. Repeated collisions caused these masses to coalesce into larger asteroid-size bodies, called protoplanets, which in a few tens of millions of years accumulated into the four inner planets we call Mercury, Venus, Earth, and Mars. Not all of these clumps of matter were incorporated into the protoplanets. Rocky and metallic pieces that still remain in orbit are called meteoroids.

As more and more material was swept up by the inner planets, the high-velocity impact of nebular debris caused the temperatures of these bodies to rise. Because of their relatively high temperatures and weak gravitational fields, the inner planets were unable to accumulate much of the lighter components of the nebular cloud. The lightest of these, hydrogen and helium, were eventually whisked from the inner solar system by the solar winds.

At the same time that the inner planets were forming, the larger, outer planets (Jupiter, Saturn, Uranus, and Neptune), along with their extensive satellite systems, were also developing. Because of low temperatures far from the Sun, the material from which these planets formed contained a high percentage of ices—water, carbon dioxide, ammonia, and methane—as well as rocky and metallic debris. The accumulation of ices partly accounts for the large sizes and low densities of the outer planets. The two most massive planets, Jupiter and Saturn, had surface gravities sufficient to attract and hold large quantities of even the lightest elements—hydrogen and helium.

## Pleistocene Extinctions

At the end of the Pleistocene (roughly 11,500 years ago), many large mammals became extinct. Large mammals in the Americas and Australia were particularly hard-hit. In Australia, 15 of the continent's 16 of large mammals died out; North America lost 33 of 45 genera of large mammals, and in South America 46 of 58 such genera went extinct. In contrast, Europe lost only 7 of 23 such genera, and in Africa south of the Sahara only 2 of 44 died out. What caused these extinctions, why did these extinctions eliminate mostly large mammals why were the extinctions most severe in Australia and the Americas No completely satisfactory explanation exists, but two competing hypotheses are currently being debated. One holds that rapid climatic changes at the end of the Pleistocene caused extinctions, whereas another, called prehistoric overkill, holds that human hunters were responsible.

Rapid changes in climate and vegetation occurred over much of Earth's surface during the late Pleistocene, as glaciers began retreating. The North American and northern Eurasian open steppe tundras (treeless and permanently frozen land areas) were replaced by conifer and broadleaf forests as warmer and wetter conditions prevailed. The Arctic region changed from a productive herbaceous one that supported a variety of large mammals, to a relatively barren waterlogged tundra that supported a far sparser fauna. The southwestern United States region also changed from a moist area with numerous lakes, where saber-tooth cats, giant ground sloths, and mammoths roamed, to a semiarid environment unable to support a diverse fauna of large mammals.

Rapid changes in climate and vegetation can certainly affect animal populations, but the climate hypothesis presents several problems. First, why did the large mammals not migrate to more suitable habitats as the climate and vegetation changed After all, many other animal species did. For example, reindeer and the arctic fox lived in southern France during the last glaciation and migrated to the Arctic when the climate became warmer.

The second argument against the climatic hypothesis is the apparent lack of correlation between extinctions and the earlier glacial advances and retreats throughout the Pleistocene Epoch. Previous changes in climate were not marked by episodes of mass extinctions. Proponents of the prehistoric overkill hypothesis argue that the mass extinctions in North and South America and Australia coincided closely with the arrival of humans. Perhaps hunters had a tremendous impact on the faunas of North and South America about 11,000 years ago because the animals had no previous experience with humans. The same thing happened much earlier in Australia soon after people arrived about 40,000 years ago. No large-scale extinctions occurred in Africa and most of Europe because animals in those regions had long been familiar with humans.

One problem with the prehistoric overkill hypothesis is that archaeological evidence indicates the early human inhabitants of North and South America, as well as Australia, probably lived in small, scattered communities, gathering food and hunting. How could a few hunters destroy so many species of large mammals However, it is true that humans have caused major extinctions on oceanic islands. For example, in a period of about 600 years after arriving in New Zealand, humans exterminated several species of the large, flightless birds called moas. A second problem is that present-day hunters concentrate on smaller, abundant, and less dangerous animals. The remains of horses, reindeer, and other small animals are found in many prehistoric sites in Europe, whereas mammoth and woolly rhinoceros remains are scarce. Finally, few human artifacts are found among the remains of extinct animals in North and South America, and there is usually little evidence that the animals were hunted. Countering this argument is the assertion that the impact on the previously unhunted fauna was so swift as to leave little evidence.

The reason for the extinctions of large Pleistocene mammals is still unresolved and probably will be for some time. It may turn out that the extinctions resulted from a combination of different circumstances. Populations that were already under stress from climate changes were perhaps more vulnerable to hunting, especially if smaller females and young animals were the preferred targets.

## Earth's Atmosphere

Earth's atmosphere has changed through time. Compared to the Sun, whose composition is representative of the raw materials from which Earth and other planets in our solar system formed, Earth contains less of some volatile elements, such as nitrogen, argon, hydrogen, and helium. These elements were lost when the envelope of gases, or primary atmosphere, that surrounded early Earth, was stripped away by the solar wind or by meteorite impacts, or both. Little by little, the planet generated a new, secondary atmosphere by volcanic outgassing of volatile materials from its interior.

Volcanic outgassing continues to be the main process by which volatile materials are released from Earth—although it is now going on at a much slower rate. The main chemical constituent of volcanic gases (as much as 97 percent of volume) is water vapor, with varying amounts of nitrogen, carbon dioxide, and other gases. In fact, the total volume of volcanic gases released over the past 4 billion years or so is believed to account for the present composition of the atmosphere with one important exception: oxygen. Earth had virtually no oxygen in its atmosphere more than 4 billion years ago, but the atmosphere is now approximately 21 percent oxygen.

Traces of oxygen were probably generated in the early atmosphere by the breakdown of water molecules into oxygen and hydrogen by ultraviolet light (a process called photodissociation). Although this is an important process, it cannot begin to account for the present high levels of oxygen in the atmosphere. Almost all of the free oxygen now in the atmosphere originated through photosynthesis, the process whereby plants use light energy to induce carbon dioxide to react with water, producing carbohydrates and oxygen.

Oxygen is a very reactive chemical, so at first most of the free oxygen produced by photosynthesis was combined with iron in ocean water to form iron oxide-bearing minerals. The evidence of the gradual transition from oxygen-poor to oxygen-rich water is preserved in seafloor sediments. The minerals in seafloor sedimentary rocks that are more than about 2.5 billion years old contain reduced (oxygen-poor) iron compounds. In rocks that are less than 1.8 billion years old, oxidized (oxygen-rich) compounds predominate. The sediments that were precipitated during the transition contain alternating bands of red (oxidized iron) and black (reduced iron) minerals. These rocks are called banded-iron formations. Because ocean water is in constant contact with the atmosphere, and the two systems function together in a state of dynamic equilibrium, the transition from an oxygen-poor to an oxygen-rich atmosphere also must have occurred during this period.

Along with the buildup of molecular oxygen (O2) came an eventual increase in ozone (O3) levels in the atmosphere. Because ozone filters out harmful ultraviolet radiation, this made it possible for life to flourish in shallow water and finally on land. This critical state in the evolution of the atmosphere was replaced between 1100 and 542 million years ago. Interestingly, the fossil record shows an explosion of life forms 542 million years ago. Oxygen has continued to play a key role in the evolution and form of life. Over the last 200 million years, the concentration of oxygen has risen from 10 percent to as much as 25 percent of the atmosphere, before setting (probably not permanently) at its current value of 21 percent. This increase has benefited mammals, which are voracious oxygen consumers. Not only do we require oxygen to fuel our high-energy, warm-blooded metabolism, our unique reproductive system demands even more. An expectant mother's used (venous) blood must still have enough oxygen in it to diffuse through the placenta into her unborn child's bloodstream. It would be very difficult for any mammal species to survive in an atmosphere of only 10 percent oxygen.

Geologists cannot yet be certain why the atmospheric oxygen levels increased, but they have a hypothesis. First, photosynthesis is only one part of the oxygen cycle. The cycle is completed by decomposition, in which organic carbon combines with oxygen and forms carbon dioxide. But if organic matter is buried as sediment before it fully decomposes, its carbon is no longer available to react with the free oxygen. Thus there will be a net accumulation of carbon in sediments and of oxygen in the atmosphere.

# Currency and the Emergence of China’s Market Economy

China’s Song dynasty (960一1279 E.C) building on developments of the earlier Tang dynasty(618-907 C.E.), saw a remarkable economic expansion in which increasing agricultural and industrial production, as well as internal and international trade played important roles in establishing a market economy. China’s various regions increasingly specialized in the cultivation of particular food crop for the production of particular manufactured good, trading their own products for imports from other regions. The market was not the only influence on the Chinese economy government bureaucracies played a large role in the distribution of staple foods such as rice, wheat and millet, and dynastic authorities closely watched militancy sensitive enterprise such as the iron industry. Nevertheless, millions of cultivator produced fruits and vegetables for sale on the open market, and manufacturers of silk, porcelain, and other goods supplied both domestic and foreign markets. The Chinese economy became more tightly integrated than ever before, and foreign demand for Chinese products fueled rapid economic expansion.

Indeed, trade grew so rapidly during Tang and Song times that China experienced a shortage of the copper coins that served as money for most transactions. To alleviate the shortage, Chinese merchants developed alternative to cash that resulted in even more economic growth. Letters of credit came into common use during the early Tang dynasty Known as ‘flying cash,’ they enabled merchants to deposit goods or cash at one location and draw the equivalent in cash or merchandise elsewhere in China. Later developments include the use of promissory notes, which the payment of a given sum of money at a late date, and which entitled the bearer draw funds against cash deposits bankers.

The search for alternatives to cash also led to the invention of paper currency. Wealthy merchants pioneered the use of printed paper money during the late ninth century. In return for cash deposits from their clients, they issued printed notes that clients could redeem for merchandise. In a society short of cash. These notes greatly facilitated commercial transactions. Occasionally, however, because of temporary economic reverses or poor management, merchants were not able to honor their notes. The resulting discontent among creditors often led to disorder and sometimes even to riots.

By the eleventh century, however, the Chinese economy had become so dependent on alternatives to cash that it was impractical to banish paper currency altogether. To preserve its convenience while forestalling public disorder, governmental authorities forbade private parties from issuing paper currency and reserved that right for the state. The first paper money priced under government auspices appeared in 1024 in Sichuan province, most active center of early printing. By the end of the century, government authorities throughout China issued printing paper money—complete with identification numbers and dire warning against the printing of counterfeit (illegal) notes.

Printed paper money caused serious problems for several centuries after its appearance. Quite apart from contamination of the money supply by counterfeit notes, government authorities frequently printed currency representing more value than they actually possessed in cash reserves —a practice not unknown in more recent times. The result was a partial loss of public confidence in paper money. By the late eleventh century, some notes of paper money would fetch only 95 percent of their value in cash. Not until the Qing dynasty (1644-1911C.E) did Chinese authorities place the issuance of printed money under tight fiscal controls. In spite of abuses, however, printed paper money provided a powerful stimulus to the Chinese economy.

Trade and urbanization transformed Tang and Song China into a prosperous, Cosmopolitan society. Merchants from India, Persia, and Asia congregated large trading cities like Chang’an and Luoyang, and Arab, Persian, and Malay seafarers established communities especially in bustling southern China port cities like Guangzhou and Quanzhou. Indeed, high productivity and trade brought the Tang and Song economy a dynamism that China’s borders could be restrain. Chinese consumers developed a taste for exotic goods the stimulated the trade throughout much of the eastern hemisphere. Spices from the Islands of the Southeast Asia make their way to China, along with products as diverse as kingfisher feathers and tortoise shell from Vietnam, pearls and incense from India, and horses and melons from central Asia. These items became symbols of the refined elegant lifestyle—in many cases because of attractive equalities inherent in the commodities themselves the Sometimes simply because of their scarcity and the foreign provenance. In exchange for such exotic items, Chinese sent the board vast quantities silk, porcelain, and lacquerware. In central Asia, South East Asia, India, Persia, and the port cities of East Africa, wealthy merchants and rulers wore Chinese silk and set their tables with Chinese porcelain. China's economic surge during the Tang and Song Dynasty thus promoted trade and economic growth throughout much of the eastern hemisphere.

## Greek Sacred Groves and Parks

In Greek and Roman civilization, parks were associated with spirituality, public recreation, and city living. Greek philosophers pondered the meaning of nature and its innermost workings, the relationships between animals and humankind, and how matter related to spirit. The philosophy of Aristotle (384-322 B.C.) advanced the fundamental notion of nature as the embodiment of everything outside culture, an essence opposed to art and artificiality. This sense of nature and culture as distinct opposites continues to govern ideas about the environment and society today. Meanwhile, the suggestion of a state of nature, wholesome and pure, defined in opposition to civilized life, found acceptance in Aristotle's time through the concept of the Golden Age—a legendary ideal that had significance for landscape planning and artistic experiment. Described by Greek poets and playwrights, the Golden Age of perpetual spring depicted an era before the adoption of agriculture, when humans embraced nature's wonder and communicated with spirits in sacred woods. In The Odyssey (800 B.C.), Homer, the great Greek writer, described a garden that was a place of constant productivity, where "fruit never fails nor runs short, winter and summer alike."

Greek interest in spintuality and nature manifested itself in the tradition of the sacred grove. Usually comprised of a few trees, a spring, or a mountain crag, sacred groves became intensely mystical places by their associations with gods, spirits, or celebrated folk heroes. Twisted trees, sections of old-growth forest, and rocks or caves typically surrounded the naturalistic shrines and altars. As the Roman official and writer Pliny the Elder (A.D. 23-79) put it, "Trees were the first temples of the gods, and even now simple country people dedicate a tree of exceptional height to a god with the ritual of olden times, and we worship forests and the very silences they contain."

The Greeks were not alone in their spiritual veneration of nature. Examples of pantheism—the belief that God and the universe or nature are the same—and the worship of trees permeated many cultures. The nations of northern Europe utilized trees as places of worship. In Scandinavian mythology, the tree called Yggdrasil held up the world, its branches forming the heavens and its roots stretching into the underworld. A spring of knowledge bubbled at its base, and an eagle perched amid its sturdy branches. The Maori people of New Zealand celebrated a tree that separated the sky from the earth. For many ancient civilizations, trees signified life, permanence, and wisdom.

In some spiritual traditions, landscapes such as gardens or deserts were treated as abstract emblems of spiritual states such as innocence or despair. Rather than symbolic landscapes, as in the Judeo-Christian tradition, Greek sacred groves operated as literal homes of the gods. Instead of being confined to prehistory or celestial space, spiritual parkscapes were present within the existing cultural terrain. One could not visit a symbol of peace and severity, but one could experience these qualities in a sacred grove.

The spiritual significance of the sacred grove mandated specific preservationist measures. Civil restrictions and environmental codes of practice governed the use of such spaces. Enclosing walls prevented sheep from desecrating sacred sites, while patrolling priests issued spiritual guidance along with fines for vandalism. Laws forbade hunting, fishing, or the cutting of trees. Those not dissuaded by monetary penalties were threatened with the anger of the resident gods.

Such environmental care suggested to historian J. Donald Hughes that sacred groves represented "classical national parks." By helping to insulate sacred groves from pressures of deforestation, erosion, and urbanization, Greek codes protected ecosystems from destruction. Sacred groves nonetheless represented imperfect parkscapes. Some encompassed relatively small areas such as a section of a hillside or a series of caves. Meanwhile, the fundamental purpose of the grove— the visitation of resident gods—sometimes promoted activities not entirely conducive to modern concepts of conservation. Animals were routinely captured to serve as sacrifices to the gods. Many groves witnessed horticultural and architectural improvements. Flowers were planted, trails cut, and statues, fountains, and caves installed for the benefit of visitors. The grove served as a recreational center for Greek society, a realm of ritual, performance, feasting, and even chariot racing.

## The Chaco Phenomenon

A truly remarkable transformation in settlement patterns occurred in the San Juan basin in northwestern New Mexico in the late tenth and early eleventh centuries, with small household farmsteads giving way to aggregated communities centered on communal masonry buildings that are now called “great houses.” These structures are found throughout the basin but are concentrated in Chaco Canyon, where several examples contained hundreds of rooms and reached four stories in height. The largest great house is Pueblo Bonito, with over 600 rooms covering two acres. The entire episode of great house construction in Chaco, the Bonito phase (A.D. 900-1140), was obviously a time of immense cooperative effort. At least 200,000 wooden beams averaging 5 meters long and 20 centimeters in diameter were brought to the canyon from distances between 40 and 100 kilometers away to build a dozen great houses, signifying a huge labor investment and a complex production process. The bulk of construction took place in the eleventh century, but by A.D. 1140 it had ceased abruptly, after which there was a rapid decline in use of the great houses and apparent abandonment of the canyon in the thirteenth century.

For more than a century archaeologists have struggled to understand the circumstances surrounding the rise and collapse of Chacoan society—dubbed the Chaco Phenomenon. In particular, research has focused on determining why such an apparently inhospitable place as Chaco, which today is extremely arid and has very short growing seasons, should have favored the concentration of labor that must have been required for such massive construction projects over brief periods of time. Until the 1970s, it was widely assumed that Chaco had been a forested oasis that attracted farmers who initially flourished but eventually fell victim to their own success and exuberance, as they denuded the canyon of trees and vegetation to build large great houses. In the 1980s this reconstruction was largely dismissed in response to evidence that there had never been a forest in Chaco, and that canyon soils had poor agricultural potential. As scientific interpretations about Chaco changed, the focus of explanatory models changed from the attractiveness of the canyon for farmers to the position of the canyon within a regional network of dispersed agricultural communities.

The adoption of a regional perspective in explaining the Chaco Phenomenon was based in part on the discovery of formal trails connecting many of the great houses in Chaco, as well as linking the canyon to smaller great houses located throughout the San Juan basin, the latter are referred to as Chaco “outliers.” These trails are densest around the concentration of great houses in the center, and the canyon itself is roughly at the center of the basin. Consequently, the canyon occupies the geographical and social center of the network formed by the connecting trails. The current consensus view is that religion provides the fundamental explanation for this centrifugal pattern.

Archaeologists now describe Chaco during the Bonito phase as a location of high devotional expression and the pilgrimage center of a sacred landscape. These descriptions emphasize aspects of the archaeological record presumed to be associated with ritual activity, including caches of turquoise beads and pendants, unusual ceramic vessels and wooden objects, several rooms with multiple human burials, and especially the large number of kivas (multipurpose rooms used for religious, political, and social functions) found in great houses. Most of these indicators occur only at Pueblo Bonito, but archaeologists generally assume that all the great houses had a similar ritual function. In fact, some scholars have suggested that the great houses were temples rather than residences.

However, new geological field studies in Chaco have produced results that may require a significant reassessment of the assumption that the canyon was not a favorable agricultural setting. It appears that during the first half of the eleventh century, during the extraordinary boom in construction, a large volume of water and suspended sediment flowed into the canyon. A large natural lake may have existed at the western end of Chaco, near the biggest concentration of great houses. The presence of large quantities of water and, equally important, a source of sediment that replenished agricultural fields, presumably made the canyon an extremely attractive place for newly arriving people from the northern San Juan River basin.

## Costs and Benefits of Dispersal

In order to move from one home base to another, animals must expend calories not only while moving but even before the dispersal when they invest in the development of the muscles needed to move. For example, if a cricket is to leave a deteriorating environment and move to a new and better place, it will need large flight muscles to fly away. Presumably, the calories and materials that go into flight muscle development and maintenance have to come out of the general energy budget of the animal. This means that other organ systems cannot develop as rapidly as they could otherwise, which may mean that the flight-capable individual is, in some other respects, less fit to survive.

Dispersing individuals not only have to pay energetic, developmental, and travel costs but are also more often exposed to predators—all of which raises the question, why are animals so often willing to leave home even when this means leaving a familiar, resource-rich location? This question is particularly pertinent for species in which some individuals disperse while others do not or do not disperse as far. One species in which some individuals travel farther than others is Belding's ground squirrel. Young male squirrels travel about 150 meters from the burrow in which they were born, whereas young females usually settle down only 50 meters or so from where they were born. Why should young Belding's ground squirrels disperse at all, and why should the males disperse farther than their sisters?

According to one argument, dispersal by juvenile animals of many species may be an adaptation against problems associated with inbreeding. When two closely related individuals mate, their offspring are more likely to manifest genetic diseases than are the offspring of genetically unrelated individuals, and as a result, inbreeding tends to produce animals that are less likely to survive to adulthood and reproduce. Dispersal of juveniles makes inbreeding less likely.

If avoidance of inbreeding is the point of dispersing, then one might expect as many female ground squirrels as males to travel 150 meters from their natal burrow. In fact females do not disperse as far as males, perhaps because the costs and benefits of dispersal differ for the two sexes. It has been suggested that the reproductive success of female Belding's ground squirrels depends on their possession of a territory in which to rear their young. Female ground squirrels that remain near their birthplace enjoy assistance from their mothers in the defense of their burrows against rival females. Thus, the benefits of remaining on familiar ground are greater for females than for males.

There may, however, be another reason why male mammals disperse greater distances than females. The usual rule is that males, not females, fight with one another for access to mates, and, therefore, males that lose such conflicts may find it advantageous to move away from same-sex rivals that they cannot subdue. Although this hypothesis probably does not apply to Belding's ground squirrels, since young males have not been seen fighting with older ones around the time of dispersal, the idea is more plausible with respect to some other species, such as lions.

Lions live in large groups, or prides, from which young males disperse. In contrast, the daughters of the resident lionesses usually spend their entire lives close to where they were born. The sedentary females benefit from their familiarity with good hunting grounds and safe breeding dens in their natal territory, among other things. The departure of many young male lions coincides with the arrival of new mature males that violently displace the previous masters of the pride and chase off the males that are not yet adults in the pride as well. These observations support the mate-competition hypothesis for male dispersal. However, if young males are not evicted after a pride takeover, they often leave anyway without any coercion from adult males and without ever having attempted to mate with their female relatives. Moreover, mature males that have claimed a pride sometimes disperse again, expanding their range to add a second pride of females, at a time when their daughters in the first pride are becoming sexually mature. Inhibitions against inbreeding apparently exist in lions and cause males to leave home.

## The Long History of Overexploitation

Overexploitation is the overuse by humans of a population of organisms to an extent that threatens the viability of the population or radically alters the natural community in which it lives. There is a tendency to think that overexploitation is a relatively new phenomenon. However, that view is a bit na?ve, as we will see in some examples of past overexploitation.

After the most recent glaciation, which was at its height between about 20,000 and 14,000 years ago, the grasslands in central North America harbored an extraordinary array of large animals. The diversity of antelope, horses, cheetahs, giant ground sloths, mammoths, mastodons, and other animals easily rivaled that of the large animal fauna of Africa today. However, about 11,000 years ago, at the end of the Pleistocene epoch, many disappeared; 34 genera of large mammals became extinct in fewer than 1,000 years, while 40 more became extinct in South America. This was a massive die-off when you consider that only 20 large mammal genera had become extinct in North America over the previous three million years.

Is it a coincidence that so many large mammals became extinct shortly after the time that humans, crossing from Siberia to Alaska, probably first arrived in the Western Hemisphere? Paul Martin, an anthropologist, thinks not and has argued in many articles and books that overhunting was primarily responsible for the extinctions. Martin's critics have argued that the extinctions were primarily the result of significant climate change. If climate change was responsible, we would expect many small mammals, primarily rodents, to have become extinct in the region, too; however, only four North American genera of small animals became extinct at the end of the Pleistocene, compared with 46 genera over the preceding three million years. On the other hand, perhaps small mammals are less susceptible to climate change than large mammals are. We cannot definitely say which answer is correct, and the truth may lie in the middle, but many scientists believe that the end of the Pleistocene saw a massive overkill by the first human inhabitants of the Americas.

The best evidence that overhunting by early people eliminated some species comes from islands. On many remote islands, birds evolved in the absence of mammalian predators, sometimes losing their ability to fly in the process. When people arrived on these islands, they found easy prey. For example, when Polynesians, now known as Maori, arrived in New Zealand about A.D. 1200, the islands had 11 species of moas: flightless birds that ranged in size from as small as a turkey to larger than an ostrich. By the time Europeans colonized the islands in the 1700s, the moas were gone, along with five species of rail and six waterfowl species. The demise of the moas and other birds undoubtedly was hastened by forest clearing and other changes brought about by the Maori, but the abundance of moa remains at Maori village sites makes it clear that hunting was a major factor.

On small islands throughout the Pacific, scores of birds are known to have become extinct after the arrival of Polynesians. In the Hawaiian Islands, 44 species of endemic land birds out of 82 became extinct between the arrival of Polynesians and the arrival of Europeans. Again, habitat changes were undoubtedly important, but it is likely that overhunting was a major problem, especially for various species of flightless geese, ibis, and rail. On Madagascar, the loss was not limited to birds. The arrival of people 1,500 to 2,000 years ago caused the extinctions of two giant tortoises, a bear-sized giant lemur, a small species of hippopotamus, many other mammals, and elephant birds, some of which rivaled the largest Moas in size.

Currently, the worst overexploitation may be happening through global overfishing. This is partially disguised by the fact that we are still able to harvest huge quantities of marine species; only on closer inspection does one notice that the predatory fish that used to dominate catches are being replaced by species further down the food chain.

## Constraints on Natural Selection

Natural selection is the process in which organisms with certain traits survive and reproduce while organisms that are less able to adapt to their environment die off. As Darwin pointed out, natural selection does not necessarily produce evolutionary progress, much less perfection. The limits to the effectiveness of natural selection are most clearly revealed by the universality of extinction. More than 99.9 percent of all evolutionary lines that once existed on Earth have become extinct. Mass extinctions remind us forcefully that evolution is not a steady approach to an ever-higher perfection but an unpredictable process in which the best-adapted organisms may be suddenly exterminated y a catastrophe and their place taken by lineages that prior to the catastrophe seemed to be without distinction or prospects.

There are numerous constraints, or limits, on the power of natural selection to bring about change. First, the genetic variation needed to perfect a characteristic may not be forthcoming. Second, during evolution, the adoption of one among several possible solutions to a new environmental opportunity may greatly restrict the possibilities for subsequent evolution. For instance, when a selective advantage for a skeleton developed among the ancestors of the vertebrates and the arthropods, the ancestors of the arthropods had the prerequisites for developing an external skeleton, and those of the vertebrates had the prerequisites for acquiring an internal skeleton. The entire subsequent history of these two large groups of organisms was affected by the two different paths taken by their remote ancestors. The vertebrates were able to develop such huge creatures as dinosaurs, elephants, and whales. A large crab is the largest type that the arthropods were able to achieve.

Another constraint on natural selection is developmental interaction. The different components of an individual organism—its structures and organs—are not independent of one another, and none of them responds to selection without interacting with the others. The whole developmental machinery is a single interacting system. Organisms are compromises among competing demands. How far a particular structure or organ can respond to the forces of selection depends, to a considerable extent, on the resistance offered by other structures and organs, as well as components of the genotype (the totality of an individual's genes).

The structure of the genotype itself imposes limits on the power of natural selection. The classical metaphor of the genotype was that of a beaded string on which the genes were lined up like pearls in a necklace. According to this view, each gene was more or less independent of the others. Not much is left of this previously accepted image. It is now known that there are different functional classes of genes, some charged to produce material, others to regulate it, and still others that are apparently not functioning at all. There are single coding genes, moderately repetitive DNA, highly repetitive DNA, and many other kinds of DNA. Discovering exactly how they all interact with one another is still a rather poorly understood area of genetics.

A further constraint on natural selection is the capacity for non-genetic modification. The more plastic the organism's body characteristics are (owing to developmental flexibility), the more this reduces the force of adverse selection pressures. Plants, and particularly microorganisms, have a far greater capacity for individual modification than do animals. Natural selection is involved even in this phenomenon, since the capacity for nongenetic adaptation is under strict genetic control.  When a population shifts to a new specialized environment, genes will be selected during the following generations that reinforce and may eventually largely replace the capacity for nongenetic adaptation.

Finally, which organisms survive and reproduce in a population is partly the result of chance, and this also limits the power of natural selection. Chance operates at every level of the process of reproduction, from the transmission of parental chromosomes to the survival of the newly formed individual. Furthermore, potentially favorable gene combinations are often destroyed by indiscriminate environmental forces such as storms, floods, earthquakes, or volcanic eruptions, without natural selection being given the opportunity to favor these genotypes. Yet over time, in the survival of those few individuals that become the ancestors of subsequent generations, relative fitness always plays a major role.

## Metamorphosis

Organisms that metamorphose undergo radical changes over the course of their life cycle. A frog egg hatches a tadpole that metamorphoses into an adult frog within a few days or weeks. A fruit fly egg hatches a larva that feeds for a few hours or days and then enters the pupal stage during which it develops a protective covering. The changes that occur during the metamorphosis of a single species may be so great that the species occupies two separate and very different niches or places in an environment at different times. In fact, the larvae of two species may be more similar to each other than to the corresponding adult forms of their own species.

Organisms that utilize different resources at different stages of their life cycle face an unusual evolutionary problem, exploiting different niches may be difficult with a single body plan. The solution is a juvenile (immature) form specialized for one niche, followed by metamorphosis to an entirely new body plan, adapted to a different niche in the adult. Clearly, species that metamorphose must undertake complex genetic and physiological processes in the transformation. These changes require complex regulatory mechanisms that involve turning on and off many genes at appropriate times. In addition, the reorganization of the body plan in a metamorphic species entails considerable energy costs. What sorts of ecological advantages could outweigh these complications?

One prevailing hypothesis is that metamorphic species specialize so as to exploit habitats with high but transient (short term) productivity----and hence high potential for growth. Part of this strategy is that specializations for feeding, dispersal, and reproduction are separated across stages. A frog tadpole occupies an aquatic environment (such as a pond) with extremely high potential for growth. The existence of the pond or its high production may be transient, however. Whereas an aquatic larva is not capable of dispersal to new ponds if its habitat becomes unsuitable, the adult frog is. In this case rapid growth in the larva is separated from dispersal and reproduction in the adult. Although the adult feeds, its growth rate is far less than that of the tadpole. The energy adults obtain from feeding is dedicated to dispersal and reproduction.

Many insects benefit from the same strategy. Although a butterfly larva feeds voraciously, often on a very specific set of host plant species, the adult does not grow. If it feeds, it does so only to maintain energy reserves required for dispersal and reproduction. The monarch butterfly exemplifies this strategy. Its larvae feed specifically on milkweeds. Monarch pupae also develop on this host plant. The emerging adults migrate long distances----from all over eastern North America  to nine small sites in the Sierra Madre mountains of Mexico. There, females become sexually mature and migrate north, mating along the way and feeding only to maintain energy reserves. In this example, the feeding specialist stage is again separated from the dispersal and reproduction stages.

In the previous examples, the reproductive function is delegated to the adult. Under certain ecological conditions, however, it is apparently advantageous for reproduction to occur in the larval stage. Thus, even the reproductive function typically fulfilled by the adult can apparently be modified under certain circumstances. Species that show this modification of a metamorphic life cycle are said to demonstrate neoteny, a life cycle in which the larvae of some populations or races become sexually mature and no longer metamorphose into adult. Some populations of the salamander Ambystoma maculatum show this trait. In fact, the larvae of this species were originally classified as a separate species before it was recognized that they are neotenic forms.

The selective factors leading to neoteny are not well understood. We know, however, that neotenicforms are more frequently found in extreme environments, often high altitudes or latitudes. High-altitude populations of certain salamanders have higher frequencies of neoteny than do low-elevation population of these species. If the larval environment is rich compared to the harsh adult environment, selection may favor neoteny. One research study, has ruled out simple food effects, supplemental food did not increase the frequency with which organisms reached the adult stage. This suggests that neoteny may be a genetically determined feature of some amphibian life histories.

## Determining the Ages of the Planets and the Universe

The planets of our solar system all revolve around the Sun in the same direction and in orbits that lie in nearly the same plane. This is strong evidence that the planets formed simultaneously from a single disk of material that rotated in the same direction as the modern planets.

Precisely when the planets came into being has been a difficult issue to resolve. While Earth's water is necessary for life, its abundance near the planet's surface makes rapid erosion inevitable. Continuous alteration of the crust by erosion and also by igneous (volcanic) and metamorphic (pressure and heat within Earth) processes makes unlikely any discovery of rocks nearly as old as Earth. Thus geologists have had to look beyond this planet in their efforts to date Earth's origin. Fortunately, we do have samples of rock that appear to represent the primitive material of the solar system. These samples are meteorites, which originate as extraterrestrial objects, called meteors that have been captured in Earth's gravitational field and have then crashed into our planet.

Some meteorites consist of rocky material and, accordingly, are called stony meteorites. Others are metallic and have been designated iron meteorites even though they contain lesser amounts of elements other than iron. Still others consist of mixtures of rocky and metallic material and thus are called stony-iron meteorites. Meteors come in all sizes, from small particles to the small planets known as asteroids; no asteroid, however, has struck Earth during recorded human history. Many meteorites appear to be fragments of larger bodies that have undergone collisions and broken into pieces. Iron meteorites are fragments of the interiors of these bodies, comparable to Earth's core, and stony meteorites are from outer portions of these bodies, comparable to Earth's mantle (the layer between the core and outer crust).

Meteorites have been radiometrically dated by means of several decay systems, including rubidium-strontium, potassium- argon, and uranium-thorium. The dates thus derived tend to cluster around 4.6 billion years, which suggests that this is the approximate age of the solar system. After many meteorites had been dated, it was gratifying to find that the oldest ages obtained for rocks gathered on the surface of the Moon also were approximately 4.6 billion years. This must, indeed, be the age of the solar system. Ancient rocks can be found on the Moon because the lunar surface, unlike that of Earth, has no water to weather and erode rocks and is characterized by only weak movements of its crust.

Determining the age of the universe has been more complicated. Most stars in the universe are clustered into enormous disk-like galaxies. The distance between our galaxy, known as the Milky Way, and all others is increasing. In fact, all galaxies are moving away from one another, evidence that the universe is expanding. It is not the galaxies themselves that are expanding but the space between them. What is happening is analogous to inflating a balloon with small coins attached to its surface. The coins behave like galaxies: although they do not expand, the space between them does. Before the galaxies formed, matter that they contain was concentrated with infinite density at a single point from which it exploded in an event called the big bang. Even after it assembled into galaxies, matter continued to spread in all directions from the site of the big bang.

The evidence that the universe is expanding makes it possible to estimate its age. This evidence, called the redshift, is an increase in the wavelengths of light waves traveling through space—a shift toward the red end of the visible spectrum of wavelengths. Expansion of the space between galaxies causes this shift by stretching light waves as they pass through it. The farther these light waves have traveled through space, the greater the redshift they have undergone. For this reason, light waves that reach Earth from distant galaxies have larger redshifts than those from nearby galaxies. Calculations based on these redshifts indicate that about 13.7 billion years ago all of the galaxies would have been at one spot, the site of the big bang. This, then, is the approximate date of the big bang and the age of the universe.

## European Context of the Scientific Revolution

The Scientific Revolution represents a turning point in world history. By 1700 European scientists had overthrown the science and worldviews of the ancient philosophers: Aristotle and Ptolemy. Europeans in 1700 lived in a vastly different intellectual world than that experienced by their predecessors in, say, 1500. The role and power of science, as a way of knowing about the world and as an agency with the potential of changing the world, likewise underwent profound restricting as part of the Scientific Revolution.

The social context for science in Europe in the sixteenth and seventeenth centuries had changed in several dramatic ways from the middle Ages (roughly, 500 C.E. to the 1400s C.E.). Advances in military technology, the European voyages of exploration, and contact with the New World altered the context in which the Scientific Revolution unfolded. The geographical discovery of the Americas generally undermined the closed Eurocentric cosmos of the later middle Ages, and the science of geography provided a stimulus of its own to the Scientific Revolution. With an emphasis on observational reports and practical experience, new geographical discoveries challenged accepted knowledge. Cartography (mapmaking) thus provided exemplary new ways of learning about the world in general, ways self-evidently superior to mastering established doctrines from dusty books. Many of the scientists of the Scientific Revolution seem to have been involved in one fashion or another with geography or cartography.

In the late 1430s, Johannes Gutenberg, apparently independently of the development of woodblock printing in Asia, invented printing with movable type, and the spread of this powerful new technology after 1450 likewise altered the cultural landscape of early modern Europe. The new medium created a revolution in communications that increased the amount and accuracy of information available and made copying of books by scribes obsolete. Producing some 13,000 works by 1500, printing presses spread rapidly throughout Europe and helped to break down the monopoly of learning in universities and to create a new group of nonreligious intellectuals. Indeed, the first printshops became something of intellectual centers themselves, with authors, publishers, and workers collaborating in unprecedented ways in the production of new knowledge. Renaissance humanism, that renowned philosophical and literary movement emphasizing human values and the direct study of classical Greek and Latin texts, is hardly conceivable without the technology of printing that sustained the efforts of learned humanists. Regarding science, the advent of printing and humanist scholarship brought another wave in the recovery of ancient texts. Whereas Europeans first learned of ancient Greek science largely through translations from the Arabic in the twelfth century, in the later fifteenth century scholars brought forth new editions from Greek originals and uncovered influential new sources, notably the Greek mathematician Archimedes. Similarly, printing disseminated previously obscure handbooks of technical and magical secrets that proved influential in the developing Scientific Revolution.

Particularly in Italy, the revival of cultural life and the arts in the late fourteenth and fifteenth centuries commonly known as the Renaissance must also be considered as an urban and comparatively secular phenomenon, aligned with courts and courtly patronage but not with the universities, which were religiously base. One associates the great flourish of artistic activity of the Renaissance with such talents as Donatello, Leonardo da Vinci, Raphael, and Michelangelo. In comparison with medieval art, the use of perspective—a projection system that realistically renders the three dimensions of space onto the two dimensions of a canvas—represents a new feature typical of Renaissance painting, and through the work of Leon Battista Alberti, Albrecht Durer, and others, artists learned to practice mathematical rules governing perspective. So noteworthy was this development that historians have been inclined to place Renaissance artists at the forefront of those uncovering new knowledge about nature in the fifteenth and sixteenth centuries. Whatever one may make of that claim, early modern artists needed accurate knowledge of human muscular anatomy for lifelike renditions, and an explosion of anatomical research in the Renaissance may be attributed to this need in the artistic community.

## Early life-forms and Earth's Atmosphere

Why has life flourished on Earth? This question has a two-part answer. First, Earth has been a cradle for life because of its position relative to the Sun. second, once life began on Earth, simple early life-forms (photosynthetic bacteria) slowly but inexorably altered the environment in a manner that not only maintained life but also paved the way for later, complex life-forms. These changes allowed later organisms to evolve and thrive. Humans and other higher organisms owe their life-supporting environment to these early life-forms.

Earth's earliest atmosphere contained several gases: hydrogen, water vapor, ammonia, nitrogen, methane, and carbon dioxide, but no oxygen. Gas mixtures emitted from present-day volcanoes resemble this early atmosphere, suggesting its origin from volcanic eruptions. In Earth's earliest atmosphere, methane and carbon dioxide occurred at much higher levels than at present—a circumstance that was favorable for early life. Methane and carbon dioxide are greenhouse gases that warm atmospheres by retarding loss of heat to space. These two gases kept Earth warm during the Sun's early history, when the Sun did not burn as brightly as it now does. (An early dim period, with later brightening, is normal for stars of our Sun's type.)

Earth's modern atmosphere, which is 78 percent nitrogen gas, 21 percent oxygen, and about 1 percent argon, water vapor, ozone, and carbon dioxide, differs dramatically from the earliest atmosphere just described. The modern atmosphere supports many forms of complex life that would not have been able to exist in Earth's first atmosphere because the oxygen level was too low. Also, if atmospheric methane and carbon dioxide were as abundant now as they were in Earth's earliest atmosphere, the planet's temperature would likely be too hot for most species living today. How and when did the atmosphere change?

The answer to this riddle lies in the metabolic activity of early photosynthetic life-forms that slowly but surely transformed the chemical composition of Earth's atmosphere. Some of these early organisms were photosynthetic relatives of modern cyanobacteria (blue-green bacteria). In the process of photosynthesis, carbon dioxide gas combined with water yields oxygen. In Earth's early days, all over the planet countless photosynthetic bacteria performed photosynthesis. Together, these ancient bacteria removed massive amounts of carbon dioxide from Earth's atmosphere by converting it to solid organic carbon. These ancient bacteria also released huge quantities of oxygen into the atmosphere. Other ancient bacteria consumed methane, greatly reducing its amount in the atmosphere. When our Sun later became hotter, the continued removal of atmospheric carbon dioxide and methane by early bacteria kept Earth's climate from becoming too hot to sustain life. Modern cyanobacteria still provide these valuable services today.

The bacterial oxygen release improved conditions for life in two ways. First, oxygen is essential for the metabolic process known as cell respiration that allows cells to efficiently harvest energy from organic food. Second, oxygen in the upper atmosphere reacts to form a protective shield of ozone. Earth is constantly bombarded by harmful ultraviolet (UV) radiation from the Sun. Today, Earth's upper-atmosphere ozone shield absorbs enough UV to allow diverse forms of life to survive. But because early Earth lacked oxygen in its atmosphere, it also lacked a protective ozone barrier. As a result, early life on Earth was confined to the oceans, where the water absorbed the UV radiation. Only after oxygen released by ancient bacteria drifted up into the upper atmosphere and reacted with other oxygen molecules to form a protective layer of ozone could life flourish at the surface and on the land. The absence of an oxygen atmosphere on Mars and other planets in our solar system means that these planets also lack an ozone shield that would protect surface-dwelling life from UV radiation. The surface of Mars is bombarded with deadly radiation; if any life exists on Mars, it would almost certainly be subterranean.

## Climate Change and the Natufian People

The so-called Natufian culture inhabited what is now the Middle East between approximately 14,000 and 11,500 years ago. This period is commonly split into two subperiods, Early Natufian (14,000 to 13,000 years ago) and Late Natufian (13,000 to 11,500). The Natufians were hunter-gatherers who relied primarily on gazelle, although they also cultivated some cereal grains. During the early period at least, they lived year-round in villages in built stone houses. Like all human beings, their way of life depended on the climate. Around 13,000 years ago, their climate began to change, becoming colder and drier, a period known as the Younger Dryas.

We know that times were hard in the increasingly arid landscapes of the Younger Dryas, but quite how hard remains unclear. The droughts certainly caused many ponds and rivers to disappear completely and the larger lakes to shrink in size. The people who lived in the south, in today's deserts of the Negev and the Sinai, were most likely hit the hardest. They returned to a completely transient hunter-gatherer way of life, moving from place to place. Survival required improved hunting weapons: game (animals hunted for food) had become scarce, and consequently, success had become essential when a kill was possible. And so we see the invention of the Harif point, a new kind of arrowhead.

Further north, the impact of the Younger Dryas may have been less severe. Yet survival still required more than just a return to the ancient mobile hunter-gatherer lifestyle, especially as there were now many more people needing food than had been the case during earlier periods, when the Natufians lived in permanent dwellings. One response was to hunt a much wider range of animals than before, and hence we find in Late Natufian settlements the bones of many small-game species as well as larger, ever-present gazelle.

Another response to the changing climate was to continue, and perhaps expand the cultivation of plants. Wild cereals were particularly hard hit by the Younger Dryas owing to a decrease in the concentration of carbon dioxide (CO2) in the atmosphere. This diminution, carefully documented from air bubbles trapped in Antarctic ice, inhibited their photosynthesis and markedly reduced their yields. Consequently, whatever cultivation practices had begun during the Early Natufian period—weeding, transplanting, watering, pest control—may now have become essential to secure sufficient food. And these may have created the first domesticated strains.

This appears to be what happened at the village of Abu Hureyra just before its abandonment. When the archaeologist Gordon Hillman studied the cereal grains from the site, he found a few grains of rye from plants that had undergone the transition into domestic forms. When dated, they were shown to lie between 11,000 and 10,500 B.C.—the oldest domesticated cereal grain from anywhere in the world. Along with these grains, Hillman found seeds from the weeds that typically grow in cultivated soil. And so it appears that, as the availability of wild plant foods declined due to the onset of the Younger Dryas, the Abu Hureyra people invested an ever greater amount of time and effort in caring for the wild rye and by doing so unintentionally transformed it into a domestic crop. But even this could not support the village—it was abandoned as people were forced to return to a mobile lifestyle, perhaps carrying pouches of cereal grain. The domesticated rye of Abu Hureyra reverted to its wild state.

The geographical range of the Late Natufians also changed. With their increased interest in plant cultivation, the Late Natufians drifted away from the depleted woodlands where their forebears once flourished. They were drawn to the alluvial soils (soils deposited by rivers) of the valleys, not only those of the River Jordan, but also those found by the great rivers of the Mesopotamian plain and in the vicinity of lakes and rivers throughout the Middle East. Large expanses of these rich, fertile soils became available as the rivers and lakes struck during the Younger Dryas Wild, but cultivated, cereals grew well in such soil, especially when close to the meager springs, ponds, and streams that survived the arid conditions.

## The Origin of Coral Reefs

Coral reefs are natural structures formed from deposits of the calcium carbonate secretions of coral, a marine animal that lives in colonies. In general, coral reefs are grouped into one of three categories, atolls, barrier reefs, and fringing reefs. Atolls are usually easily distinguished because they are modified horseshoe-shaped reefs that rise out of very deep water far from land and enclose a lagoon (a body of certain water surrounded by a coral reef). With few exceptions, atolls are found only in the Indo-Pacific area. Barrier reefs and fringing reefs, on the other hand, tend to grade into each other and are not readily separable. Some scientists would prefer to group them into a single category. Both types occur adjacent to a landmass, with a barrier reef being separated from the landmass by a greater distance and deeper water channel than the fringing reef. Fringing reefs and barrier reefs are common throughout the coral reef zones in all oceans.

Different types of reefs and reefs in different oceans may have diverse origins and histories. The greatest interest in the origin of reefs has centered on atolls. For many years, humans speculated as to how such reefs could develop in such deep water, miles from the nearest emergent land. This interest was heightened when it was discovered that reef corals cold not live deeper than 50-70 meters. This led to the development of several theories concerning the origin of atolls. Only one need be discussed here, the X grow on the shores of newly formed volcanic islands that have pushed to the surface from deep water. These islands often begin to subside, and if the subsidence is not too fast, reef growth will keep up with the subsidence. The reef growth will then form a barrier reef and, ultimately, an atoll as the island disappears beneath the sea. When the island has disappeared, corals continue to grow on the outside and keep the reef at the surface. On the inside, where the island used to be, quiet water conditions and high sedimentation prevail. These conditions prevent continued vigorous coral growth, hence, a lagoon develops. This theory links all three reef types into evolutionary sequence, but is not an explanation for all fringing and barrier reef types.

Since the current surface features of atolls give no evidence of a volcanic base, in the years after the development of Darwin's theory other explanations were offered, and the whole concept of the origin of atolls became embroiled in the controversy over the origin of coral reefs. If Darwin's theory was correct, it must be assumed that drilling down through the current atoll reefs would yield layer after layer of reef limestone until, finally, volcanic rock would be encountered. The ability to drill to the base of atoll reefs and resolved the problem had to wait until the mid-twentieth century in 1953. Ladd and other geologists reported borings at Eriwetok atoll in the Marshall Islands that penetrated 1,283meters of reef limestone and then hit volcanic rock. This was the evidence that Darwin's theory was substantially correct. The correctness of this theory has been strengthened by the discovery of flat-topped mountains or guyots that, at present, have their tops many hundreds or thousands of meters below the ocean surface, but have on their surface the remains of shallow water corals. Evidently, these mountains sank too fast for reef growth to keep above the ocean surface.

Although the subsidence theory links all three reef types in a successional sequence, not all barrier reefs and fringing reefs can be explained by this mechanism. Indeed, the reasons barrier and fringing reef types occur around continental margins and high non-volcanic islands are simply that these areas offer suitable environmental conditions for the growth of reefs and a suitable substrate (surface) on which to begin growth. The extensive reefs around the Indonesian Islands, the Philippines, New Guinea, Fiji and most of the Caribbean Islands are there because a suitable substrate in shallow water existed on which they could initiate growth. In none of these areas are large land areas subsiding, not will these reefs ultimately become atolls.

## Crown of Thorns Starfish and Coral Reefs

The crown of thorns starfish, Acanthaster Tlanci, is large, twenty-five to thirty-five centimeters in diameter, and has seven to twenty-one arms that are covered in spines. It feeds primarily on coral and is found from the Indian Ocean to the west coast of Central America, usually at quite low population densities. Since the mid-1950s, population outbreaks at densities four to six times greater than normal have occurred at the same time in places such as Hawaii, Tahiti, Panama, and the Great Barrier Reef. The result has often been the loss of a fifty percent to nearly one hundred percent of the coral cover over large areas.

A single Acanthaster can consume five to six square meters of coral polyps per year, and dense populations can destroy up to six square kilometers per year and move on rapidly. Acanthasters show a preference for branching corals, especially Acroporids. After an outbreak in a particular area, it is common to find that Acroporids have been selectively removed, leaving a mosaic of living and dead corals. In places where Acroporids previously dominated the community devastation can be almost complete, and local areas of reefs have collapsed.

Areas of dead coral are usually colonized rapidly by algae and often are later colonized by sponges and soft corals. Increases in abundance of plant-eating fish and decreases in abundance of coral-feeding fish accompany these changes. Coral larvae settle among the algae and eventually establish flourishing coral colonies. In ten to fifteen years the reefs often return to about the same percentage of coral cover as before. Development of a four-species diversity takes about twenty years.

Two schools of thought exist concerning the cause of these outbreaks. One group holds that they are natural phenomena that have occurred many times in the past, citing old men's recollections of earlier outbreaks and evidence from traditional cultures. The other group maintains that recent human activities ranging from physical coral destruction through pollution to predator removal have triggered these events. One theory, the adult aggregation hypothesis, maintains that most species is more abundant than we realize when a storm destroys coral and causes a food shortage. The adult Acanthasters converge on remaining portions of healthy coral and feed hungrily. Certainly there have been outbreaks of Acanthaster following large storms, but there is little evidence that the storms have caused the enough reef damage to create a food shortage for these starfish.

Two other hypotheses attempt to explain the increased abundance of Acanthaster after episodes of high terrestrial runoff following storms. The first hypothesis is that low salinity and high temperatures favor the survival of the starfish larvae. The second hypothesis emphasizes the food web aspect, suggesting that strong fresh water runoff brings additional nutrients to the coastal waters, stimulating phytoplankton production and promoting more rapid development and better survival of the starfish larvae.

Those favoring anthropogenic (human influenced) causes have pointed to the large proportion of outbreaks that have been near centers of human populations. It has been suggested that coral polyps are the main predators of the starfish larvae. Destruction of coral by blasting and other bad land use practices would reduce predation on the starfish larvae and cause a feedback in which increases in Acanthaster populations cause still further coral destruction. Unfortunately, there are too few documented instances of physical destruction of coral being followed by outbreaks of Acanthaster for these hypotheses to be fully supported.

Another group of hypothesis focuses on removal of Acanthaster's predators. Some have suggested that the predators might have been killed off by pollution whereas others have suggested that the harvesting of vertebrate and invertebrate predators of Acanthaster could have reduced mortality and caused increased abundance of adults. The problem with this group of hypothesis is that it is difficult to understand how reduced predation would lead to sudden increases in Acanthaster numbers in several places at the same time in specific years. It seems probable that there is no single explanation but that there are elements of the truth in several of the hypotheses. That is there are natural processes that have led to outbreaks in the past, but human impact has increased the frequency and severity of the outbreaks.

## The Origins of Plant and Animal Domestication

The emergence of plant and animal domestication represented a monumental change in the ways that humans interacted with Earth's resources: the rate at which Earth's surface was modified and the rates of human population growth. The development of agriculture was accompanied by fundamental changes in the organization on human society: disparities in wealth, hierarchies of power, and urbanization.

Phrases like "plant and animal domestication" and "the invention of agriculture" create the impression that humans made the transition to cultivating plants and tending animals rather abruptly, maybe with a flash of insight. Most scholars don't think so. It seems more likely that humans used and manipulated wild plants and animals for many hundreds of thousands of years. The transition to gardens, fields, and pastures was probably gradual, the natural outgrowth of a long familiarity with the environmental requirements, growth cycles, and reproductive mechanisms of whatever plants and animals humans liked to eat, ride, or wear.

For years, scholars argued that the practices of cultivation and animal domestication were invented in one or two locations on Earth and then diffused from those centers of innovation. Genetic studies are now showing that many different groups of people in many different places around the globe learned independently to create especially useful plants and animals through selective breeding. Probably both independent invention and diffusion played a role in agricultural innovation. Sometimes the ideas of domestication and cultivation were relayed to new places. In other cases the farmers or herders themselves moved into new zones, taking agriculture or improvements such as new tools or new methods or new plants and animals with them.

Scholars used to assume that people turned to cultivating instead of gathering their food either because they had to in order to feed burgeoning populations, or because agriculture provided such obviously better nutrition. It now seems that neither of these explanations is valid. First of all, the risk attached to exploring new food sources when there were already too many mouths to feed would be too great. Second, agriculture did not necessarily improve nutrition or supplies of food. A varied diet based on gathered (and occasionally hunted) food probably provided a wider, more secure range of nutrients than an early agriculturally based diet of only one or two cultivated crops. More likely, populations expanded after agricultural successes, and not before.

Richard MacNeish, an archaeologist who studied plant domestication in Mexico and Central America, suggested that the chance to trade was at the heart of agricultural origins worldwide. Many of the known locations of agricultural innovation lie near early trade centers. People in such places would have had at least two reasons to pursue cultivation and animal raising; they would have had access to new information, plants, and animals brought in by traders, and they would have had a need for something to trade with the people passing through. Perhaps, then, agriculture was at first just a profitable hobby for hunters and gatherers that eventually, because of market demand, grew into the primary source of sustenance. Trade in agricultural products may also have been a hobby that led to trouble.

E. N. Anderson, writing about the beginnings of agriculture in China, suggests that agricultural production for trade may have been the impetus for several global situations now regarded as problems: rapid population growth, social inequalities, environmental degradation, and famine. Briefly explained, his theory suggests that groups turned to raising animals and plants in order to reap the profits of trading them. As more labor was needed to supply the trade, humans produced more children. As populations expanded, more resources were put into producing food for subsistence and for trade. Gradually, hunting and gathering technology was abandoned as populations, with their demands for space, destroyed natural habitats. Meanwhile, a minority elite emerged when the wealth provided by trade did not accrue equally to everyone. Yet another problem was that a drought or other natural disaster could wipe out an entire harvest, thus, as ever larger populations depended solely on agriculture, famine became more common.

## Attempts at Determining Earth's Age

Since the dawn of civilization, people have been curious about the age of Earth. In addition, we have not been satisfied in being able to sate merely the relative geologic age of a rock or fossil. Human curiosity demands that we know actual age in years.

Geologists working during the nineteenth century understood rock bodies, they would have to concentrate on natural processes that continue at a constant rate and that also leave some sort of tangible record in the rocks. Evolution is one such process, and geologist Charles Lyell (1797-1875) recognized this. BY comparing the amount of evolution exhibited by marine mollusks then, Lyell estimated that 80 million years had elapsed since the beginning of the Tertiary Period. He came astonishingly close to the mark, since it was actually about 65 million years. However, for older sequence of evolutionary development, estimates based on parts in the fossil record. Rates of evolution for many orders of plants and animals were not well understood.

In another attempt, geologists reasoned that if rates of deposition could be determined for sedimentary rocks, they might be able to estimate the time required for deposition of a given thickness of strata, or rock layers. Similar reasoning suggested that one could estimate total elapsed geologic time by dividing the average thickness of sediment transported annually to the oceans into the total thickness of sedimentary rock that had ever been deposited in the past. Unfortunately, such estimates did not adequately account for past difference in rates of sedimentation or losses to the total section of strata during episodes of erosion. Also, some very ancient sediments were no longer recognizable, having been converted to igneous and metamorphic rocks in the course of mountain building. Estimates of Earth's total age based on sedimentation rates ranged from as little as million to over a billion year.

Yet another scheme for approximating Earth's age had been proposed in 1715 by Sir Edmund Halley (1656-1742), whose name we associate with the famous comet. Halley surmised that the ocean formed soon after the origin of the planet and therefore would be only slightly younger that the age of the solid Earth. He reasoned that the original ocean was not salty and that subsequently salt derived from the weathering of rocks was brought to the sea by streams. Thus, if one knew the total amount of salt dissolved in the ocean and the amount added each year, it might be possible to calculate the ocean's age in 1899, Irish geologist John Joly (1857-1933) attempted the calculation. From information provide by gauges placed at the mouths of streams. Joly was able to estimate the annual increment of salt to the oceans. Then, knowing the salinity of ocean water and the approximate volume of water, he calculated the amount of salt already held in solution in the oceans. An estimate of the age of the ocean was obtained by diving the total salt in the ocean by the rate of salt added each year. Beginning with essentially non-saline oceans, it would have taken about 90 million years of the oceans to reach their present salinity, according to Joly. The figure, however, was off the currently accepted mark of 4.54 billion by a factor of 50, largely because there was no way to account accurately by recycled salt and salt incorporated into clay mineral deposited on the sea floors. Even though in error, Joly's calculations clearly supported those geologists who insisted on an age for Earth far in excess of a few million years. The belief in Earth's immense antiquity was also supported by Darwin, Huxley, and other evolutionary biologists, who saw the need for time in the hundreds of millions of years to accomplish the organic evolution apparent in the fossil record.

## The Early History of Motion Pictures

Motion pictures and television are possible because of two quirks of the human perceptual system: the phi phenomenon and persistence of vision. The phi phenomenon refers to what happens when a person sees one light sources go out while another one close to the original is illuminated. To our eyes, it looks like the light moves from one place to another. In persistence of vision, our eyes continue to see an image for a spit second after the image has disappeared from view. First observed by the ancient Greeks, persistence of vision became more widely known in 1824 when Peter Roget(who also developed the thesaurus) demonstrated that human begins retain an image of an object for about one-tenth of a second after the object is taken from view. Following Roget's pronouncement, a host of toys that depended on this principle sprang up in Europe. Bearing fanciful manes (the Thaumatrope, the Praxinoscope), these devices made a series of hand- drawn pictures appear to move.

Before long, several people realized that a series of still photographs on celluloid film could be used instead of hand drawing. In 1878 a colorful Englishman later turned American. Edward Muybridge, attempted to settle a $25.000 bet over whether the four feet of a galloping horse ever simultaneously left the ground. He arranged a series of 24 cameras alongside a racetrack to photograph a galloping horse. Rapidly viewing the series of pictures produced an effect much like that of a motion picture. Muybirdge's technique not only settled the bet (the feet did leave the ground simultaneously at certain instances) but also photography. Instead of 24 cameras talking one pictures in rapid order, it was Thomas Edison and his assistant, William Dickson, who finally developed what might have been the first practical motion-picture camera and viewing device, Edison was apparently trying to provide a visual counterpart to his recently invented phonograph. When his early efforts did not work out, he turned the project over his assistant. Using flexible film, Dickson solved the vexing problem of how to move the film rapidly through the camera by perforating its edge with tiny holes and pulling it along by means of sprockets, projections on a wheel that fit into the holes of the film in 1889 Dickson had perfected a machine called the Kinetoscope and even starred in a brief film demonstrating how it worked.

These early efforts in the Edison lab were not directed at projecting movies to large crowds. Still influenced by the success of his phonograph, Edison thought a similar device could make a money by showing brief films to one person at a time for a penny a look. Edison built a special studio to produce films for his new invention, and by 1894, Kinetoscope parlors were spring up in major cities. The long-range commercial potential of his invention was lost on Edison. He reasoned that the real money would be made by selling his peep-show machine. If a large number of people were shown he film at the same time, fewer machines would be needed. Developments in Europe proved Edison wrong as inventors there devised large-screen projection devices. Faced with competition, Edison perfected the Vitascope and unveiled it in New York City in 1896.

Early monies were simple snippets of action—acrobats tumbling, horse running, jugglers juggling, and so on. Eventually, the novelty wore off and films became less of an attraction. Public interest was soon rekindled when early filmmakers discovered that movies could be used to tell story. In France, Alice Guy-Blachèproduced The Cabbage Fairy, a one- minute film about a fairy who produces children in a Cabbage patch, and exhibited it at the Paris International Exhibition in 1896. Guy-Blachèwent on to found her own studio in America. Better known is the work of a fellow French filmmaker and magician, Georges Méliès. In 1902 Méliès produced a science-fiction film that was the great-great-grandfather of Star Wars and Star Trek; it was called A Trip to the Moon.

## Bioluminescence in Marine Creatures

At night along the sea's edge, the ocean sometimes seems to glow, as if lit from within. This glow is the result of bioluminescence, a phenomenon exhibited by many of the sea's zooplankton. Bioluminescence is the production of cold light through internal biological processes, as opposed to phosphorescence or fluorescence, both of which are re-emitted light that was initially absorbed from an external source.

Many of the sea's creatures, including squid, dinoflagellates, bacteria, worms, crustaceans, and fish, are known to produce light. The process that marine creatures use to create light is like that of the common firefly and similar to that which creates the luminous green color seen in plastic glow sticks, often used as children's toys or for illumination during nighttime events. When a glow stick in bent, two chemicals mix, react, and create a third substance that gives off light.  Bioluminescent organisms do essentially the same thing; they have a substance, called luciferin, that reacts with oxygen in the presence of enzyme, luciferase. When the reaction is complete, a new molecule is formed that gives off light— glowing blue—green in the underwater world. This biologically driven chemical reaction occurs within the organism's special light-producing cells, called photocyptes, or light-producing organs, called photophores. Probably one of the most complex light-producing systems is that of the squid. Some squid have both photophores and chromatophores (organs for changing color) with their skin, thus enabling them to control both the color and intensity of the light produced. Recent research has also revealed that in some squid and fish, bioluminescent light may be produced by bacteria that live in a mutually beneficial partnership inside the animal's light organs.

How and why bioluminescence occurs is not fully understood; however, in the undersea realm, it appears to be used in a variety of interesting and ingenious ways. The most commonly observed form of bioluminescence in the sea id the pinpoint sparking of light at night that can create cometlike trails behind moving objects. Almost always, this is the result of dinoflagellates reacting to water motion. The relatively short, momentary displays of light may have evolved to startle, distract, or frighten would-be predators. Collection nets brought up from the sea's depths at night frequently glow green at great distance. Slowly fading green blobs or pulses of light can be seen coming from the organisms within, often from gelatinous creatures. This type of light display may be used to stun disorient, or lure prey. Like a wide-eyed deer caught on a road and dazed by headlights, undersea creatures living within the ocean's darkness may be momentarily disoriented by short flashes of bioluminescent light. Another of the sea's light-producing organisms is a small copepod (a type of crustacean) named Sapphirina iris. In the water, Sapphirina creates short flashes of a remarkably rich, azure blue light. But its appearance under a microscope is even more spectacular, the living copepod appears as if constructed of delicately handcrafted, multicolored pieces of stained glass. Within the deep sea, some fish also have a dangling bioluminescent lure or a patch of luminescent skin near the mouth, which may be used to entice unsuspecting prey.

Other sea creatures have both light-sensing and light-producing organs. These creatures are thought to use bioluminescence as a form of communication or as a means of identifying an appropriate mate. In the lantern fish, the pattern of photophores distinguishes one species from another. In other fish, bioluminescence may help to differentiate males from females. The squid uses light as a means of camouflage. By producing light from the photophores on its underside, the squid can match light form above and become nearly invisible to predators looking up from below. Squid, as well as some of the gelatinous zooplankton, have also been known to release luminescent clouds or strands of organic material, possibly as a decoy to facilitate escape. And finally, because what they eat is often bioluminescent, many of the transparent deep-sea creatures have red or black stomachs to hide the potentially flashing contents of ingested bioluminescent creatures. Without such a blacked-out stomach, their digestive organs would flash like a neon sign that says, "Eat me, eat me!"

## The Role of Diapause

If conditions within an organism's environment occasionally or regularly become harsh, it may be advantageous for an organism to have a resistant stage built into the life cycle. In such a life history strategy, the organism suspends any growth, reproduction, or other activities for a period of time so that they may occur at a later, more hospitable time. This genetically determined resting stage, characterized by the cessation of development and protein synthesis and suppression of the metabolic rate, is called diapause. Many other kinds of resting stages, with different levels of suppression of physiological activities, are known. Some of these resistant stages can be extremely long-lived. In one case, seeds of the arctic lupine, a member of the pea family recovered from ancient lemming burrows in the Arctic, germinated in three days even though they were carbon-dated at more than 10,000 years old!

Unfavorable conditions that are relatively predictable probably pose a simpler problem for organisms than do unpredictable conditions. Adaptations to the regular change of seasons in the temperate and polar regions may be relatively simple. For example, many seeds require a period of stratification, exposure to low temperatures for some minimum period, before they will germinate. This is a simple adaptation to ensure that germination occurs following the winter conditions rather than immediately prior to their onset. In contrast, unfavorable conditions that occur unpredictably pose considerable problems for organisms. In fact, unpredictability is probably a greater problem than is the severity of the unfavorable period. How can organisms cope with the unpredictable onset of good or poor conditions?

Many adaptations to this general problem are based on a resting stage that awaits favorable conditions. We will consider two examples from the vertebrates. The first is the red kangaroo. This marsupial inhabits the deserts of central Australia where the onset of rains and the resulting sudden growth of vegetation are extremely unpredictable. Obviously, it is advantageous for a kangaroo female to produce young at a time when plant productivity is sufficient to support her offspring. For such a relatively large mammal, however, gestation (the period of development during pregnancy) is so long that if a female waited to mate and carry the young until after the rains came, the favorable period might be past. The kangaroo's life history adaptation to this problem involves the use of embryonic diapause during gestation (development in the uterus).

After a 31-day gestation period, the female gives birth to a tiny helpless young typical of marsupials. The newborn crawls into the mother's pouch and attaches to a teat where it continues to grow and develop. After 235 days it leaves the pouch but remains with the mother and obtains milk from her. Two days after giving birth, the female mates again. The fertilized egg enters a 204-day period of embryonic diapause during which it remains in the uterus but does not attach. It then implants, and 31 days later, birth of the second young occurs. Note that the first young leaves the pouch at just this time. Again, the female mates, fertilization occurs, and another diapause follows. The eventual result is that at any one time, the female has three young at various stages of development: one in diapause, one in the pouch, and one outside the pouch. Among other benefits, this allows her to freeze the development of an embryo during times of drought and food shortage until the offspring in the pouch is able to leave.

A similar strategy—accelerated development combined with a resting stage—has also allowed amphibians to inhabit deserts. The spadefoot toads, such as Couch's spadefoot toad, inhabit some of the most severe deserts in North America. Adults of this species burrow deeply into the substrate where it is cooler and perhaps more moist. Here they enter into a resting state in which they are covered with a protective layer of dead skin. When it rains, the adults emerge and congregate to mate at temporary ponds. Development is greatly accelerated: the eggs hatch within 48 hours, and the tadpoles change into toads at 16-18 days. Consequently, they can complete the life cycle during the brief window of favorable conditions, then return to the resistant resting stage to await the next rainfall. Resting stages thus comprise a series of adaptations that allow the species to avoid the most difficult conditions for life.

## Dinosaurs and Parental Care

From fossil evidence alone the question of whether or not dinosaurs cared for their young is very difficult to answer. Because behaviors are not preserved in the fossil record, we can only make inferences from indirect evidence. Parental care can be divided into two types of behavior: prehatching (building nests and incubating eggs—for example, sitting on top of them so as to warm the eggs and encourage hatching) and posthatching (feeding the young and guarding the nests). Most of our evidence comes from alleged dinosaur rookeries (places where nests are built). Several have been excavated in eastern Montana, where a large concentration of dinosaur nests was found at a place now called Egg Mountain. Most of these probably belonged to the hadrosaur Maiasaura. Preserved in these nests are the bones of baby dinosaurs. The finds at Egg Mountain and other sites around the world document that dinosaurs laid their eggs in nests.

The nests at Egg Mountain are reported to be equally spaced, separated by a space corresponding to the length of an adult Maiasaura. From this arrangement scientists have inferred that the nests were separated in this way to allow incubation in a tightly packed nesting colony. Although this interpretation is open to challenge, the discovery of Oviraplor adults on top of Oviraplor egg clutches (as determined by embryos in some eggs), is relatively powerful evidence that at least these dinosaurs incubated their nests.

Evidence for parental care following hatching is much more controversial. Behavioral speculation based on indirect fossil evidence is dangerous because the data is not always as unambiguous as might appear. At Egg Mountain, many nests contain baby dinosaur bones. Not all the dinosaurs in the nest are the same size. Many of the small bones found in the nests are associated with jaws and teeth, teeth that show signs of wear. It seems reasonable to assume that the wear was caused by the chewing of the coarse plants that were the hatchlings' diet. Because the young were still in the nest, this food may have been brought to the rookery by foraging adults. This line of reasoning suggests that these animals had an advanced system of parental care. A closer look at the evidence clouds this interpretation. Analysis of dinosaur embryos indicates that worn surfaces are present on the teeth of juveniles even before hatching. Just as a human baby moves inside the mother before birth, modern-day archosaurs also grind their teeth before birth, wearing the surface in some spots. Thus, the fossil evidence for an advanced parental care system in extinct dinosaurs is suggestive but inconclusive, and it is hard even to imagine the sort of paleontologic discovery that could settle this debate for good.

The strongest evidence that extinct dinosaurs had some form of advanced parental care system is based on an understanding of the phylogenetic relationships among dinosaurs and their closest living relatives. Living dinosaurs (birds), even primitive ones such as ostriches and kiwis, exhibit parental care, so some form of parental care can be inferred to have existed in the last common ancestor of all birds. Although unappreciated, crocodiles are reptiles that are also caring parents. They build nests, guard the nests, and in some cases dig their young out of the nest when they hear the chirping young ones hatching. The young even communicate with each other while still in the egg by high-frequency squeaks (as birds do). Some evidence suggests that this squeaking is a cue for the synchronization of the hatching. Since birds and crocodiles share a common ancestor, the simplest explanation for the characteristics they share (such as nest building and some form of parental care) is that they evolved only once—that these attributes were present in their common ancestor and passed on to its descendants. Because extinct dinosaurs also descended from that ancestor, the simplest and most general theory is that extinct dinosaurs also shared these characteristics, even though they cannot be directly observed, and we cannot be sure how elaborate their parental care was.

# Water Supply in Venice

The city of Venice, built on saltwater marshes and crisscrossed by canals, experienced problems with its water supply for most of its history. One fifteenth-century French traveler noted that "in a city" in which the inhabitants are in water up to their mouths, they often go thirsty "How was the community to solve this important problem?

Water drawn from the lagoon (the large, shallow body of water between Venice and the Mediterranean Sea) and the canals within the city served many domestic uses such as washing and cooking inventories of even the most modest households list large numbers of buckets, which were emptied and rinsed, the ones used to carry the brackish (somewhat salty) canal water were kept separate from those intended for fresh water. Still, even serving such needs would have been impossible if the canals of Venice had been extremely polluted. The government was obliged to impose controls, and in the early fourteenth century, the Great Council prohibited the washing of all cloth and dyed woolens in the canals, adding that water used for dyeing could not be flushed into the canals. Henceforth dirty water of that sort was to go into the lagoon. Thanks to resistance on the part of the dyers, infractions were many, the law did not reflect common practice. A century later, however, most of the dye works that used blood or indigo (a dark blue dye)had shifted to the periphery of the city, as had all activities "that let off bad odors or smells.", such as butchering. Blood, carcasses, and spoiled meat were to go into the lagoon. The canals of Venice began to be protected in the name of nascent ecological awareness.

Much more stringent measures were necessary to guarantee a supply of drinking water, however. In the early centuries of settlement in the lagoon basin, the populations depended on wells on the nearby coastal region. By the ninth century, however, with the increase in population density, cisterns became necessary. Basically, the cisterns were large, covered pits dug into the ground and lined with clay to hold water. The cisterns were located in the city, but unlike the wells, the cisterns were not supplied with water from the lagoon, they collected rainwater instead. Cisterns became widespread in the growing city.

Over a period of several hundred years, Venice developed an elaborate system of cisterns and gome-the gutters or pipes that carried rainwater to the cisterns and that, for a single cistern, might extend over an area of several streets. Wealthy households had their own cisterns. In less affluent areas of the city, cisterns were often owned and maintained by neighborhood groups. In crowded parts of the city where landlords offered small house for rent, one or two cisterns were provided for each street. A network of public cisterns paralleled these private and semiprivate arrangements. Every public square in the city had a cistern to serve the poorest venetians.

In the thirteenth century, a decision was made to create 50 additional cisterns, primarily in the recently urbanized area at the edge of the city. At the same time, a campaign was launched to repair the existing cisterns. Expansion of the cistern system stopped during much of the fourteenth century as Venice, like other cities in Europe, suffered from bubonic plague. In the fifteenth century, however, a new program of cistern construction and repair was undertaken.

In spite of the expansion of the cistern system, Venice continued to have problems with its water supply, especially during dry periods. Flotillas of boats had to be dispatched to the mouths of nearby rivers-first to the Bottenigo, then to the Brenta- to fetch fresh water. The fresh water was then sold by the bucket or poured into the cisterns. The public authorities made efforts to take bolder action to ensure the supply of fresh water from this parallel source and a number of projects were suggested during the fourteenth and fifteenth centuries to channel river water and even to construct an aqueduct. However, the high cost of such initiatives precluded their execution.

## Early Theories of Continental Drift

The idea that the past geography of Earth was different from today is not new. The earliest maps showing the east coast of South America and the west coast of Africa probably provided people with the first evidence that continents may have once been joined together, then broken apart and moved to their present positions.

During the late nineteenth century, Austrian geologist Eduard Suess noted the similarities between the Late Paleozoic plant fossils of India, Australia, South Africa, and South America. The plant fossils comprise a unique group of plants that occurs in coal layers just above the glacial deposits on these southern continents. In this book The Face of the Earth (1885), he proposed the name "Gondwanaland" (called Gondwana here) for a supercontinent composed of the aforementioned southern landmasses. Suess thought these southern continents were connected by land bridges over which plants and animals migrated. Thus, in his view, the similarities of fossils on these continents were due to the appearance and disappearance of the connecting land bridges.

The American geologist Frank Taylor published a pamphlet in 1910 presenting his own theory of continental drift. He explained the formation of mountain ranges as a result of the lateral movements of continents. He also envisioned the present-day continents as parts of larger polar continents that eventually broke apart and migrated toward equator after Earth's rotation was supposedly slowed by gigantic tidal forces. According to Taylor, these tidal forces were generated when Earth's gravity captured the Moon about 100 million years ago. Although we know that Taylor 's explanation of continental drift is incorrect, one of his most significant contributions was his suggestion that the Mid-Atlantic Ridge—an underwater mountain chain discovered by the 1872-1876 British HMS Challenger expeditions—might mark the site at which an ancient continent broke apart, forming the present –day Atlantic Ocean.

However, it is Alfred Wegener, a German meteorologist, who is generally credited with developing the hypothesis of continental drift. In his monumental book, The Origin of Continents and Oceans (1915), Wegener proposed that all landmasses were originally united into a single supercontinent that he named "Pangaea." Wegner portrayed his grand concept of continental movement in a series of maps showing the breakup of Pangaea and the movement of various continents to their present-day locations. What evidence did Wegener use to support his hypothesis of continental drift? First, Wegener noted that the shorelines of continents fit together, forming a large supercontinent and that marine, nonmarine, and glacial rock sequences of Pennsylvanian to Jurassic ages are almost identical for all Gondwana continents, strongly indicating that they were joined together at one time. Furthermore, mountain ranges and glacial deposits seem to match up in such a way that suggests continents could have once been a single landmass. And last, many of the same extinct plant and animal groups are found today on widely separated continents, indicating that the continents must have been in proximity at one time. Wegener argued that this vast amount of evidence from a variety of sources surely indicated the continents must have been close together at one time in the past.

Alexander Du Toit, a South African geologist was one of Wegener's ardent supporters. He noted that fossils of the Permian freshwater reptile "Mesosaurus" occur in rocks of the same age in both Brazil and South Africa. Because the physiology of freshwater and marine animals is completely different, it is hard to imagine how a freshwater reptile could have swum across the Atlantic Ocean and then found a freshwater environment nearly identical to its former habitat. Furthermore, if Mesosaurus could have swum across the ocean, its fossil remains should occur in other localities besides Brazil and South Africa. It is more logical to assume that Mesosaurus lived in lakes in what are now adjacent areas of South America and Africa but were then united in a single continent.

Despite what seemed to be overwhelming evidence presented Wegener and later Du Toit and others, most geologists at the time refused to entertain the idea that the continents might have moved in the past.

## Egypt Circa 3100 B.C.

The city of Memphis, located on the Nile near the modern city of Cairo, was founded around 3100 B.C., as the first capital of a recently united Egypt. The choice of Memphis by Egypt's first kinds reflects the site's strategic importance. First, and most obvious, the apex of the Nile River delta was a politically opportune location for the state's administrative center, standing between the united lands of Upper and Lower Egypt and offering ready access to both parts of the country. The older predynastic (pre- 3100 B.C.) centers of power. This and Hierakonpolis, were too remote from the vast expanse of the delta, which had been incorporated into the unified state. Only a city within easy reach of both the Nile valley to the south and the more spread out, difficult terrain to the north could provide the necessary political control that the rulers of early dynastic Egypt (roughly 3000-2600 B.C.) required.

The region of Memphis must have also served as an important node for transport and communications, even before the unification of Egypt. The region probably acted as a conduit for much, if not all, of the river-based trade between northern and southern Egypt. Moreover, commodities (such as wine, precious oils, and metals) imported from the Near East by the royal courts of predynastic Upper Egypt would have been channeled through the Memphis region on their way south. In short, therefor, the site Memphis offered the rulers of the Early Dynastic Period an ideal location for controlling internal trade within their realm, an essential requirement for a state-directed economy that depended on the movement of goods.

Equally important for the national administration was the ability to control communications within Egypt. The Nile provided the easiest and quickest artery of communication, and the national capital was, again, ideally located in this respect. Recent geological surveys of the Memphis region have revealed much about its topography in ancient times. It appears that the location of Memphis may have been even more advantageous for controlling trade, transport, and communications than was previously appreciated. Surveys and drill cores have shown that the level of the Nile floodplain has steadily risen over the last five millenniums. When the floodplain was much lower, as it would have been in predynastic and early dynastic ties, the outwash fans (fan-shaped deposits of sediments) of various wadis (stream-beds or channels) that carry water only during rainy periods) would have been much more prominent features on the east bank. The fan associated with the Wadi Hof extended a significant way into the Nile floodplain, forming a constriction in the vicinity of Memphis. The valley may has narrowed at this point to a mere three kilometers, making it the ideal place for controlling river traffic.

Furthermore, the Memphis region seems to have been favorably located for the control not only of river-based trade but also of desert trade routes. The two outwash fans in the area gave access to the extensive wadi systems of the eastern desert. In predynastic times, the Wadi Digla may have served as a trade route between the Memphis region and the Near East, to judge from the unusual concentration of foreign artifacts found in the predynastic settlement of Maadi. Access to, and control of, trade routes between Egypt and the Near East seems to have been a preoccupation of Egypt's rulers during the period of state formation. The desire to monopolize foreign trade may have been one of the primary factors behind the political unification of Egypt. The foundation of the national capital at the junction of an important trade route with the Nile valley is not likely to have been accidental. Moreover, the Wadis Hof and Digla provided the Memphis region with accessible desert pasturage. As was the case with the cities of Hierakonpolis and Elkab, the combination within the same area of both desert pasturage and alluvial arable land (land suitable for growing crops) was a particularly attractive one for early settlement, this combination no doubt contributed to the prosperity of the Memphis region from early predynastic times.

## Population Growth in Nineteenth-Century Europe

Because of industrialization, but also because of a vast increase in agricultural output without which industrialization would have been impossible, Western Europeans by the latter half of the nineteenth century enjoyed higher standards of living and longer, healthier lives than most of the world's peoples. In Europe as a whole, the population rose from 188 million in 1800 to 400 million in 1900. By 1900, virtually every area of Europe had contributed to the tremendous surge of population, but each major region was at a different stage of demographic change.

Improvements in the food supply continued trends that had started in the late seventeenth century. New lands were put under cultivation, while the use of crops of American origin, particularly the potato, continued to expand. Setbacks did occur. Regional agricultural failures were the most common cause of economic recessions until 1850, and they could lead to localized famine as well. A major potato blight (disease) in 1846-1847 led to the deaths of at least one million persons in Ireland and the emigration of another million, and Ireland never recovered the population levels the potato had sustained to that point. Bad grain harvests at the same time led to increased hardship throughout much of Europe.

After 1850, however, the expansion of foods more regularly kept pace with population growth, though the poorer classes remained malnourished. Two developments were crucial. First, the application of science and new technology to agriculture increased. Led by German universities, increasing research was devoted to improving seeds, developing chemical fertilizers, and advancing livestock. After 1861, with the development of land-grant universities in the United States that had huge agricultural programs, American crop-production research added to this mix. Mechanization included the use of horse-drawn harvesters and seed drills, many developed initially in the United States. It also included mechanical cream separators and other food-processing devices that improved supply.

The second development involved industrially based transportation. With trains and steam shipping, it became possible to move foods to needy regions within Western Europe quickly. Famine (as opposed to malnutrition) became a thing of the past. Many Western European countries, headed by Britain, began also to import increasing amounts of food, not only from Eastern Europe, a traditional source, but also from the Americas, Australia, and New Zealand. Steam shipping, which improved speed and capacity, as well as new procedures for canning and refrigerating foods (particularly after 1870), was fundamental to these developments.

Europe's population growth included on additional innovation by the nineteenth century: it combined with rapid urbanization. More and more Western Europeans moved from countryside to city, and big cities grew most rapidly of all.  By 1850, over half of all the people in England lived in cities, a first in human history. In one sense, this pattern seems inevitable. Growing numbers of people pressed available resources on the land, even when farmwork was combined with a bit of manufacturing, so people crowded into cities seeking work or other resources. Traditionally, however, death rates in cities surpassed those in the countryside by a large margin, cities had maintained population only through steady in- migration. Thus rapid urbanization should have reduced overall population growth, but by the middle of the nineteenth century this was no longer the case. Urban death rates remained high, particularly in the lower-class slums, but they began to decline rapidly.

The greater reliability of food supplies was a factor in the decline of urban death rates. Even more important were the gains in urban sanitation, as well as measures such as inspection of housing. Reformers, including enlightened doctors, began to study the causes of high death rates and to urge remediation. Even before the discovery of germs, beliefs that disease spread by "miasmas" (noxious forms of bad air) prompted attention to sewers and open garbage. Edwin Chadwick led an exemplary urban crusade for underground sewers in England in the 1830s. Gradually, public health provisions began to cut into customary urban mortality rates. By 1900, in some parts of Western Europe life expectancy in the cities began to surpass that of the rural areas. Industrial societies had figured out ways to combine large and growing cities with population growth, a development that would soon spread to other parts of the world.

## Stone Tools and Pottery Fragments

Aside from ancient buildings, in sheer bulk the largest part of the archaeological record is made up of stone tools and pottery fragments (shards). Stone tools are the earliest known artifacts, having been first used more than two million years ago, and they have remained in use to the present day. When a chunk of fine-grain stone is struck with sufficient force at the proper angle with another rock or with a wood or bone baton, a shock wave will pass through the stone and detach a flake of the desired size and shape. In analyzing ancient stone tools, many archaeologists have mastered the skills needed to make stone tools themselves. Few things are sharper than a fragment struck from fine-grain flint or from obsidian (volcanic glass). Obsidian is so fine grained that flakes of it can have edges only about twenty molecules thick-hundreds of times thinner than steel tools.

Through experimentation, some archaeologists are able to produce copies of almost every stone tool type used in antiquity. A common research strategy is to make flint tools, use them to cut up meat, saw wood, clean hides, bore holes, etc, and then compare the resulting wear traces with the marks found on ancient artifacts. Sometimes electron-scanning microscopes are used to study minute variations in these use marks. Some rough correspondence can be found between the types of uses and the characteristics of wear marks, but there are many ambiguities.

Ethnographic data from people who still use these tools, like one study of how the IKung hunter-gatherers use different styles of stone spear points to identity their different social groupings, indicate that even crude-looking stone tools may reflect a great deal of the social and economic structure.

Ceramics were in use much later than the first stone tools (appearing in quantity in many places about 10,000 years ago), but they were used in such massive quantities in antiquity that, for many archaeologists, work life consists mainly of the slow sorting and analyzing of pottery fragments. Ceramic pots were first made by hand and dried in the sun or in low temperature kilns, a process that did not produce a very durable material. But in many areas of Africa, Asia and Europe high-temperature kilns produced pottery that is nearly a form of glass, and fragments of these pots survive even when the pottery is broken.

Ceramics form such a large part of archaeologists' lives because ceramics express so much about the people who made them. Pots are direct indicators of function in that they show how diets and economies changed over time. Archaeologists have documented how pottery in the American Southwest changed in prehistoric times as a diet developed that included boiled seeds of various native plants, and pottery was developed to withstand the heat and mechanical stresses of the boiling process.

Ceramics are almost always analyzed on the basis of their style. This idea of style is hard to define, but changing styles are the basis on which archaeologists date much of the archaeological record. But for many archaeologists, ceramic styles are more than just convenient devices of dating. For many archaeologists, stylistic decoration of artifacts is the primary means by which one can enter the cognitive world of the ancients. Societies throughout history have invested their objects with styles that have profound and complex meanings and effects. In the case of the Maya and every other early civilization, rulers used particular symbols and styles as mechanisms through which they portrayed, communicated, and implemented their power. In all societies, styles fix social meaning and are powerful ways in which social groups define and construct their culture. Styles of objects, language, and personal behavior identity people in terms of gender, age group, ethnic group, socioeconomic class, and in many other important ways. Some researchers, for example, have argued that a particular kind of pottery, called Ramey incised (which is incised with figures of eyes, fish, arrows, and abstract objects and was used by the people in the area of present-day Missouri and Illinois at about A.D 900), was primarily used to distribute food but was also used to communicate the idea that the society's elite, for whom the pots were made, were mediators of cosmic forces.

## Animal Behavior

By the early 1900s the field of animal behavior had split into two major branches. One branch, ethology, developed primarily in Europe. To ethologists, what is striking about animal behaviors in that they are fixed and seemingly unchangeable? For example, kittens and puppies play in characteristic but different ways. Present a kitten with a ball of yarn and invariably it draws back its head and bats the yarn with claws extended. Kittens are generally silent as they play, and their tails twitch. Puppies, by contrast, are most likely to pounce flat-footed on a ball of yarn. They bit and bark and their tails wag. Ethologists came to believe that ultimately even the most complex animal behaviors could be broken down into a series of unchangeable stimulus/response reactions. They became convinced that the details of these patterns were as distinctive of a particular group of animals as were anatomical characteristics. For well over half a century, their search for and description of innate patterns of animal behavior continued.

Meanwhile, mainly in North America, the study of animal behavior took a different tack, developing into comparative behavior. Of interest to comparative behaviorists was where a particular came from, that is, its evolutionary history, how the nervous system controlled it, and the extent to which it could be modified. In 1894, C. Lloyd Morgan, an early comparative behaviorist, insisted that animal behavior be explained as simply as possible without reference to emotions or motivations since these could not be observed or measured. In Morgan's research, animals were put in simple situations, presented with an easily described stimulus, and their resultant behavior described.

The extension to animals of behaviorism—the idea that the study of behavior should be restricted to only those elements that can be directly observed—was an important development in comparative behavior. Studies of stimulus/response and the importance of simple rewards to enforce and modify animal behavior were stressed. Not surprisingly, comparative behaviorists worked most comfortably in the laboratory. Comparative behaviorists stressed the idea that animal behavior could be modified, while their ethologist colleagues thought it was innate and unchangeable. Inevitably, the two approaches led to major disagreements.

To early ethologists, the major driving force in behavior was instinct, behaviors that are inherited and unchangeable. Moths move towards light because they inherit the mechanism to so respond to light. Although dogs have more options available to them, they bark at strangers for much the same reasons. The comparative behaviorists disagreed: learning and rewards are more important factors than instinct in animal behavior. Geese are not born with the ability to retrieve lost eggs when they roll out the nest, they learn to do so. If their behavior seems sometimes silly to humans because it fails to take new conditions into account, that is because the animal's ability to learn is limited. There were too many examples of behaviors modified by experience for comparative behaviorists to put their faith in instincts.

The arguments came to a peak in the 1950s and became known as the nature or nurture controversy. Consider how differently an ethologist and a comparative behaviorist would interpret the begging behavior of a hatchling bird. The first time a hatchling bird is approached by its parent, it begs for food. All baby birds of a particular species beg in exactly the same way. Obviously, said the ethologists, they inherited the ability and the tendency to beg. Baby birds did not have to learn the behavior, they were born with it—a clear example of innate, unchanging behavior. Not so, countered the comparative behaviorists. Parent birds teach their young to beg by stuffing food in their open mouths. Later experiments showed that before hatching, birds make and respond to noises of their nest mates and adults. Is it not possible that young birds could learn to beg prenatally?

It was hard for ethologists to accept that innate behaviors could be modified by learning. It was equally difficult for comparative behaviorists to accept that genetic factors could dominate learning experiences. The controversy raged for over a decade. Eventually, however, the distinctions between the two fields narrowed. The current view is that both natural endowments and environmental factors work together to shape behavior.

## Sea Turtle Hatchling Strategies for Navigation

Sea turtles' eggs are laid at night to minimize the likelihood of their discovery by predators, and the offspring, when ready to emerge from their eggshells and dig their way out of the sand, hatch at night for the same reason. Since the offspring are especially vulnerable immediately after hatching, it is vital for them to get to the sea as soon as possible. Turtle hatchlings use a number of cues to tell them where the sea is.

The most important cue seems to be light. The night sky is usually brightest over the sea. Cover a turtle hatchling's eyes, and it cannot find the sea even if there is other information available, such as a downward slope of the sand toward the water's edge. The hatchlings respond to light cues covering a vertical range of only about 30°above the horizon or, depending on the species, even less. Responding only to lights that are close to the horizon decreases the risk that hatchlings will become confused. They seem less attracted to yellow light than to other colors—loggerhead turtles show an aversion to yellow light—and this preference may keep them from becoming disoriented by the rising Sun.

It is usually safest to have more than one internal compass, and hatchlings seem to be guided by more than light alone. They steer away from sand dunes and vegetation. Possibly these objects merely block light behind them that might mislead turtle hatchlings about where the sea is, but it is also possible that turtles are sensitive to the shape of such objects and process these shapes as signals that the sea is located in some other direction. Such reinforcing cues, however, are not enough to guide hatchlings away from the artificial lights that now burn on many a beach environment. Artificial lighting is often strong enough to completely overcome the signals a hatchling sea turtle is programmed to recognize. Artificial light, if it is bright enough, becomes a stimulus so powerful that the hatchlings respond to nothing else, crawling toward it from hundreds of meters away.

If all goes well and the hatchlings scramble over the sand in the right direction, avoid their enemies, and reach the surf, a new set of orienting mechanisms takes over. As soon as they are afloat, the hatchlings begin to swim at something over 1.5 kilometers per hour. They dive into the path of the wave undertow, where the receding waters sweep them outward, away from the beach. When they surface again, the head for open sea. This time, they are guided not by sight but apparently exclusively by the direction of the incoming waves. Experiments with loggerheads, greens, and leatherbacks have shown that hatchlings swim toward approaching waves; but if the sea is calm, they swim randomly or in circles. Under experimental conditions, hatchlings will swim into the waves even if doing so sends them back to the beach again.

The farther a hatchling gets from shore, the less reliable wave direction becomes as a pointer to the open sea. Researchers have shown that hatchling green sea turtles released from a hatchery in Borneo, East Malaysia, are able to navigate around small islands and keep swimming offshore, even when there are few waves to guide them. They may be relying on yet another internal compass this time oriented to Earth's magnetic field. Recent experiments suggest that leatherback and olive ridley hatchlings "switch on" their geomagnetic compass almost as soon as they are out of the nest. Though the hatchlings position themselves geomagnetically as soon as they leave the nest and appear to be able to use that position as a reference point, they will not follow it automatically if other cues, such as light and sound, are available. Hatchlings find their geomagnetic compass useful only after they have already been able to determine the direction they should swim. A simple directional compass—one that always sent the turtles westward, for instance—would be useless if the open sea lay in some other direction. Therefore, a magnetic compass does not so much tell a hatchling turtle which way to go as keep it on course once it has determined the direction it should swim from some other cue.

## Three Theories about Origin of Life

Oxygen and nitrogen are major components of our current atmosphere. But the kinds of hydrogen reactions with other gases that are required to transform simple organic molecules into complex ones are interrupted by oxygen, which combines with hydrogen atoms from other compounds. Therefore, life on Earth must have originated when there was very little oxygen in Earth's atmosphere. The modern scientific theory of life's origin was first formulated in the 1920s by Russian scientist Aleksandr Oparin and independentiy by British scientist J. B. S. Haldane. The assumption that life sprang up from chemical reactions that were initiated in the early atmosphere (oxygen-poor/hydrogen-rich) and came to completion in the early oceans was posited by the Oparin-Haldane hypothesis, as it came to be called. Oparin and Haldane suggested that the hydrogen-containing gases caused to react with each other to form organic compounds by energy sources such as sunlight and lightning.

With regard to the view that these complex organic compounds could have begun to shape in Earth's oceans, some researchers remain skeptical. The probability that the fundamental building blocks of life, formaldehyde (H2CO) and hydrogen cyanide(HCN), even though they were probably available, would have been concentrated sufficiently to allow further reactions to occur was likely small. And the more complex organic compounds that might have formed in this way would not have lasted long in the surface-ocean environment, because photochemical and thermal reactions would have destroyed them. Therefore, researchers have sought alternative explanations for how complex organic compounds formed.

There is one possibility that the relevant organic compounds were created in space, and asteroids or comets brought them to Earth, probably as tiny dust particles. Recovered from the stratosphere (an upper region of Earth's atmosphere), interplanetary dust particles (IDPs) is tiny particles that are known to be extraterrestrial origin. From various researches, we know that organic compounds, including amino acids, exist in IDPs as well as in some meteorite. Now, we actually have identified the fact that amino acids and many other complex organic compounds in interstellar dust clouds. It is believed that they form from reactions between charged particles and neutral molecules. Those atoms appear in interstellar dust clouds at very low temperatures-on the order of 200 or more degrees below zero on the Celsius scale. It may seem surprising that organic chemistry could occur in the interstellar environment, but it is precisely the extremely low temperatures involved that allow complex organic molecules to exist because temperatures are too cold to allow them to decompose. It is thought that some of the molecules created in the interstellar environment have survived the collapse of the gas and dust cloud that formed our solar nebula and Sun. They would have been incorporated into solid materials that condensed out of the nebula and formed asteroids and comets. Such materials might have been delivered to Earth in great quantities during the heavy bombardment period of solar system history, between 4.5 and 3.8 billion years ago.

The hypothesis that life took place in or around hydrothermal vents (hot springs), where new seafloor is being created along mid-ocean ridges (underwater mountain chains) at the ocean's bottom is the third theory of life's origin. By seawater that flows a kilometer or more down through crevices in the rock, is heated, and then rises rapidly back to the surface, the ridges are cooled. During the process, the water gathers substances such as hydrogen, hydrogen sulfide, and dissolved ferrous iron. When it meets the cold water, the extremely hot (350°C) vent water generates a dark plume comprised mostly of iron sulfide, a compound produced by the reaction between ferrous iron and hydrogen sulfide.

Still, the explanation that submarine hydrothermal vents a likely place for life to have originated is controversial. In vent systems, there are various types of materials from which organic molecules can be synthesized. However, complex organic molecules are not stable at the high temperatures observed in vents positioned directly on the axis of a ridge. If life did originate at the mid-ocean ridges, it probably did so in cooler, off-axis vents. Some researchers claim that perfect place for life to have begun would be in some near-freezing surface environment because even the off-axis vents are too warm. The dispute as to whether life originated in a hot or cold environment is unlikely to stop.

## Costs of Quitting a Job

Economic theory predicts that when the costs of quitting one's job are relatively low, mobility is more likely. This observation underlines the analysis of the rise in quit rates during periods of prosperity, and the effects of mobility costs can be seen when looking at residential location and job turnover. Industries with high concentrations of employment in urban areas, where a worker's change of employer does not necessarily require investing in a change of residence, appear to have higher rates of job turnover than industries concentrated in nonmetropolitan areas do.

Beyond the costs that can be associated with such measurable characteristics as age and residential location are those that are psychic in nature. These latter costs, though unobservable to the researcher, are very likely to differ widely across individuals. Some people adapt more quickly to new surroundings than others do, for example. Recent studies have found considerable heterogeneity among workers in their propensity to change jobs, with one study reporting that almost half of all permanent separations that took place over a three-year period involved a small number (13 percent) of workers who had three or more separations during the period (in contrast, 31 percent of workers had no separations at all during the period).

It is also possible that the costs of job changing by employees vary internationally. Data suggest that workers in the United States may well be more likely to change employers than workers elsewhere may be. Indeed, data confirm that, on average, American workers have been with their current employers fewer years than workers in most other developed countries, particularly workers in Europe and Japan, have been with theirs. It is not known why Americans are more mobile than most others are, but one possibility relates to the lower levels of company training received by American workers. Another possibility, however, is that the costs of mobility are lower in the United States (despite the fact that Japan and Europe are more densely populated and hence more urban). What would create these lower costs?

One hypothesis that has received at least some investigation is that housing policies in Europe and Japan increase the costs of residential, and therefore job, mobility, Germany, the United Kingdom, and Japan, for example, have controls on the rent increases that proprietors can charge to existing renters while tending to allow proprietors the freedom to negotiates any mutually agreeable rent on their initial lease with the renter. Thus, it is argued that renters who move typically face very large rent increases in these countries. Similarly, subsidized housing is much more common in these countries than in the United States, but since it is limited relative to the demand for it, those British, German, or Japanese workers fortunate enough to live in subsidized units are reluctant ( it is argued) to give them up. The empirical evidence on the implications of housing policy for job mobility, however, is both limited and mixed.

It could also be hypothesized that the United States, Australia, and Canada, all of which exhibit shorter job tenures than do most European countries or Japan, are large, sparsely populated countries that historically have attracted people willing to emigrate from abroad or resettle internally over long distances. In a country of "movers," moving may not be seen by either worker or employer as an unusual or especially traumatic event.

While questions remain about the causes of different job mobility rates across countries, the social desirability of job mobility can also be debated. On one hand, mobility can be seen as socially useful because it promotes both individual well-being and the quality of job matches. Moreover, the greater the number of workers and employers "in the market" at any given time, the more flexibility an economy has in making job matches that best adapt to a changing environment. Indeed, when focusing on this aspect of job mobility, economists have long worried whether economies have enough mobility. On the other hand, lower mobility costs (and therefore greater mobility) among workers may well serve to reduce the incentives of their employers to provide job training. Whether the presence of job changing costs is a social boon or bane, these costs and the mobility associated with them are factors with which all employers must contend.

## The Role of the Ocean in Controlling Climate

To predict what the climate will be like in the future, scientists must rely on sophisticated computer models. These models use mathematical equations to represent physical processes and interactions in the atmosphere, ocean, and on land. A starting point is usually based on current measurements or estimates of past conditions. Then, using a spherical grid laid out over the entire globe, thousands of calculations are performed at grid intersections to represent and assess how conditions in the air, in the sea, and on land will change over time. Because of their complexity and size, supercomputers are used to run full-scale climate models. Much of the uncertainty in their outputs comes from the way that various aspects of the climate are represented by different models, and even more so, because there are aspects of climate that are not well understood—one of which is how the ocean impacts climate.

The ocean's role in global warming stems principally from its huge capacity to absorb carbon dioxide and to store and transport heat. In the sea, photosynthesis by marine plants and algae, especially phytoplankton, removes great quantities of carbon dioxide from the atmosphere. Hence, the greater the growth (productivity) of phytoplankton in the sea, the greater the removal of carbon dioxide. But what controls the ocean's productivity? There are several limiting factors, but results from a recent experiment suggest that in areas of the ocean where other nutrients are plentiful, iron may be one of the most important and, until recently, unrecognized variables controlling phytoplankton production. Some have proposed a radical, highly controversial and uncertain means to counteract global warming—adding iron to the oceans to induce phytoplankton blooms. Perhaps increased phytoplankton growth would use up a significant amount of carbon dioxide in the atmosphere, but perhaps not, and there might well be side effects that could be detrimental to the ocean ecosystem.

Within the ocean, the production of limestone, in the form of calcium carbonate skeletons or shells, also reduces atmospheric carbon dioxide. However, when deposits of limestone become exposed and weathered on land or are recycled in the sea, carbon dioxide is released back into the atmosphere. What is not well understood is how much carbon dioxide resides in the sea and at what rate it is taken up and recycled. Relatively new research has also discovered beneath the sea a new and potentially significant threat to skyrocketing Earth temperature: gas hydrates. Gas hydrates are a solid, crystalline form of water, like ice, except that they contain additional gas, typically methane, and are often found stored in ocean sediments. Increased ocean temperatures could cause gas hydrates to dissociate, releasing massive amounts of methane gas into the atmosphere and cause undersea landslides in the process. Consequently, hydrates may, if released, significantly increase global warming as well as create a geologic hazard to offshore drilling operations.

The ocean is also a great reservoir and transporter of heat. Heat from the ocean warms the atmosphere and fuels tropical storms. Heat is transported by currents from the equator to the poles. Ocean circulation is strongly controlled by wind and by the sea's balance of salt and heat. Scientists think that climate warming may slow down circulation, while cooling may speed it up, but these responses are not well understood. Evaporation from the ocean also supplies the precipitation that creates fields of snow and ice at high latitudes. Snow and ice coverage change the reflectivity Earth's surface and are an important influence on how much incoming radiation is either absorbed or reflected. Furthermore, clouds and water vapor in the atmosphere come mainly from the sea and strongly influence climate. Surprisingly, clouds are one of the least understood and most poorly modeled parts of the climate change equation. Most climate modeling grids fail to take into account common-sized cloud formations. Aerosols, tiny particles of soot, dust, and other materials, are thought to seed cloud formation scatter incoming radiation and promote cooling, but this effect, which would counteract warming, is also only superficially understood. Computer models of climate change must take into account all of the processes within the ocean, over land, and in the sky that potentially influence warming. No wonder there is such uncertainty.

## Grain in Colonial North America

Although the colonists of seventeenth- and early-eighteenth-century British North America consumed most of the grain produced in the colonial economy, few households were self-sufficient. Instead, they traded with their neighbors for what they did not produce themselves. In any given year, farmers who produced more grain than they needed would exchange their surpluses locally with other farmers who had different surpluses, with local laborers who supported themselves by selling their labor, or with the local storekeeper, who might also be the miller (trade person who ground grain into flour). Satisfying the domestic demand for breadstuff, then, depended on trade between neighbors. The colonists recorded these myriad transactions as credits and debts in their individual account books. Debts and credits could remain outstanding for years before being settled. Trading based on book credit gave more value to maintaining equilibrium between local supply and demand and to preserving a cooperative spirit among neighbors than to expanding production beyond the immediate needs of the locality.

Colonists also traded grain surpluses long-distance, responding to impersonal demand beyond the community. Some of the long-distance trade catered to regional and urban domestic demand. As the urban areas matured, they increasingly relied on producers in distant areas for grain and other agricultural supplies. In the early 1750s, the most densely populated towns of eastern and southern New England had begun importing substantial quantities of flour and rice from the middle and southern colonies to compensate for grain deficits that developed in their region. Other urban areas followed their example, though their greater proximity to grain regions enabled them to tap supplies closer to home. Assuming that in the early 1770s at least half of the demand for grain from farmers with surpluses was satisfied through long-distance channels, the proportion of grain produced for consumption beyond the local market probably accounted for about a quarter of total grain production consumed by humans.

The colonists organized the long-distance grain economy differently from their local economy. New mechanisms enabled the long-distance economy to respond sensitively to variations in demand, and these in turn gave it greater dynamism than the community-centered, local economy possessed. The contrast between the local and long-distance grain trade is best illustrated by looking at the flour-milling industry.

Nearly every area of colonial settlement had a local gristmill to which farmers brought grain to be custom ground. The limited capital value of most custom mills, the need to process rye and corn as well as wheat, together with seasonal factors affecting the water supply, restricted the volume of wheat flour that could be produced. The production of flour for long-distance exchange and particularly for export usually took place in merchant mills that were larger, had more capital, and were increasingly specialized.

The difference between a merchant mill and a custom mill was one of degree as much as kind. Most merchant mills had started as custom mills, and the colonial and state governments often compelled merchant mills to set aside certain days for custom work. Mills that acquired the designation “merchant” did so because they catered to the demand of merchants in the principal ports. These merchants enabled certain millers to specialize in wheat flour by placing orders for large parcels of it and paying in cash. That in turn allowed the millers to offer cash to the primary producers and grain brokers who delivered wheat to their mills. Cash was the economic motivator of this export-oriented economy for the simple reason that farmers would prepare and haul their grain to landings and mills and even increase their wheat acreage to obtain this commodity.

Cash gave farmers choices they did not enjoy when they traded with neighbors alone. Beyond opening up access to a range of products that could not be produced locally, it freed them from the web of mutual indebtedness and allowed more choices in the selection of trading partners. In other words, the cash economy allowed producers to seek the best bargains in that wider, impersonal market of which the export of agricultural surpluses formed the principal part. Of course, few in this age would have welcomed total release from the support and obligations that local trade conferred.

## Controversy about Causing Emotion

The fact that we react to certain experiences with “Emotion” is obvious. For example, the feeling of embarrassment, which triggers a physiological response that may cause blushing, is caused by a foolish act committed in the company of friends. Although this description of an embarrassed reaction seems logical, the American psychologist William James, in 1884， believed that the course of an emotional experience follows another sequence of events.

Following the argument of James, what subjective experience tells us is completely opposite that the sequence of events in an emotional experience. First, he insisted that both physiological excitement and physical reaction are generated by an incident. Only then does the individual perceive or interpret the physical response as an emotion. That is, we associate blushing that caused by physical reaction with embarrassment, such as saying something silly may cause us to blush. In 1890, James went on to claim that "people feel sorry because they cry, furious because they strike, afraid because they shudder." Simultaneously with James' proposition, Carl Lange, a Danish physiologist and psychologist, independently formulated virtually similar theory. The James-Lange theory of emotion (Lange and James, 1922) suggests that different patterns of arousal in the autonomic nervous system create the different emotions people feel, and that physiological arousal occurs prior to the emotion is perceived.

In 1927, another early theory of emotion that challenged the James-Lange theory was proposed by Walter Cannon. He claimed that physical changes caused by the diverse emotions are not sufficiently distinct to allow people to distinguish one emotion from another. _ After Cannon stated his original theory, in 1934, it was further developed by physiologist Philip Bard. The Cannon-Bard theory suggests that the following chain of events takes place when an emotion is felt. Stimuli which trigger emotion are received by the senses and then are relayed simultaneously to the cerebral cortex, which imparts the conscious mental experience of the emotion, and to the sympathetic nervous system, which generates the physiological state of arousal. In other words, the feeling of emotion occurs roughly the same time when the physiological arousal is experienced. One does not cause the other.

In 1962, Schachter and Singer proposed a two-factor theory. Stanley Schachter thought that the early theories of emotion excluded a critical component that the subjective cognitive interpretation of why a state of arousal has occurred. According to this theory, two things must happen in order for a person to feel an emotion. At first, the person must experience physiological arousal. Then, for the person can label it as specific emotion, there must be a cognitive interpretation or explanation. Thus, Schachter delivered the conclusion that a true emotion can appear only if a person is physically aroused and can find the reason for it. When people are in a state of physiological arousal but do not know why they are aroused, they tend to label the state as an emotion that is appropriate to their situation at the time. There were several attempts to replicate the findings of this theory, but they have not been successful.

Richard Lazarus, in the 1990, proposed the emotion theory that most heavily emphasizes the cognitive aspect. According to his theory, the first step in an emotional response is cognitive appraisal, and all other aspects of emotion, including physiological arousal, rely on the cognitive appraisal. This theory is most compatible with the subjective experience of an emotion’s sequence of events-the sequence that William James reversed long ago. People first appraise a stimulus, or an event, when they encounter it. This cognitive appraisal determines whether the person will have an emotional response, and, if so, what type of response. From this appraisal, the physiological arousal and all other aspects of the emotion arise. In brief, Lazarus contends that emotions are roused when cognitive appraisals of events or circumstances are positive or negative-but not neutral. Some critics criticize the Lazarus theory by saying that some emotional reactions are instantaneous, which means they occur too rapidly to pass through a cognitive appraisal. In respond to the criticisms, Lazarus remarks that some mental processing occurs without conscious awareness, meaning that a person should not know what he or she is responding to or what emotion to feel, or else, some form of cognitive realization must manifest but brief.

## The Distribution of Gliding Animals

Generally, gliding is used for some animal species as a mean of fleeing from the predators since it enables them to move between trees without the need to descend to the ground and it also is an energy-efficient way to travel long distances between scattered food resources. For scientist, gliding animals (flying squirrels, flying frogs, and flying lizards with wings of skin that allow them to glide through the tropical forest) have long been the intriguing subject of study. Recently, researchers have found that Southeast Asia has a unique abundance and diversity of these animals. This observation leads them to the following questions. What could be an explanation about biological diversity of these animals found in the forest of Southeast Asia and what could explain the scarcity of gliding animals in other regions? Most of all, what makes Southeast Asian rain forests unusual?

Several theories have been proposed by many scientists to explain the diversity of gliding animals in Southeast Asia. The first theory might be called the tall-trees hypothesis. According to this theory, taller trees in Southeast Asia could offer longer glides as well as the opportunity to boost in a dive before gliding because the forests of this region are taller than any other forests in the world, which comes from the domination of dipterocarp family, a family of tall, tropical hardwood trees. And by providing a more advantageous situation for gliding between tall-trees, the lower wind speeds might also contribute to the great number of appearance of gliding animals. This speculation, however, has several flaws. First, gliding animals are found throughout the Southeast Asian region, even in relatively short-stature forests located in the northern area of the rain forest in China, Thailand and Vietnam. Also, some gliders thrive in low secondary forests, plantations, and even city parks. It is obvious that gliding animals do not need tall trees for their activities. In addition, many gliding animals initiate their glides from the middle of tree trunks, not necessarily ascending to the tops of trees to take off.

Another theory, known as broken-forest hypothesis, speculates that animals in Southeast Asia must risk descending to the ground or glide to move between trees because the top layer of the forest-the tree canopy-has fewer woody vines connecting tree crowns in Southeast Asian forests than in New World and African forests. It also presumes that the tree canopy in Asian forests is more uneven in height, due to the existence of tall dipterocarp trees with lower trees between them, and this imbalance is favored by gliding animals. But it is observed by ecologist working in different regions of world that, depending on the site conditions of soil, climate, slope elevation, and local disturbance, there is a tremendous local variation in tree height, canopy structure, and abundance of vines. Indeed, we can find many locations with abundant woody vines and numerous connections between trees in Southeast Asia and similarly many Amazonian forests with few woody vines.

A last theory differs from the others in suggesting that it is the presence of dipterocarp trees themselves that is promoting the evolution of gliding species. According to this theory, dipterocarp forests can be "food-deserts" for the animals that live in them. The animals living in dipterocarp forests that have developed gliding divide into two main groups: leaf eaters and carnivores that eat small prey such as insects and small vertebrates. _ for leaf-eating gliders the problems is not the absence of any leaves but the desert-like absence of edible leaves. Dipterocarp trees often account for 50 percent or more of the total number of canopy trees in a forest and over 95 percent of the large trees, yet dipterocarp leaves are unavailable to most vertebrate plant eaters because of the high concentration of toxic chemicals in their leaves. Many species of gliding animals avoid eating dipterocarp leaves and so must travel widely through the forest, bypassing the dipterocarp tree, to find the leaves they need to eat. And gliding is a more efficient way of traveling between trees than descending to the ground and walking or else jumping between trees.

Since there is the lower abundance of prey and other insects, many carnivorous animals also may need to forage more widely for food. This scarcity of food source is caused by dipterocarps' irregular flowering and fruiting cycles of two- to seven-year intervals, resulting in a shortage of the flowers, fruits, seeds, and seedlings that are the starting point of so many food chains. The lower abundance of prey in dipterocarp forests forces animals such as lizards and geckos to move between tree crowns in search of food, with gliding being the most efficient means.

## The Sentinel Behavior of Meerkats

A species of small mongooses in Africa called meerkats share sentinel (guard) duties to warn other group members by repeating alarm calls if a predator is seen. This is an important job, because when meerkats are foraging, their heads are in the ground seeking prey, and they cannot see a predator coming.

The question is, why do group members take turns acting as sentinels? Kin selection, that is, being able to save the lives of family members can be one hypothesis for this type of sentinel behavior. Family members share copies of a meerkat's genes. Kin selection is achieved by helping a meerkat’s own offspring as well as non descendant kin, including sibling, nieces, nephews, aunts, and uncles. Therefore, if members of a certain group are closely related, a sentinel ensures that copies of its genes can be passed on to future generations by saving the majority of family members by alerting others, even at the expense of its own life.

Assuming this hypothesis is true, we can predict that group members have close genetic ties. Otherwise, kin selection would not work. But this prediction does hold true. A dominant, breeding female is mother to 75 percent of all the litters in a group, and one dominant male fathers 75 percent of all the pups born. Even though a typical meerkat group includes a few immigrants, most subordinate adults are siblings or half siblings. Therefore, it is likely that subordinate adults share 25 or 50 percent of their genes.

On account of most meerkat group members being family, it is possible that kin selection has favored sentinel behavior.  Nonetheless, by itself, a close inherent relationship is not enough evidence to conclude that kin selection has played a role. Thus, we need further evidence, and must improve the prediction. Based on the same hypothesis, a more specific prediction is that each mongoose should increase the frequency of sentinel behavior when they are guarding family members. This new prediction needed testing, so the group was observed to determine which members stand guard and when. The immigrants without any kin relations to other group members acted as sentinels just as much as the individuals with many relatives nearby. Therefore, the result of this test does not support the kin-selection hypothesis.

Another hypothesis that is often suggested to explain such cooperative behavior is that it results from reciprocal altruism~each individual takes turns standing guard to benefit the rest of the group, rather than itself. The reciprocal altruism theory can work only when those who cheat by avoiding guard duty can be identified and punished by the rest of the group. This hypothesis produces the prediction that there should be a regular rotation of sentry duty within the group and that the ones who neglect this duty should be chastised. However, this is not observed. In fact, the group members do take turns on sentry duty, but there is no predetermined order for this. In addition, when some members shorten their shift, other group members increase their contributions to compensate. The predictions and observations of the reciprocal-altruism hypothesis do not coincide with each other.

Yet another hypothesis for the evolution of meerkat sentinel behavior is that it results from selfish antipredator behavior. This idea stems from the fact that the meerkat watching for predators increases its personal safety, and warning others does not harbor any disadvantage. So, when a meerkat has had enough to eat, it should watch for predators. The sentinel on duty can then return to foraging. This hypothesis produces a prediction that sentinel duty is not dangerous or risky in any way. This does seem to be true. Over the course of 2,000 hours of observation, no sentinels were attacked or killed by predators. They may actually be safer because they are the first to sense the predator. Moreover, they generally stand guard within 5 meters of a burrow, and are the first underground when a predator comes close.

If a meerkat’s personal safety is increased with serving as a sentinel, it would be possible to predict that an individual would spend a proportion of its time guarding, whether it was solitary or part of a group. As predicted, individual meerkats spend about the same time on guard duty as members of large groups. Groups with more members suffer less predation because there is a sentinel for a longer portion of foraging time than in small groups.

## Agriculture in Medieval Japan

A rapid population of Japan occurred during its medieval times. Japan's population was around 7 million but it rose keenly to 12 million from year 1200 to 1600. In this period, numerous hamlets formed throughout the country. They were mostly formed in the lands listed as "unsettled" or as a "wasteland" before 1300. There were many facets in increase in number of new hamlets, but by far the most significant characteristic of newly formed hamlets were that they were much bigger in terms of size compared to that of the hamlets built before 1300. There are many factors for forming of such large towns that contributed to increase in population mass. Some factors that can be considered are people's demand for local authority, voluntarily, to defend themselves against outside threats or to form religious communities. Whatever the impetus, such formation of large villages was due to improvements in the agricultural technologies. Some improvements in technologies involved turning over of fields, irrigation methods, and usage of waterwheels, iron tools and diversification of crop output.

Among many improvements in agriculture, field leveling was the most basic practice used to optimize the land for farming. The farmers would create flat land for farming by leveling a field. They then would use the surfeit soil from the field to level the slightly slanted field. As a result, two fields of difference in altitude would be formed. Such difference in elevation allowed farmers to use the lower for rice paddy and the higher for dry crops. Practice of field leveling allowed a paddy culture to settle and allowed vast variety in dry crops to be produced due to the formation of drop crop field. Though the labor involved in formation of fields was enormous, the field preparation enabled marshlands alongside the rivers to be used for husbandry even if the rivers were uncontrolled.

Rice crops require ample water for growth and it takes much time until they are ready to be harvested. So farmers naturally worked by places where they had access to ample supply of water, such as riverbanks, streams and ponds. However, natural water supply was inefficient for the growth of rice, especially in sweltering summers. This led to the usage and development of ditches and dikes. Development in drawing the water from the distant locations led number of dams to increase and directed them to wherever they needed them. This was most evident in Yamato Basin where famers built permanent dams. The water detained in the pools was kept for times when they needed water for farming in droughty seasons. Such development led to keen proliferation of crop output as the heated water metabolized the germination of crops and caused crops to mature even faster.

By mid 1500s, one quarter of all paddy land were used to double crop. The farmers not only used fields to grow two crops in a year, but they even grew three in a single annual cycle. An envoy from Korea stated that Japanese farmers from Hyogo region would grow barley and sow in winter and harvest them in summer. Followed by rice cropping in summer and fall, buckwheat was harvested in winter. As time went on agriculture advanced, such technique progressed from generation to generation. Farming became more consistent and the crop output became even greater. A greater sense of discipline in land tilling and wide range of crops being planted in the same piece of land broadened the understanding of agriculture in farmers.

Crops harvested were used for farmers themselves. In many cases, one hectare of decent land was enough to sustain their entire family. They would only plow enough land for food to cater families for several reasons. Much of the medieval Japanese reclamation of land was due to the search for enough arable land to meet the food needed for just a single household. In case a farmer having enough fields for crop output required for his family, he would expand his fields no that one had to put into farming for his crops to grow. This was further compounded by the scarcity of land for fanning as well as limiting capacity for water and fertilizer supplies, not to mention the likelihood of antagonizing neighbors. Taking these variable factors into consideration, farmers of this period persisted with single hectare or less of arable land, just enough to sustain their families.

## Foundational and Keystone Species

The harmony present in any ecological system relies on the inclusion of different types of species, each with a specific role or set of roles. Although to some extent all species contribute in important ways, scientists are now learning about the pivotal parts played by, what are being called foundational and keystone species. Interestingly, the latter represent only a small fraction of the overall animal population within an ecosystem while the former can make up a significant portion of it. In both cases, though, their removal often results in massive changes to, if not the complete destruction of, their ecosystems. Efforts to conserve these species are currently based on the new idea that they prevent the start of a domino effect that would, once started, be unstoppable.

Foundational species are the backbones of the systems they inhabit. These species are referred to as primary producers, which means that they generate a large amount of the abundance other species require to survive. In most cases, they are a type of vegetation or stationary animal. Coral, which tends to grow in large colonies, is often pointed to as an example. Eventually a group of colonies will form a coral reef, which can sustain a complete ecosystem around it. The reef contains the skeletal remains of coral at its bottom and living coral on the top. Numerous animals, including zooplankton and sponges, live in the small crevices located in the rock-like bottom. At the top, the coral interacts with seaweed and other forms of vegetation to regulate the levels of nutrients and gases in the water. There are also more than four thousand types of fish that live on or around most coral reefs. Fish rely on the holes in the reef for protection. The more colorful species of coral provide excellent camouflage for fish, as well. Obviously, without its foundational species, an ecosystem would collapse.

Keystone species play less apparent but equally important roles. The name comes from the keystones used in the building of stone archways. The keystone receives the smallest amount of pressure of all the stones in the arch, but, if it is removed, the arch will collapse. In the same way, research is now showing, certain species within ecosystems, although they are smaller in numbers and biomass than most of the other species present, act like keystones. These species are being categorized as either predators or engineers, depending on their relationships with the various species around them.  These categories are not absolute, though, and animals are moved from one to the other as new facts come to light.

In the case of predator keystone species, there are four carnivores that prey on herbivores and other animals. Also, the herbivores usually have no other natural predator in the ecosystem. The sea otter is now considered by many scientists to be a keystone species, because it controls the number of sea urchins, which have few other predators. Both species can be found around kelp forests, which are in the warm parts of the world's oceans. Because kelp is an underwater plant, its roots are not used for the collection of nutrients. Instead, they are there to anchor the plant. As soon as enough sea urchins chewed on the roots, which are fragile, the kelp would be removed from the ecosystem. If the sea otter were to disappear, the urchins would quickly grow in number and destroy all the kelp.

Engineer keystone species maintain the balance in ecosystems in different ways. Although bears tend to live in forests, they bring in important sources of nutrients from ocean and sea-based ecosystems. The bears capture large salmon from the water and take them into the forest to eat them. This distributes large amounts of protein in the form of bear waste matter as well as uneaten portions of salmon. The protein eventually supports life in the forest, either as a food source for smaller animals or the vegetation. Another species that plays a part similar to that of bears is the beaver. Through the construction of dams, beavers convert small rivers into ponds and marshes. The new landscape in turn supports a variety of fish, which in turn provides a dependable source of food for the beavers. The removal of beavers from an ecosystem would also remove the landscape it depends on.

## The Development of Printing

Printing with movable type, a revolutionary departure from the old practice of copying by hand, was invented in the 1440s by Johannes Gutenberg, a German goldsmith. Mass production of identical books and pamphlets made the world of letters more accessible to a literate audience. Two preconditions proved essential for the advent of printing: the industrial production of paper and the commercial production of manuscripts.

Increased paper production in the fourteenth and fifteenth centuries was the first stage in the rapid growth of manuscript books—hand-copied works bound as books—which in turn led to the invention of mechanical printing. Papermaking came to Europe from China via Arab intermediaries. By the fourteenth century, paper mills were operating in Italy, producing paper that was much more fragile but much cheaper than parchment or vellum, animal skins that Europeans had previously used for writing. To produce paper, old rags were soaked in a chemical solution, beaten by mallets into a pulp, washed with water, treated, and dried in sheets—a method that still produces good-quality paper today.

By the fifteenth century, a brisk industry in manuscript books was flourishing in Europe's university towns and major cities. Production was in the hands of merchants called stationers, who supplied materials, arranged contracts for book production, and organized workshops known as scriptoria, where the manuscripts were copied, and acted as retail booksellers. The largest stationers, in Paris and Florence, were extensive operations by fifteenth-century standards. The Florentine Vespasiano da Bisticci, for example, created a library for Cosimo de' Medici, the head of Florence's leading family, by employing 45 copyists to complete 200 volumes in 22 months. Nonetheless, bookmaking in scriptoria was slow and expensive.

The invention of movable type was an enormous technological breakthrough that took bookmaking out of the hands of human copyists. Printing was not new: the Chinese had been printing by woodblock since the tenth century, and woodcut pictures (in which an image is cut on wood and then transferred to paper) made their appearance in Europe in the early fifteenth century. Movable type, however, allowed entire manuscripts to be printed. The process involved casting durable metal molds to represent the letters of the alphabet. The letters were arranged to represent the text on a page and then pressed in ink against a sheet of paper. The imprint could be repeated numerous times with only a small amount of human labor. In 1467 two German printers established the first press in Rome and produced 12,000 volumes in five years, a feat that in the past would have required one thousand scribes working full time for the same number of years.

After the 1440s, printing spread rapidly from Germany to other European countries. The cities of Cologne, Strasbourg, Nuremberg, Basel, and Augsburg had major presses, many Italian cities had established their own by 1480. In the 1490s, the German city of Frankfurt became an international meeting place for printers and booksellers. The Frankfurt book fair, where printers from different nations exhibited their newest titles, represented a major international cultural event and remains an unbroken tradition to this day. Early books from other presses were still rather exclusive and inaccessible, especially to a largely illiterate population. Perhaps the most famous early book, Gutenberg's two-volume edition of the Latin Bible, was unmistakably a luxury item. Altogether 185 copies were printed. First priced at well over what a fifteenth-century professor could earn in a year, the Gutenberg Bible has always been one of the most expensive books in history, both for its rarity and its exquisite crafting.

Some historians argue that the invention of mechanical printing gave rise to a communications revolution as significant as, for example, the widespread use of the personal computer today. The multiplication of standardized texts altered the thinking habits of Europeans by freeing individuals from having to memorize everything they learned; it certainly made possible the speedy and inexpensive dissemination of knowledge. It created a wilder community of scholars, no longer dependent on personal patronage or church sponsorship for texts. Printing facilitated the free expression and exchange of ideas, and its disruptive potential did not go unnoticed by political and church authorities. Emperors and bishops in Germany, the homeland of the printing industry, moved quickly to issue censorship regulations.

## Removing Dams

For nearly a century, two United States governmental agencies, the United States Army Corps of Engineers and the Bureau of Reclamation, have constructed dams to store water and to generate electricity. Building these dams provided cheap electricity, created jobs for workers, stimulated regional economic development, and allowed farming on lands that would otherwise be too dry. But not everyone agrees that big dam projects are entirely beneficial. Their storage reservoirs stop the flow of rivers and often submerge towns, farms, and historic sites. They prevent fish migrations and change aquatic habitats essential for native species.

The tide may have turned, in fact, against dam building. In 1998 the Army Corps announced that it would no longer be building large dams. In the few remaining sites where dams might be built, public opposition is so great that getting approval for projects is unlikely. Instead, the new focus may be on removing existing dams and restoring natural habitats. In 1999 Bruce Babbitt, then the United States interior secretary, said, "Of the 75,000 large dams in the United States, most were built a long time ago and are now obsolete, expensive, and unsafe. They were built with no consideration of the environmental costs. As operating licenses come up for renewal, dam removal and habitat restoration to original stream flows will be among the options considered."

The first active hydroelectric dam in the United States to be removed against the wishes of its owners was the 162-year- old Edwards Dam, on the Kennebec River in Augusta, Maine. For many years, the United States Fish and Wildlife Service had advocated the removal of this dam, which prevented migration of salmon, shad, sturgeon, and other fish species up the river. In a precedent-setting decision, the Federal Energy Regulatory Commission ordered the dam removed after concluding that the environmental and economic benefits of a free-flowing river outweighed the electricity generated by the dam. In July 1999 the dam was removed and restoration work began on wetlands and stream banks long underwater.

The next dams likely to be taken down are the Elwha and Glines Dams on the Elwha River in Olympic National Park in the state of Washington. Built nearly a century ago to provide power to lumber and paper mills in the town of Port Angeles, these dams blocked access to upstream spawning beds for six species of salmon on what once was one of the most productive salmon rivers in the world. Simply removing the dams will not restore the salmon, however. Where 50- kilogram king salmon once fought their way up waterfalls to lay their eggs in gravel beds, there now are only concrete walls holding back still water and deep beds of muddy deposits. Removing the mud, uncovering gravel beds where fish spawn, and finding suitable salmon types to rebuild the population is a daunting task. Congress will have to appropriate somewhere around $300 to $400 million to remove these two relatively small dams and rehabilitate the area.

Environmental groups, encouraged by these examples, have begun to talk about much more ambitious projects. Four giant dams on the Snake River in Washington State, for example, might be removed to restore salmon and steelhead fish runs to the headwaters of the Columbia River. The Hetch Hetchy Dam in Yosemite National Park might be taken down to reveal what John Muir, the founder of the prestigious environmental organization Sierra Club, called a valley —just as beautiful and worthy of preservation as the majestic Yosemite.|| Some groups have even suggested removing the Glen Canyon Dam on the Colorado River. In each of these cases, powerful interests stand in opposition. These dams generate low-cost electricity and store water that is needed for agriculture and industry. Local economies, domestic water supplies, and certain types of recreation all would be severely impacted by destruction of these dams.

How does one weigh the many different economic, cultural, and aesthetic considerations for removing or not removing these dams? Do certain interests, such as the rights of native people or the continued existence of native species of fish or wildlife, take precedence over economic factors, or should this be a utilitarian calculation of the greatest good for the greatest number? And does that number include only humans or do other species count as well?

## Portraits as Art

According to the Oxford English Dictionary, portraiture is, "a representation or delineation of a person, especially of the face, made by life, by drawing, painting, photography, engraving... a likeness." However, this simplistic definition disregards the complexities of portraiture. Portraits are works of art that engage with ideas of identity as they are perceived, represented, and understood in different times and places, rather than simply aim to represent a likeness. These concepts of identity can encompass social hierarchy, gender, age, profession, and the character of the subject, among other things. Rather than being fixed, these features are expressive of the expectations and circumstances of the time when the portrait was made. It is impossible to reproduce the aspects of identity; it is only possible to evoke or suggest them. Consequently, even though portraits represent individuals, it is generally conventional or typical - rather than unique - qualities of subject that are stressed by the artist. Portrait art has also undergone significant shifts in artistic convention and practice. Despite the fact that the majority of portraits portray the subject matter in some amount of verisimilitude, (an appearance of being true or real), they are still the outcome of prevailing artistic fashions and favored styles, techniques, and media. Therefore, portrait art is a vast art category which provides a wide range of engagements with social, psychological, and artistic practices and expectations.

Since portraits are distinct from other genres or art categories in the ways they are produced, the nature of what they represent, and how they function as objects of use and display, they are worthy of separate study. First, during their production, portraits require the presence of a specific person, or an image of the individual to be represented, in almost all cases. In the majority of instances, the production of portraiture has necessitated sittings, which result in interaction between the subject(s) and artist throughout the creation of the work. If the sitter is of high social standing or is occupied and unavailable to sit in the studio regularly, portraitists could use photographs or sketches of their subject. In Europe, during the seventeenth and eighteenth century, the sitting time was sometimes decreased by focusing solely on the head and using professional drapery painters to finish the painting. For instance, Sir Peter Lily, the English artist, had a collection of poses in a pattern book that enabled him to focus on the head and require fewer sittings from his aristocratic patrons. Portrait painters could be asked to present the likeness of individuals who were deceased. In this sort of instance, photographs or prints of the subject could be reproduced. Theoretically, portraitists could work from impressions or memories when creating a painting, but this is a rare occurrence according to documented records. Nonetheless, whether the work is based on model sittings, copying a photograph or sketch, or using memory, the process of painting a portrait is closely linked with the implicit or explicit attendance of the model.

Furthermore, portrait painting can be differentiated from other artistic genres like landscape, still life, and history by its connection with appearance, or likeness. As such, the art of portrait painting got a reputation for imitation, or copying, instead of for artistic innovation or creativity; consequently it is sometimes viewed as being of a lower status than the other genres. According to Renaissance art theory, (which prevailed until the start of the nineteenth century) fine art was supposed to represent idealized images, as well as to be original and creative instead of to copy other works. Portraiture, in comparison, became linked with the level of a mechanical exercise as opposed to a fine art. Michelangelo’s well known protest that he would not paint portraits because there were not enough ideally beautiful models is only one example of the dismissive attitude to portraiture that persisted among professional artist - even those who, ironically, made their living from portraiture. In the time of modernism, during the nineteenth and twentieth centuries, the attitude towards portraiture was critical. Even so, artists from around the globe persisted painting portraits in spite of their theoretical objections. Picasso, for instance, became renowned for cubist still-life painting early in his career, but some of his most effective early experiments in this new style were his portraits of art dealers.

## The British Economy under the Roman Empire

Following the Roman Empire conquering the area in the first century A.D., there is a great deal of archaeological evidence for the economic growth of the British Isles. Prior to this event, the economy of the British Isles, which was based on manufacturing, was centered mainly on the household and on craft skills, and where the best quality and greatest range of goods were largely a monopoly of the tribal aristocracies. This was the nature of the economy which lasted in regions of Britain that were unconquered by the Roman Empire, even though some Roman products were utilized in such areas. The majority of these Roman artifacts were glass vessels, pots, as well as small metal objects that were dispersed over a vast region. They perhaps held a symbolic value and were not necessarily used for their originally designed purposes. The spread of Roman objects beyond Roman Britain does not seem to have happened on an enormous scale. In areas where artifacts are more numerous, it is likely due to gift giving during close interactions between the Roman government and the tribes.

In regions that experienced direct economic control under the Romans, however, economic growth is clearly notable. There was an enormous increase in the number and variety of goods in circulation and the range of settlements in which they were found. This is clearly true in the overwhelming majority of excavated sites in Roman Britain, with the only exceptions being some rural regions that continued the pre-Roman, Iron Age pattern. The majority of sites resulted in the discovery of an abundance of iron, glass, and pottery, and good quantities of copper alloys, lead, tin, silver, and occasionally gold. For example, the humble iron nail is found in numbers not repeated until the Industrial Revolution.

The technology levels and range of the manufacturing of these objects also developed alongside the sheer increase in their quantity. During the Iron Age, the typical household objects were usually manufactured using a low technology of craft manufacture. Later, this changed to more specialized and larger-scale production methods. During this time, specialized workers could utilize equipment manufactured through time and resource investments. In these regions, small-scale workshops used by specialized craftsmen betoken full-time employment in this work. Regardless of the large increase in the scale of manufacturing, there is little evidence of major growth in the size of productive units. We are left with the impression of an economy still based on small-scale craft production.

Where we do see an important change is in the removal of any exclusive association between the best traditional craftsmen and the governing elite. The powerful could show off their status in new ways, particularly by using Roman architecture and domestic decoration, but the traditional classes of decorative metalwork manufacture no longer seem to have been under the control of the tribal leaders. Rich objects from a wide range of archaeological sites imply the deterioration of this monopoly. There are a number of contributing factors. The control of precious metals moved to the imperial government immediately after the conquest, and gold and silver were also removed from circulation when captured as booty during the invasion. Similarly, changes in taste and the fashions of wealth and status display were stimulated by the arrival of new things like Roman dress, architecture, and sculpture.

These changes in manufacture were accompanied by increased distances over which many goods were transported to their consumers. The bulk of pottery and other items originated locally, during the Iron Age; but after the Roman invasion, these objects had been produced over a far greater range of distances. In this way, vast regions of the Roman province were incorporated into a society where there was wide access to material wealth. New changes in manufacturing production were coupled with huge increase in the importation of goods from elsewhere in the empire. These commodities, which included Mediterranean foodstuffs such as olive oil as well as comparatively low-value objects such as decorated pottery, also achieved a wide distribution and are found in many different types of site.

## Southwest Agriculture

After the arrival of hunter-gatherers in the southwestern region of North America, several alternative types of agriculture emerged, all involving different solutions to the Southwest's fundamental problem: how to obtain enough water to grow crops in an environment in which rainfall is so low and unpredictable that little or no farming is practiced there today. People experimented with alternative strategies for almost a thousand years in different locations, and many experiments succeeded for centuries, but eventually all except one succumbed to environmental problems caused by human impact or climate change.

One strategy was to live at higher elevations where rainfall was higher, as did the Mogollon, the people at Mesa Verde, and the people of the early agricultural phase at Chaco Canyon known as the Pueblo I phase. But that carried a risk, because it is cooler at high than at low elevations, and in an especially cool year, it might be too cold to grow crops at all. An opposite extreme was to farm at the warmer low elevations, but there the rainfall is insufficient even for dryland agriculture. The Hohokam got around that problem by constructing the most extreme irrigation system in the Americas outside Peru. But irrigation entailed the risk that human digging of ditches and canals could lead to sudden heavy water runoff from rainstorms, digging further down into the ditches and canals and carving out deep channels called arroyos. In that case, the water level would drop below the field level, making irrigation impossible for people without pumps.

A more conservative strategy was to plant crops only in areas with reliable springs and groundwater tables. That was the solution initially adopted by the Mimbres and by people in the phase known as Pueblo II. However, it then became dangerously tempting to expand agriculture during wet decades with favorable growing conditions into marginal areas with less reliable springs and groundwater. The population multiplying in those marginal areas might then find itself unable to grow crops and might starve when the unpredictable climate turned dry again. That fate actually befell the Mimbres, who started by farming the floodplain and then began to farm adjacent land above the floodplain as their population came to exceed the floodplain's capacity to support it. They got away with their gamble during a wet climate phase, when they were able to obtain half their food outside the floodplain. However, when drought conditions returned, that gamble left them with a population double what the floodplain could support, and Mimbres society collapsed suddenly under the stress.

Still another solution was to occupy an area only for a few decades, until the area's soil became exhausted, then to move to another area. That method worked when people were living at low population densities, when there were many unoccupied areas to move to, and when each occupied area could be left unoccupied again for sufficiently long after occupation so that its vegetation and soil nutrients had time to recover. However, the method of shifting sites after a short occupation became impossible at high population densities, when people filled up the whole landscape and there was nowhere left empty to move to.

One more strategy was to plant crops at many sites even though rainfall was locally unpredictable and then to harvest crops at whichever sites did get enough rain to produce a good harvest and to redistribute some of the harvest to the people still living at all the sites that did not happen to receive enough rain that year. But redistribution was not without risks because it involved a complex political and social system to integrate activities between different sites, so when that complex system collapsed, lots of people ended up starving.

The remaining strategy was to plant crops and live near permanent or dependable sources of water, but on landscape benches above the main floodways, so as to avoid the risk of a heavy flood washing out fields and villages, and to practice a diverse economy, exploiting ecologically diverse zones so that each settlement would be self-sufficient. That solution, adopted by people whose descendents live today in the Southwest's Hopi and Zuni villages, has succeeded for more than a thousand years.

## Earth’s Energy Cycle

To understand most of the processes at work on Earth, it is useful to envisage interactions within the Earth system as a series of interrelated cycles. One of these is the energy cycle, which encompasses the great “engines”—the external and internal energy sources—that drive the Earth system and all its cycles. We can think of Earth’s energy cycle as a “budget”: energy may be added to or subtracted from the budget and may be transferred from one storage place to another, but overall the additions and subtractions and transfers must balance each other. If a balance did not exist, Earth would either heat up or cool down until a balance was reached.

The total amount of energy flowing into Earth’s energy budget is more than 174,000 terawatts (or 174,000 ×1012watts). This quantity completely dwarfs the 10 terawatts of energy that humans use per year. There are three main sources from which energy flows into the Earth system.

Incoming short-wavelength solar radiation overwhelmingly dominates the flow of energy in Earth’s energy budget, accounting for about 99.986 percent of the total. An estimated 174,000 terawatts of solar radiation is intercepted by Earth. Some of this vast influx powers the winds, rainfall, ocean currents, waves, and other processes in the hydrologic (or water) cycle. Some is used for photosynthesis and is temporarily stored in the biosphere in the form of plant and animal life. When plants die and are buried, some of the solar energy is stored in rocks, when we burn coal, oil, or natural gas, we release stored solar energy.

The second most powerful source of energy, at 23 terawatts or 0.013 percent of the total, is geothermal energy, Earth’s internal heat energy. Geothermal energy eventually finds its way to Earth’s surface, primarily via volcanic pathways. It drives the rock cycle and is therefore the source of the energy that uplifts mountains, causes earthquakes and volcanic eruptions, and generally shapes the face of the Earth.

The smallest source of energy for Earth is the kinetic (motion) energy of Earth’s rotation. The Moon’s gravitational pull lifts a tidal bulge in the ocean; as Earth spins on its axis, this bulge remains essentially stationary. As Earth rotates, the tidal bulge runs into the coastlines of continents and islands, causing high tides. The force of the tidal bulge *piling up* against land masses acts as a very slow brake, actually causing Earth’s rate of rotation to decrease slightly. The transfer of tidal energy accounts for approximately 3 terawatts, or 0.002 percent of the tidal energy budget.

Earth loses energy from the cycle in two main ways: reflection, and degradation and reradiation. About 40 percent of incoming solar radiation is simply reflected, unchanged, back into space by the clouds, the sea, and other surfaces. For any planetary body, the percentage of incoming radiation that is reflected is called the “albedo”. Each different material has a characteristic reflectivity. For example, ice is more reflectant than rocks or pavement; water is more highly reflectant than vegetation; and forested land reflects light differently than agricultural land. Thus, if large expanses of land are converted from forest to plowed land, or from forest to city, the actual reflectivity of Earth’s surface, and hence its albedo, may be altered. Any change in albedo will, of course, have an effect on Earth’s energy budget.

The portion of incoming solar energy that is not reflected back into space, along with tidal and geothermal energy, is absorbed by materials at Earth’s surface, in particular the atmosphere and hydrosphere. This energy undergoes a series of irreversible degradations in which it is transferred from one reservoir to another and converted from one form to another. The energy that is absorbed, utilized, transferred, and degraded eventually ends up as heat, in which form it is reradiated back into space as long-wavelength (infrared) radiation. Weather patterns are a manifestation of energy transfer and degradation.

## Sociality in Animals

Social insects represent the high point of invertebrate evolution. Some species live in communities of millions, coordinating their building and foraging, their reproduction, and their offspring care. Yet sociality is found in only a few species of insects, and is rare among vertebrates as well: wildebeest (large antelope) and lions are the exception rather than the rule. Nearly all fish, amphibians, reptiles, birds, and mammals are solitary, except when courting and mating. Birds and mammals usually rear their young, but year-round family groups are almost unknown, though they are intensely studied where they do exist. The same is true for insects.

We know, or think we know, that social groups are good. Wolves are better predators when they hunt in packs, and pigeons escape from falcons far more often when feeding in flocks. Group building projects—the dams beavers build to block a body of water that provides them with relative safety from predators and the lodges they build for shelter, for instance—can provide a high level of protection and comfort. Why, then, are social species so very rare? In fact, living socially presents inevitable problems that transcend habitat needs so that only when these costs are offset by corresponding benefits is group living a plus.

The most obvious cost is competition. All the members of a species share the same habitat; when they live together, they are trying to eat the same food and occupy the same nesting sites. In general, there is far less competition away from a group, and selection should favor any individual who (all things being equal) sets off on its own, leaving the members of its group behind to compete among themselves for limited resources. Another difficulty is that concentrations of individuals facilitate disease and parasite transmission. On the whole, social animals carry more parasites and species-specific diseases than do solitary animals. Parasites and diseases diminish the strength and limit the growth of animals, and among highly social creatures, epidemics can devastate whole populations. Distemper (a viral disease) has been known to wipe out entire colonies of seals, for instance. So the penalty of social life is potentially huge.

But in some instances, the payoffs can be even greater. Two have already been mentioned: cooperative hunting and defensive groups. Social hunting is likely to evolve where prey is too large to be taken by individuals operating alone. To capture wildebeest some members of a group of lions follow their prey and herd them toward others lying in ambush. In other species, individuals forage or hunt simultaneously and share the food. Vampire bats that have had a bad day, for instance, are fed by more successful members of the community, but they are expected to return the favor in the future. Cooperation can even involve sharing information about the location of food. Some colonial birds, such as bank swallows, use the departure direction of a successful forager (food hunter) to locate concentrations of prey. Information transfer can be unintentional though some species make use of special assembly calls or behavior.

Cooperation in group defense, such as we see in circles of musk oxen or elephants, is quite rare among vertebrates but is prevalent among the social insects. The strategy of employing many eyes to watch for danger, on the other hand, is widespread in birds and mammals. A herd of gazelles (small antelope) is far more likely to spot a lurking lion or a concealed cheetah than is a lone individual, and at a greater distance. In fact, a group enters into a kind of time-sharing arrangement in which individual antelope alternate biting off a mouthful of grass with a period of erect and watchful chewing. A larger group can afford more bites per individual per minute, there being more eyes to scan for danger. For a small antelope living in a forest where visibility is limited, however, remaining hidden is probably a better bet than assembling into noisy herds.

Among the millions of species of insects, only a few thousand are social. Those rarities are generally confined to termites and Hymenoptera. All termites are social: their diet (cellulose) requires that each generation feed a special kind of bacteria or fungi to the next generation to aid in its digestion. Of the numerous hymenopterans, some are social—including all ants and a few bees and wasps—but many are solitary.

## Understanding Ancient Mesoamerican Art

Starting at the end of the eighteenth century and continuing up to the present, explorers have searched for the ruins of ancient Mesoamerica, a region that includes Central America and central and southern Mexico. With the progress of time, archaeologists have unearthed civilizations increasingly remote in age. It is as if with each new century in the modern era an earlier stratum of antiquity has been revealed. Nineteenth-century explorers, particularly John Lloyd Stephens and Frederick Catherwood, came upon Maya cities in the jungle, as well as evidence of other Classic cultures. Twentieth- century research revealed a much earlier high civilization, the Olmec. It now scarcely seems possible that the frontiers of early Mesoamerican civilization can be pushed back any further, although new work—such as in Oaxaca, southern Mexico—will continue to fill in details of the picture.

The process of discovery often shapes what we know about the history of Mesoamerican art. New finds are just as often made accidentally as intentionally. In 1971 workers installing sound and light equipment under the Pyramid of the Sun at Teotihuacan stumbled upon a remarkable cave that has since been interpreted by some scholars as a royal burial chamber. Archaeology has its own fashions too: the isolation of new sites may be the prime goal in one decade and the excavation of pyramids the focus in the next. In a third decade, outlying structures rather than principal buildings may absorb archaeologists' energies. Nor should one forget that excavators are vulnerable to local interests. At one point, reconstruction of pyramids to attract tourism may be desired; at another, archaeologists may be precluded from working at what has already become a tourist attraction. Also, modern construction often determines which ancient sites can be excavated. In Mexico City, for example, the building of the subway initiated the excavations there and renewed interest in the old Aztec capital.

But the study of Mesoamerican art is not based exclusively on archaeology. Much useful information about the native populations was written down in the sixteenth century, particularly in central Mexico, and it can help us unravel the pre- Columbian past (the time prior to the arrival of Columbus in the Americas in 1492). Although many sources exist, the single most important one to the art historian is Bernardino de Sahagún's General History of the Things of New Spain. A Franciscan friar (member of the Roman Catholic religious order), Sahagún recorded for posterity many aspects of pre- Hispanic life in his encyclopedia of twelve books, including history, ideology, and cosmogony (theories of the origin of the universe), as well as detailed information on the materials and methods of the skilled native craft workers. Furthermore, traditional ways of life survive among the native peoples of Mesoamerica, and scholars have increasingly found that modern practice and belief can decode the past. Remarkably, some scholars have been turned this process around, teaching ancient writing to modern peoples who may use it to articulate their identity in the twenty-first century.

During the past 40 years, scholars also have made great progress in deciphering and interpreting ancient Mesoamerican writing systems, a breakthrough that has transformed our understanding of the pre-Columbian mind. Classic Maya inscriptions, for example— long thought to record only calendrical information and astrological incantations—can now be read, and we find that most of them glorify family and ancestry by displaying the right of individual sovereigns to rule. The carvings can thus be seen as portraits or public records of dynastic power. Although scholars long believed that Mesoamerican artists did not sign their works, Mayanist scholar David Stuart's 1986 deciphering of the Maya glyphs (written symbols) for "scribe" and "to write" opened a window on Maya practice; now we know at least one painter of ceramic vessels was the son of a king. Knowledge of the minor arts has also come in large part through an active art market. Thousands more small-scale objects are known now than in the twentieth century, although at a terrible cost to the ancient ruins from which they have been plundered.

## The Emergence of Civilization

Starting around 8000 B.C.E., the most extensive exploitation of agriculture occurred in river valleys, where there were both good soil and a dependable water supply regardless of the amount of rainfall. In the Near East, this happened in the Fertile Crescent, the region extending up the Nile Valley in Egypt, north through the Levant (Palestine, Lebanon, and Syria), and southeast into the Tigris and Euphrates river valleys of Mesopotamia. The richest soil was located in the deltas at the mouths of the rivers, but the deltas were swampy and subject to flooding. Before they could be farmed, they needed to be drained and irrigated, and flood-control systems had to be constructed. These activities required administrative organization and the ability to mobilize large pools of labor. In Mesopotamia, perhaps as a consequence of a period of drought, massive land-use projects were undertaken after 4000 B.C.E. to cultivate the rich delta soils of the Tigris and Euphrates Rivers. The land was so productive that many more people could be fed, and a great population explosion resulted. Villages grew into cities of tens of thousands of persons.

These large cities needed some form of centralized administration. Archaeological evidence indicates that the organization initially was provided by religion, for the largest building in each city was a massive temple honoring one of the Mesopotamian gods. In Uruk, for example, a 60-foot-long temple known as the White House was built before 3000 B.C.E. There were no other large public buildings, suggesting that the priests who were in charge of the temples also were responsible for governing the city and organizing people to work in the fields and on irrigation projects building and maintaining systems of ditches and dams.

The great concentration of wealth and resources in the river valleys brought with it further technological advances, such as wheeled vehicles, multicolored pottery and the pottery wheel, and the weaving of wool garments. Advances in metal technology just before 2000 B.C.E. resulted in the creation of bronze, a durable alloy (or mixture) of about 90 percent copper and 10 percent tin that provided a sharp cutting edge for weapons.

By 3000 B.C.E., the economies and administrations of Mesopotamia and Egypt had become so complex that some form of record keeping was needed. As a result, writing was invented. Once a society became literate, it passed from the period known as prehistory into the historic period. In fact, the word "history" comes from a Greek word meaning "narrative"— people could not provide a detailed permanent account of their past until they were able to write.

The totality of these developments resulted in the appearance, around 3000 B.C.E., of a new form of culture called civilization. The first civilizations had several defining characteristics. They had economies based on agriculture. They had cities that functioned as administrative centers and usually had large populations. They had different social classes, such as free persons and slaves. They had specialization of labor, that is, different people serving, for example, as rulers, priests, craft workers, merchants, soldiers, and farmers. And they had metal technology and a system of writing. As of 3000 B.C.E., civilization in these terms existed in Mesopotamia, Egypt, India, and China.

This first phase of civilization is called the Bronze Age because of the importance of metal technology. The most characteristic Near Eastern Bronze Age civilizations, those of Mesopotamia and Egypt, were located in river valleys, were based on the extensive exploitation of agriculture, and supported large populations. Bronze was a valuable commodity in these civilizations, the copper and tin needed for its manufacture did not exist in river valleys and had to be imported. Bronze was therefore used mainly for luxury items, such as jewelry or weapons, not for everyday domestic items, which were made from pottery, animal products, wood, and stone. In particular, bronze was not used for farming tools. Thus, early civilizations based on large-scale agriculture, such as those of Mesopotamia and Egypt, were feasible only in soils that could be worked by wooden plows pulled by people or draft animals such as oxen. Other Bronze Age civilizations, however, such as those that arose in the Levant and eastern Mediterranean took advantage of their location on communication routes to pursue economies based on trade.

## Written Records

For those ancient civilizations that used writing—for instance, all the great civilizations in Mesoamerica, China, Egypt, and the Near East—written historical records can answer many social questions. A prime goal of the archaeologist studying these societies is therefore to find appropriate texts. Many of the early excavations of the great sites of the Near East had the recovery of clay writing tablets as the main goal. Major finds of this kind are still being made—for example, at the ancient city of Ebla (Tell Mardikh) in Syria, where an archive of 5,000 clay tablets written in an early dialect of Akkadian (Babylonian) was discovered in the 1970s.

In each early literate society, writing had its own function and purpose. For instance, the clay tablets of Mycenaean Greece, dating from around 1200 B.C., were all, without exception, primarily records of commercial transactions (goods coming in or going out) at the Mycenaean palaces. This discovery gives us an impression of many aspects of the Mycenaean economy and a glimpse into craft organization (through the names for the different kinds of craftspeople), as well as introducing the names of the offices of state. But here, as in other cases, accidents of preservation may be important. It could be that the Mycenaeans wrote on clay only for their commercial records and used other perishable materials for literary or historical texts now lost to us. It is certainly true that for the Classical Greek and Roman civilizations, it is mainly official decrees inscribed on marble that have survived. Fragile rolls of papyrus—the predecessor of modern paper—with literary texts on them, have usually remained intact only when retained in the dry air of Egypt, or when buried beneath the volcanic ash covering Pompeii.

Coins also provide a valuable source of written records: they can reveal information about the location where they are found, which can provide evidence about trade practices there, and their inscriptions can be informative about the issuing authority, whether they were city-states (as in ancient Greece) or sole rulers (as in Imperial Rome or in the kingdoms of medieval Europe).

In recent years, one of the most significant advances in Mesoamerican archaeology has come from deciphering many of the inscribed symbols (glyphs) on the stone stelae (pillars or columns) at the largest centers. It had been widely assumed that the inscriptions were exclusively of a calendrical nature or that they dealt with purely religious matters, notably the deeds of the gods. But the inscriptions can now in many cases be interpreted as relating to real historical events, mainly the deeds of the Maya kings. We can now also begin to deduce the likely territories belonging to individual Maya centers. Maya history has thus taken on a new dimension.

Written records undoubtedly contribute greatly to our knowledge of the society in question. But one should not accept them uncritically at face value. Nor should one forget the bias introduced by the accidents of preservation and the particular uses of literacy in a society. The great risk with historical records is that they can impose their own perspective so that they begin not only to supply the answers to our questions but subtly to determine the nature of those questions and even our concepts and terminology. A good example is the question of kingship in Anglo-Saxon England. Most anthropologists and historians tend to think of a king as the leader of a state society. Therefore, when the earliest records for Anglo-Saxon England, found in the Anglo-Saxon Chronicle, which took final shape in about A.D. 1155, refer to kings around A.D. 500, it is easy for the historian to think of kings and states at that period. But the archaeology strongly suggests that a full state society did not emerge until the time of King Offa of Mercia in around A.D. 780, or perhaps King Alfred of Wessex in A.D. 871. It is fairly clear that the earlier so-called kings were generally less significant figures than some of the rulers in either Africa or Polynesia in recent times, whom anthropologists would term ”chiefs”.

## The Origin of Earth's Atmosphere

In order to understand the origin of Earth's atmosphere, we must go back to the earliest days of the solar system, before the planets themselves were formed from a disk of rocky material spinning around the young Sun. This material gradually coalesced into lumps called planetesimals as gravity and chance smashed smaller pieces together, a chaotic and violent process that became more so as planetesimals grew in size and gravitational pull. Within each orbit, collisions between planetesimals generated immense heat and energy. How violent these processes were is suggested by the odd tilt and spin of many of the planets, which indicate that each of the planets was, like a billiard ball, struck at some stage by another large body of some kind. Visual evidence of these processes can be seen by looking at the Moon.

Because the Moon has no atmosphere, its surface is not subject to erosion, so it retains the marks of its early history. Its face is deeply scarred by millions of meteoric impacts, as you can see on a clear night with a pair of binoculars. The early Earth did not have much of an atmosphere. Before it grew to full size, its gravitational pull was insufficient to prevent gases from drifting off into space, while the solar wind (the great stream of atomic particles emitted from the Sun) had already driven away much of the gaseous material from the inner orbits of the solar system. So we must imagine the early Earth as a mixture of rocky materials, metals, and trapped gases, subject to constant bombardment by smaller planetesimals and without much of an atmosphere.

As it began to reach full size, Earth heated up, partly because of collisions with other planetesimals and partly because of increasing internal pressures as it grew in size. In addition, the early Earth contained abundant radioactive materials, also a source of heat. As Earth heated up, its interior melted. Within the molten interior, under the influence of gravity, different elements were sorted out by density. By about 40 million years after the formation of the solar system, most of the heavier metallic elements in the early Earth, such as iron and nickel, had sunk through the hot sludge to the center, giving Earth a core dominated by iron. This metallic core gives Earth its characteristic magnetic field, which has played an extremely important role in the history of our planet.

As heavy materials headed for the center of Earth, lighter silicates (such as the mineral quartz) drifted upward. The denser silicates formed Earth's mantle, a region almost 3,000 kilometers thick between the core and the crust. With the help of bombardment by comets, whose many impacts scarred and heated Earth's surface, the lightest silicates rose to Earth's surface, where they cooled more rapidly than the better-insulated materials in Earth's interior. These lighter materials, such as the rocks we call granites, formed a layer of continental crust about 35 kilometers thick. Relative to Earth as a whole, this is as thin as an eggshell. Seafloor crust is even thinner, at about 7 kilometers; thus, even continental crust reaches only about 1/200th of the way to Earth's core. Much of the early continental crust has remained on Earth's surface to the present day.

The lightest materials of all, including gases such as hydrogen and helium, bubbled through Earth's interior to the surface. So we can imagine the surface of the early Earth as a massive volcanic field. And we can judge pretty well what gases bubbled up to that surface by analyzing the mixture of gases emitted by volcanoes. These include hydrogen, helium, methane, water vapor, nitrogen, ammonia, and hydrogen sulfide. Other materials, including large amounts of water vapor, were brought in by cometary bombardments. Much of the hydrogen and helium escaped; but once Earth was fully formed, it was large enough for its gravitational field to hold most of the remaining gases, and these formed Earth's first stable atmosphere.

## Historical Trends in European Urban Design

European city planning and design have a long history. Most Greek and Roman settlements were deliberately laid out on the grid system, within which the siting of key buildings was carefully thought out. The roots of modern Western urban planning and design can be traced to the Renaissance and Baroque periods (between the fifteenth and seventeenth centuries) in Europe, when artists and intellectuals dreamed of ideal cities, and rich and powerful regimes used urban design to produce extravagant symbolizations of wealth, power, and destiny. Inspired by the classical art forms of ancient Greece and Rome, Renaissance urban design sought to recast cities in a deliberate attempt to show off the power and the glory of the state and church.

Spreading slowly from its origins in Italy at the beginning of the fifteenth century, Renaissance design successfully diffused to most of the larger cities of Europe. Dramatic advances in weaponry brought a surge of planned redevelopment that featured impressive geometric-shaped fortifications and an extensive sloping, clear zone of fire. Inside new walls, cities were recast according to a new aesthetic of grand design fancy palaces, geometrical plans, streetscapes, and gardens that emphasized views of dramatic perspectives. These developments were often so extensive and so interconnected with each other that they effectively fixed the layout of cities well into the eighteenth, and even into the nineteenth, century, when walls and/or open spaces eventually made way for urban redevelopment in the form of parks, railway lines, or beltways.

As societies and economies became more complex with the transition to industrial capitalism, national rulers and city leaders looked to urban design to impose order, safety, and efficiency, as well as to symbolize the new seats of power and authority. The most important early precedent was set in Paris by Napoleon III, who presided over a comprehensive program of urban redevelopment and monumental urban design. The work was carried out by Baron Georges-Eugene Haussmann between 1853 and 1870. Haussmann demolished large sections of old Paris to make way for broad, new, tree-lined avenues, with numerous public open spaces and monuments. In doing so, he made the city not only more efficient (wide boulevards meant better flows of traffic) and a better place to live (parks and gardens allowed more fresh air and sunlight in a crowded city and were held to be a civilizing influence) but also safer from revolutionary politics (wide boulevards were hard to barricade; monuments and statues helped to instill a sense of pride and identity).

The preferred architectural style for these new designs was the Beaux Arts style. In this school, architects were trained to draw on Classical, Renaissance, and Baroque styles, synthesizing them in designs for new buildings for the Industrial Age. The idea was that the new buildings would blend artfully with the older palaces, cathedrals, and civic buildings that dominated European city centers. Haussmann's ideas were widely influential and extensively copied.

Early in the twentieth century there emerged a different intellectual and artistic reaction to the pressures of industrialization and urbanization. This was the Modern movement, which was based on the idea that buildings and cities should be designed and run like machines. Equally important to the Modernists was that urban design should not simply reflect dominant social and cultural values but, rather, help to create a new moral and social order. The movement's best-known advocate was Le Corbusier, a Paris-based Swiss who provided the inspiration for technocratic urban design. Modernist buildings sought to dramatize technology, exploit industrial production techniques, and use modern materials and unembellished, functional design. Le Corbusier's ideal city featured linear clusters of high-density, medium-rise apartment blocks, elevated on stilts and segregated from industrial districts; high-rise tower office blocks; and transportation routes all separated by broad expanses of public open space.

After 1945 this concept of urban design became pervasive, part of what became known as the International Style: boxlike steel-frame buildings with concrete-and-glass facades. The International Style was avant-garde yet respectable and, above all, comparatively inexpensive to build. This tradition of urban design, more than anything else, has imposed a measure of uniformity on cities around the world.

## How Soil is Formed

Soil formation is a dynamic process that takes place in different environments. It is strongly influenced by the parent material, climate (largely vegetation and temperature and water exchanges), topography (the elevations, depressions, directions and angles of slopes, and other surface features of the landscape), and time.

The parent material is the unconsolidated mass on which soil formation takes place. This material may or may not be derived from the on-site geological substrate or bedrock on which it rests. Parent materials can be transported by wind, water, glaciers, and gravity and deposited on top of bedrock. Because of the diversity of materials involved, soils derived from transported parent materials are commonly more fertile than soils from parent materials derived in place. Whatever the parent material, whether derived in place from bedrock or from transported material, it ultimately comes from geological materials, such as igneous, sedimentary, and metamorphic rocks, and the composition of the rocks largely determines the chemical composition of the soil.

Climate is most influential in determining the nature and intensity of weathering and the type of vegetation that further affects soil formation. The soil material experiences daily and seasonal variations in heating and cooling. Open surfaces exposed to thermal radiation undergo the greatest daily fluctuations in heating and cooling, soils covered with vegetation the least. Hill slopes facing the sun absorb more heat than those facing away from the sun. Radiant energy has a pronounced effect on the moisture regime, especially the evaporative process and dryness. Temperature can stimulate or inhibit biogeochemical reactions in soil material.

Water is involved in all biogeochemical reactions in the soil because it is the carrier of the acids that influence the weathering process. Water enters the soil material as a liquid and leaves it as a liquid by percolation (the slow movement of water through the soil's pores) and as a gas through evaporation. The water regime—the water flow over a given time— in soil material is sporadic, and in many parts of the Earth is highly seasonal. Water that enters the soil during heavy rainfall and snowmelt moves down through the soil. As it moves, it leaves behind suspended material and may carry away mineral matter in solution, a process called leaching. On sloping land, water distributes material laterally (sideways) through the soil.

Topography is a major factor in soil development. More water runs off and less enters the soil on steep slopes than on relatively level land. Water draining from slopes enters the soil on low and flat land. Thus soils and soil material tend to be dry on slopes and moist on wet on the low land. Steep slopes are subject to surface erosion and soil creep—the downslope movement of soil material, which accumulates on lower slopes and lowlands. Vegetation, animals, bacteria, and fungi all contribute to the formation of soil. Vegetation, in particular, is responsible for organic material in the soil and influences its nutrient content. For example, forests store most of their organic matter on the surface, whereas in grasslands most of the organic matter added to the soil comes from the deep fibrous root systems. Organic acids produced by vegetation accelerate the weathering process.

The weathering of rock material and the accumulation, decomposition, and mineralization or organic material require considerable time. Well-developed soils in equilibrium with weathering, erosion, and biotic influences may require 2,000 to 20,000 years for their formation, but soil differentiation from parent material may take place in as short a time as 30 years. Certain acid soils in humid regions develop in 2,000 years because the leaching process is speeded by acidic materials. Parent materials heavy in texture require a much longer time to develop into soils because of an impeded downward flow of water. Soils develop more slowly in dry regions than in humid ones. Soils on steep slopes often remain poorly developed regardless of geological age because rapid erosion removes soil nearly as fast as it is formed. Floodplain soils age little through time because of the continuous accumulation of new materials. Such soils are not deeply weathered and are more fertile than geologically old soils because they have not been exposed to the leaching process as long. The latter soils tend to be infertile because of long-time leaching of nutrients without replacement from fresh material.

## Hunting and the Setting of Inner Eurasia

Inner Eurasia refers to the large continental area extending from Russia in the west to the Pacific Ocean, and to the north of Iran, India, and most of China. The first systematic colonization of parts of Inner Eurasia occurred about 80,000 to 90,000 years ago, which is relatively late in human history compared with Africa, Europe, and southern Asia. Why was it difficult to settle?

The long, cold, arid winters of this region's steppes (grass covered plains) poised two distinctive problems for human settlers. The first was hot to keep warm. Humans may have used fire even a million years ago. Presumably their ability to scavenge animal carcasses meant that they could use skins or furs for warmth. However, there are no signs of hearths before about 200,000 years ago. This suggests that humans used fire opportunistically and had not yet domesticated it enough to survive the harsh winters of Ice Age Inner Eurasia.

The second, even trickier problem was getting food during the long winters. It was not that Inner Eurasia lacked sources of food. The problem was that the food was of the wrong kind, and it was not always available. Humans could not exploit the abundant grasses of the steppes, and most of the edible plants died off in winter. So, for long periods of each year, it was necessary to rely mainly on meat. However, hunting is a more difficult, dangerous, and unreliable way of life than gathering. Animals, unlike plants, can evade predators and may even fight back. Hunters must also cover more ground than gatherers.

Setting Inner Eurasia meant overcoming these difficulties. Systematic and reliable hunting methods meant more than the development of new technologies, they also demanded new social structures. According to the formulation of archaeologist Lewis Binford, in a typical hunter/collector food-gathering strategy parties of hunters leave camps with very specific goals in mind, based on intimate knowledge of their intended prey. They may by away for days or weeks at a time and will often store their kill at specific storage sites, from which they will bring food back to a base camp when needed. As a result, they move their base camps less often than in forager societies, but they range more widely, their movements are more carefully planned, and so are their methods of storage.

Thus, hunters have to plan in advance and in great detail. They need reliable information about the movements and habits of animal prey over large areas, which can be secured only by maintaining regular contacts with neighboring groups. Finally, they need reliable methods of storage because, where plant foods cannot provide a dietary safety net, planning has  to be precise and detailed to ensure that there is enough to tide them over in periods of shortage. Such planning appears in the choice of hunting gear, in the selection of routes and prey, in the choice of companions and timing, in the maintenance of communications with neighbors, and in the methods of storage. Failure at any point can be fatal for the entire group.

Hunting strategies also imply greater social complexity. The regular exchange of information and sometimes of material goods is critical not only within groups, but also between groups scattered over large distances. This increases the importance of symbolic exchanges of both goods and information, and makes it necessary to clarify group identity. Internally, groups may split for long periods as hunting parties travel over great distances. All in all, each group has to exist and survive in several distinct configurations.

For these reasons, archaeologist Clive Gamble has argued that the difficulties of setting the Eurasian heartland arose less from the technological than from the social and organizational features of human communities before 120,000 years ago. There is little or no archaeological evidence that these communities engaged in such practices as detailed planning or widespread contacts. Nor is there any physical evidence for storage, raw materials all come from within a radius of 50 kilometers—and usually less than 5 kilometers—of the sites where they were used.

## How Herding Can Provide Safety

In open grasslands there is no place for a large animal to hide. Thus a watchful grazing animal will see the slight movement that betrays the presence of a predator long before it is close enough to launch an attack. It sounds as though the hunters (predators) stand no chance at all. Unfortunately for the grazers, life is not so simple, however. A grazing animal must lower its head and look at the ground to feed. Its attention may be occupied for only a few seconds before it raises its head and resumes its watch while chewing the food it took, but hunters are patient and skillful and are concentrating intensely. Those few seconds provide time enough to advance a few steps and then freeze, body flattened against the ground. It may take hours, but eventually these repeated small advances will put the hunter within range— close enough to outrun its prey—and the long time the hunt has taken will have been worthwhile, because the resulting feast will be highly nutritious.

Clearly the grazers are at a disadvantage, because while they eat they are vulnerable to attack. The hunters also have a weakness, however, and it is one that allows the grazers to survive. Hunters can attack only one prey animal at a time. This applies even to the predators that hunt as a team, such as lionesses, wolves, and hunting dogs. Their hunt involves running down or ambushing an individual. Teamwork allows them to hunt animals much bigger and stronger than themselves and to hunt more successfully, but it does not allow them to attack more than one individual at a time.

The grazers exploit this weakness by making it as difficult as they can for the predators to choose an individual as a target. They do not graze alone, scattered widely across the landscape, but together, as a herd. The approaching hunter sees not a solitary animal, but a crowd of animals, all of them moving, so they are constantly crossing and recrossing each other’s paths. No sooner does the hunter choose an individual than another animal has crossed in front of it and the target has disappeared into the herd. From the hunter’s point of view this is highly confusing behavior—as, indeed, it is meant to be.

There is another advantage to the grazers. A herd is much more alert than a solitary animal. An animal has to relax its guard while it is taking food, but in a herd there are at any time some animals with their heads down, biting, and others, with their heads up, watching. What is more, those with their heads up are looking in different directions so that together they are alert to any movement anywhere on the landscape around them. There is no way for a hunter to approach a herd unobserved. When a member of the herd spots trouble, it starts to move away. Other members of the herd move with it and the entire herd starts to move. If the trouble is serious and close, the herd will run. The individual raising the alarm is simply protecting itself, but in doing so it is warming all of the others.

Herding is highly successful, provided members of the herd stay together in a tight bunch. The hunter moves with the herd, watching for an individual to wander away from the others. When that happens, it tries to move between that individual and the rest of the herd, preventing it from rejoining. Once it has done that the hunter has a good chance of making a kill. If the herd starts to run, a solitary hunter may abandon the chase, but a pack of wolves or hunting dogs will regard the running herd of animals as an opportunity and set off in pursuit. As the herd runs, one or two old or sick animals, or young animals that become separated from their mothers, may fall behind.

As soon as the hunter or hunters seize their prey, they lose interest in all other grazers since then they, too, must concentrate on eating, at which point the herd stops running, those who were left behind rejoin the group, and they all resume grazing.

## Water Management in Early Agriculture

As the first cities formed in Mesopotamia in the Middle East, probably around 3000 B.C., it became necessarily to provide food for larger populations, and thus to find ways of increasing agricultural production. This, in turn, led to the problem of obtaining sufficient water.

Irrigation must have started on a small scale with rather simple constructions, but as its value became apparent, more effort was invested in new construction to divert more water into the canals and to extend the canal system to reach greater areas of potential farmland. Because of changing water levels and clogging by waterborne particles, canals and their intakes required additional labor to maintain, besides the normal labor required to guide water from field to field. Beyond this, some personnel had to be devoted to making decisions about the allocation of available water among the users and ensuring that these directions were carried out. With irrigation water also came potential problems, the most obvious being the susceptibility of low-lying farmlands to disastrous flooding and the longer-term problem of salinization (elevated levels of salt in the soil). To combat flooding from rivers, people from early historic times until today have constructed protective levees (raised barriers of earth) between the river and the settlement or fields to be protected. This, of course, is effective up to a certain level of flooding but changes the basic water patterns of the area and can multiply the damage when the flood level exceeds the height of the levee.

Salinization is caused by an accumulation of salt in the soil near its surface. This salt is carried by river water from the sedimentary rocks in the mountains and deposited on the Mesopotamian fields during natural flooding or purposeful irrigation. Evaporation of water sitting on the surface in hot climates is rapid, concentrating the salts in the remaining water that then descends through the soil to the underlying water table. In southern Mesopotamia, for example, the natural water table comes to within roughly six feet of the surface. Conditions of excessive irrigation bring the water table to eighteen inches, and water can rise further to the root zone, where the high concentration of salts would kill most plants.

Solutions for salinization were not as straightforward as for flooding, but even in ancient times it was understood that the deleterious effects of salinization could be minimized by removing harmful elements through leaching the fields with additional fresh water, digging deep wells to lower the water table, or instituting a system of leaving fields uncultivated. The first two cures would have required considerable labor, and the third solution would have led to diminished productivity, not often viewed as a likely decision in periods of growing population. An effective irrigation system laid the foundation for many of the world's early civilizations, but it also required a great deal of labor input.

Growing agrarian societies often tried to meet their food-producing needs by farming less-desirable hill slopes surrounding the favored low-lying valley bottoms. Since bringing irrigation water to a hill slope is usually impractical, the key is effective utilization of rainfall. Rainfall either soaks into the soil or runs off of it due to gravity. A soil that is deep, well-structured, and covered by protective vegetation and much will normally absorb almost all of the rain that falls on it, provided that the slope is not too steep. However, soils that have lost their vegetative cover and surface mulch will absorb much less, with almost half the water being carried away by runoff in more extreme conditions. This runoff carries with it topsoil particles, nutrients, and humus (decayed vegetable matter) that are concentrated in the topsoil. The loss of this material reduces the thickness of the rooting zone and its capacity to absorb moisture for crop needs.

The most direct solution to this problem of slope runoff was to lay lines of stones along the contours of the slope and hence, perpendicular to the probable flow of water and sediment. These stones could then act as small dams, slowing the downhill flow of water and allowing more water to infiltrate and soil particles to collect behind the dam. This provided a buildup of sediments for plants and improved the landscape's water-retention properties.

## Origins of the Megaliths

Since the days of the earliest antiquarians, scholars have been puzzled by the many Neolithic (from 4000 B.C. to 2200 B.C.) communal tombs known as megaliths along Europe's Atlantic seaboard. Although considerable variations are found in the architectural form of these impressive monuments, there is a general overriding similarity in design and, particularly, in the use of massive stones.

The construction of such large and architecturally complex tombs by European barbarians struck early prehistorians as unlikely. The Bronze Age seafaring civilizations that lived in the region of the Aegean Sea (from 3000 B.C. to 1000 B.C.), among whom collective burial and a diversity of stone-built tombs were known, seemed a probable source of inspiration. It was suggested that Aegean people had visited Iberia in southwestern Europe in search of metal ores and had introduced the idea of collective burial in massive tombs, which then spread northward to Brittany, Britain, North Germany, and Scandinavia.

Radiocarbon dates for a fortified settlement of megalith builders at Los Millares in Spain appeared to confirm this picture, though dates for megaliths in Brittany seemed too early. When calibrated, however, it became clear that radiocarbon dates were universally too early to support a Bronze Age Aegean origin. It is now clear that the megaliths are a western and northern European invention, not an introduced idea. Even so, they are still a subject of speculation and inquiry. What induced their builders to invest massive efforts in erecting such monumental tombs? How was the necessary labor force assembled? What underlies their striking similarities?

One answer to the last question was proposed by Professor Grahame Clark, one of Britain's greatest prehistorians. Investigating the megaliths of southern Sweden, he noted that one group was concentrated in coastal locations from which deep-sea fish such as cod, haddock, and ling could have been caught in winter. Historically, much of the Atlantic was linked by the travels of people who fished, and this could well have provided a mechanism by which the megalith idea and fashions in the style of tomb architecture spread between coastal Iberia, Brittany, Ireland, western England and Scotland, and Scandinavia. The high concentrations of megaliths on coasts and the surprising number of megaliths found on small islands may support a connection with fishing.

Professor Colin Renfrew of the University of Cambridge, England, however, views the similarities as similar responses to similar needs. At the structural level, the passage that forms a major element of many graves could have been devised independently in different areas to meet the need for repeated access to the interior of these communal tombs. Other structural resemblances could be due to similarities in the raw materials available. In answer to the question of why the idea of building monumental tombs should arise independently in a number of areas, he cites the similarities in their backgrounds.

Most megaliths occur in areas inhabited in the postglacial period by Mesolithic hunter-gatherers (8500 B.C. to 4000 B.C.). Their adoption of agriculture through contact with Neolithic farmers, Renfrew argues, led to a population explosion in the region and consequent competition for farmland between neighboring groups. In the face of potential conflict, the groups may have found it desirable to define their territories and emphasize their boundaries. The construction of megaliths could have arisen in response to this need.

Renfrew has studied two circumscribed areas, the Scottish islands of Arran and Rousay, to examine this hypothesis more closely. He found that a division of the arable land into territories, each containing one megalith, results in units that correspond in size to the individual farming communities of recent times in the same area. Each unit supported between 10 and 50 people. The labor needed to put up a megalith would probably be beyond the capabilities of a community this size. But Renfrew argues that the cooperation of other communities could be secured by some form of recognized social incentive perhaps a period of feasting at which communal building was one of several activities.

Most megaliths contain collective burials. Different tombs used different arrangements, but there seems to have been an underlying theme: people placed in these tombs were representative of their society, but their identity as individuals was not important. The tombs belonged to the ancestors, through whom the living society laid claim to their land. This interpretation reinforces Renfrew's view of the megaliths as territorial markers.

## Reconstructing Ancient Environments

A stage that is imperative in any archaeological process is the reconstruction of the physical environments in which a particular segment of the archaeological record was formed. Climates and the world's geomorphology the shape and constituents of land surfaces have changed greatly over the past several million years of human history, and each archaeological analysis begins with an effort to reconstruct the physical world of the culture being analyzed.

Ancient climates can often be reconstructed from floral and faunal remains. The study of animal remains, or faunal analysis, is a complex field in which, in most cases, the archaeologist is trying to reconstruct human diet and local environments. Faunal analysts usually count the numbers and kinds of animals represented by the remains they find, and then use statistical methods to estimate the food values, ages, and sexes of the animals being exploited. The prehistoric record of the meat-eating habits of early humans is far from clear about the prevalence of scavenging. One faction of prehistorians argues there is evidence that early humans were primarily scavengers who found the remains of animals killed by lions and other carnivores, and butchered them. Another faction disagrees and proposes that early humans hunted for their own meat. Marks left by humans cutting up animals with stone tools are now being analyzed to help distinguish between cases in which people butchered animals they had killed themselves and those in which they butchered animals they scavenged from kills of other animals.

Throughout human history, plants have been our main source of food, and so floral analyses studies of the remains of plants are an extremely important part of archaeology, particularly in studies of how domesticated plants and animals and agricultural economies evolved. Carbon is chemically quite stable, so charred plants (plants converted to charcoal or carbon) and seeds preserve well. Carbonized plant remains can be retrieved by flotation: excavated sediments are mixed with water or some other fluid and the charred plant fragments rise to the surface, where they can be skimmed off and identified. The importance of such analyses lies in the fact that these plants indicate much about the climates and vegetation of the periods in which the animals lived. For example, there are debates about when and where various animals were domesticated. If phytoliths (tiny mineral particles formed inside plants) of domesticated grains are found on the teeth of these animals, the probability is high that they were part of an agricultural economy.

Human bodies are also valuable sources of information for archaeologists, particularly if the bodies are well preserved. For example, eleven naturally mummified bodies were found in beach sand in northern Chile and date to about 1000 B.C. When they were analyzed, it was found that one of them was a coca leaf chewer (the earliest known), while other bodies showed the changes of the bones of the inner ear that are characteristic of people who spend a lot of time diving in cold water. In addition, they had the kinds of dental problems and missing teeth associated with the sticky starches of an agricultural diet although about 40 percent of their diet came from marine resources.

A rapidly growing technical specialty within archaeology is geoarchaeology, which combines archaeological and geological analyses. Geology and archaeology form a natural marriage in many obvious ways because both disciplines are concerned with the alteration of natural landscapes. Glaciers, changing rainfall patterns, and many other natural forces cause changes to landscapes, and of course, so do people. Geologists are broadly concerned with ancient physical environments, and archaeologists require knowledge of these environments to interpret their finds.

Geoarchaeological analyses involve many different kinds of questions and techniques. In the Egyptian Delta region, for example, many of the earliest communities were built on large sand-and-gravel mounds created by the Nile River as it deposited the sediments it carried. But many of these communities have been buried under many meters of sediments from numerous ancient floods since that time and by other factors as well. Moreover, the streams feeding into the Nile River in the delta have changed course many times, leaving a maze of crisscrossed buried river channels. Finding these buried sand-and-gravel mounds and the archaeological sites on them often requires complex geological analyses involving special digging, satellite image analysis, and many other techniques.

## England's Economy in the Sixteenth Century

In the last half of the sixteenth century England emerged as a commercial and manufacturing power in Europe due to a combination of demographic, agricultural and industrial factors. The population of England and Wales grew rapidly from about 2.5 million in the 1520s to more than 3.5 million in 1580, reaching about 4.5 million in 1610. Reduced mortality rates and increased fertility, the latter probably generated by expanding work opportunities in manufacturing and farming (leading to earlier marriage and more children), explained this rapid rise in population. While epidemics and plague occasionally took their toll, the people in England still suffered less than did those in continental Europe. Furthermore, the country had been pulled out of the war that occurred in France and central Europe during the same period.

England provides the prominent example of the expansion of agricultural production well before the general European agricultural revolution of the eighteenth and nineteenth centuries. A larger population stimulated the increased woollen through crop civilization. English agriculture became more efficient and market-oriented than almost anywhere else on the continent. Between 1450 and 1640 the yield of grain per acre increased by at least thirty percent. In sharp contrast with farming in Spain, English land owners brought more dense marshes and woodlands into cultivation.

The great land estates of the English society largely remained intact and many wealthy land owners aggressively increased the size of their holdings, a precondition for increased productivity. Marriages between the children of landowners also increased the size of land estates. Primogeniture (the full inheritance of land by the eldest son) helped prevent land from being subdivided.Younger sons of independent land owners left the family and went to find other respective locations. Larger farms contributed more to commercialized farming at the time when an expanding population pushed up demand and prices. Farmland owners turned part of their land into pasture land for sheep in order to adapt to developing woollen trade.

Some of the great land owners as well as Yeomen (farmers whose holdings and security of land tenure guaranteed their prosperity and status), organized their holdings in the interest efficiency. Many farmers selected crops for sales in growing London market. In their quest for greater profits, many land owners put their squeeze on their tenants. Between 1580 and  1620 land lords raised rents and altered conditions of land tenure in their favor, preferring shorter phases and forcing tenants to pay an entry fee before agreeing to rent them land.Landlords evicted those who could not afford annual,more  onerous terms. But they also pushed tenants toward more productive farming methods,including crop rotation.

England's exceptional economic development also drew the country's natural resources, including iron, timber, and coal, extracted in far greater quantity than elsewhere in the continent. New industrial development expanded the production of iron and pewter in and around the city of Birmingham.

But above all textile manufacturing transformed English economy. Woolens, which accounted for eighty percent of the exports, worsteds (sturdy yarn spun from combed wool fibers), and other cloth found eager buyers in England as well as in the continent. Moreover, late in the sixteenth century as English merchants began making forays across the Atlantic these textiles were also sold in the Americas. Cloth manufacturers undercut production by urban craftspeople by "putting out" work to the villages and farms of the countryside. In such domestic industry poor rural women could spin and make cading (combing fibers in preparation for spin) in their homes.

The English textile trade was closely tied to Antwerp, in the Spanish Netherlands, where workers dyed English cloth. The entrepreneur Sir Thomas Gresham became England's representative there. He so enhanced the reputation of English business in that region that English merchants could operate on credit---the most prominent achievement for sixteenth century.He also advised the government to explore the economic possibilities of Americas, which led to the first concerted efforts at colonization, undertaken with commercial profits in mind.

## What Controls Flowering

The timing of flowering and seed production is precisely tuned to a plant's physiology and the rigors of its environment. In temperate climate plants lost flower early enough so that their seeds can mature before the deadly winds of autumn. Depending on how quickly the seed and food develop flowering may occur in spring as it does in oaks; in summer as in lettuces; or even in autumn as in asters.

What environmental cues do plants use to determine the seasons? Most cues such as temperature or water availability are quite variable: autumn can be warm; a late snow could fall in spring; also summer might be unusually cool and wet. So the only reliable cue is day length: longer days always mean that spring and summer are coming; shorter days foretell the onset of autumn and winter.

With respect to flowering botanists classify plants as day neutral, long day or short day. A day neutral plant flowers as soon as it has sufficiently grown and developed regardless of the length of day. The neutral plants include tomatoes, corn, snapdragons and roses. Although the naming is traditional, long day and short day plants are better described as short night and long night plants because their flowering actually depends on the duration of continuous darkness rather than on day length. Short night plants (which include lettuces, spinach, iris, clover and petunias) flower when the length of darkness is shorter than a species' specific critical period. Long night plants (including asters, potatoes, soy beans, goldenrod and cockleburs) flower when the length of uninterrupted darkness is longer than the species' specific critical period. Thus spinach is classified as a short night plant because it flowers only if the night is shorter than eleven hours (its critical period), and the cocklebur is a long night plant because it flowers only if an uninterrupted darkness lasts more than 8.5 hours. Both of these plants will flower with ten-hour nights.

Plant scientists can induce flowering in the cocklebur by exposing leaves to long nights (longer than its 8.5 hour critical period) in a special chamber, while the rest of the plant continues to experience short nights. Clearly, a signal that induces flowering transmitted from the leave to the flowering bud. Plant physiologists have been attempting for decades to isolate these elusive signaling molecule often called florigen (literally, flowering maker). Some researchers believe they are close to demonstrating a flower's stimulating substance for specific type of plant. Using genetic manipulation, it is likely, however, that interactions among multiple and yet unidentified plant hormones stimulate or inhibit flowering, and that these chemicals may differ among plant species. Researchers have had more success in determining how plants measure the length of uninterrupted darkness, which is a crucial stimulus for producing whatever substance control flowering.

To measure continuous darkness, a plant needs two things: some sort of metabolic clock to measure time (the duration of darkness) and a light detecting system to set the clock. Virtually all organisms have an internal biological clock that measures the time even without environmental cues. In most organisms including plants, the biological clock is poorly understood, but we know that the environmental cues, particularly light, can reset the clock. How do plants detect light? The light detecting system of plants is a pigment in leaves called phytochrome (literally, plant color).

Plants seem to use the phytochrome system in combination with their internal biological clocks to detect the duration of continuous darkness. Cockleburs, for example, flower under the schedule of sixteen hours of darkness and eight hours of light. However, interrupting the middle of the dark period with just a minute or two of lights prevents flowering. Thus their flowering is controlled by the length of continuous darkness. It is evident that even brief exposure to sunlight or white light will reset their biological clocks. The color of the light used for the light exposure is also important. A nighttime flash of pure red light inhibits flowering, while flash of light at the far-red end of the spectrum has no effect on flowering, as if no light were detected.

## The Brain Size of Bottlenose Dolphins

Large brain size does not always mean that an animal is highly intelligent. Brain size is necessarily associated with overall body size, with large animals having large brains and small animals having small brains. However, it is still necessary for there to be some minimum amount of circuitry (brain cells and processes) present for a species to have the potential to be highly intelligent, whatever way the term intelligence is defined. A measure of relative brain size that has been applied to a variety of species is the encephalization quotient (EQ), the radio of brain mass to body size. The EQ is calculated by measuring the relative size of different body parts over a wide range of species. An EQ of 1.0 means that the brain is exactly the size one would expect for an animal of a particular size, an EQ higher than 1.0 means that a species is relatively brainy.

Bottlenose dolphins have a very high EQ, about 2.8 or higher. Thus, dolphin brains are not simply absolutely large: they are relatively very large as well. Humans, by the way, have extremely high EQ values, estimated to be in the neighborhood 7.5, making our species the brainiest in existence. Nonetheless, it is worth noting that EQ levels in several species of odontocetes (toothed whales, dolphins, and porpoises) are significantly higher than is the case for any primate except our own species. The EQ value for a species relates to a number of general measures of cognitive processing ability in different mammals, as well as to a number of life history patterns in mammals. EQ may be correlated with life span, home-range size, and social systems that characterize a particular species. Oddly enough, the relationships found between EQ and other factors in primates and some other mammals do not appear to apply as well to cetaceans (whales, dolphins, and porpoises), including the bottlenose dolphin.

The reasons for the larger-than-normal brain of the bottlenose dolphin (and indeed of small odontocetes in general) are not clearly understood. To navigate and detect prey, dolphins emit calls into the environment and then listen to the echoes of the calls that return from nearby objects, a process known as echolocation. Among the more plausible suggestions for large brain size are that the complexity of processing high-frequency echolocation information requires the development of large centers in the cerebral hemispheres, and/or that the degree of sociality exhibited by many species, in which individual animals recognize and have particular long- and short-term relationships with a number of other individuals, has favored the evolutionary development of a large, complex brain. Some authors develop a strong case that extreme development of the auditory (hearing) system may be the primary reason for the dolphin's large brain. This opinion is supported by observations that the auditory regions of the dolphin brain are 7 to 250 times larger than the equivalent regions of the human brain and by observations of very fasts auditory brain stem responses to sounds. It should be noted, however, that sperm whales are very social and good echolocators (that is, good at locating objects by emitting sounds and detecting the reflections given back), yet their EQ values are low—only about 0.3. Even some small, less social odontocetes such as Indus river dolphins echolocate well but do not possess the exceptionally large brains that bottlenose dolphins do.

Noted biologist Peter Tyack has studies dolphin brains and argues persuasively that large brains evolved in dolphins to permit complex social functions. As is the case with certain primates, bottlenose dolphins and certain other large-brained odontocetes have developed societies in which there exists a balance between cooperation and competition among particular individuals. The social politics of chimpanzees and dolphins show some remarkable similarities, especially in terms of the importance of social relations extending far beyond the mother-offspring relationship to include individuals of both sexes across the age range. The development of such complex societies may have favored the evolution of large brain size.

The reason that dolphins have a large brain continues to be somewhat elusive but there must be a reason, since maintenance of brain tissue is metabolically expensive. The adult human brain, for example, may only represent 2 percent of the body weight, but it can account for nearly 20 percent of the metabolic rate (the energy used).

## Architectural Change in Eighth-Century Japan

Japanese construction techniques and architectural styles changed in the eighth century C.E. from more traditional Japanese models to imported continental (especially Chinese) modes. Several factors contributed to this, in particular with respect to the creation of two new capital cities. In essence, changes then occurring in Japanese political life were rendering past arrangements for the rulers' headquarters obsolete, and continental models offered an alternative.

To elaborate, before the eighth century, the elite marriage practice, which was an important instrument of political alliance making, had encouraged rulers to maintain multiple palaces that of their own family and those of their spouses, who commonly remained at or near their native family headquarters, at least for some years after marriage. These arrangements had the effect of encouraging frequent changes in royal residence as children matured and marriage alliances changed. The customs of multiple palaces and a moveable court were feasible as long as a ruling group was modest in size and its architectural practices relatively simple.

Moreover, because buildings using the traditional construction of thatched roofs and wooden poles placed directly in the ground rotted away in two decades or so, periodic replacement of palaces, shrines, warehouses, gate towers, and fortress walls was essential. The custom of residential mobility was thus not especially wasteful of labor and material resources:  when the time came, one simply erected a new building at a new site—reusing valuable timbers as appropriate—and burned the rest. The practical necessity of replacement was given religious sanction because the regular replacement of buildings was regarded as necessary to provide spiritual cleansing of the site.

As rulers of the sixth and seventh centuries expanded their realm, however, they acquired more and more underlings, administrative paraphernalia, weaponry, and tribute goods, and they needed more and more buildings to house them. As the scale of government grew, moreover, it became more important to have these people and resources close at hand where they could be more easily controlled and utilized. Under these circumstances, frequent moves by the court or replacement of buildings became more costly, even prohibitive.

A solution to the problem was advocated by experts from the continent. This was the use of continental principles of urban design and techniques of construction. These produced geometrically laid out capital cities whose major gates and buildings employed stone foundations, mortise-and-tenon framing (a technique for attaching timbers), and tile roofs that largely eliminated the problem of rot and the consequent need for replacement.

On the other hand, to construct cities and buildings of that sort required so much labor and material that their use effectively precluded periodic replacement or the transfer of a royal headquarters from site to site. Nevertheless, the notion of grand buildings and capital cities became immensely attractive to Japanese rulers during the seventh and eighth centuries. Continental regimes, the glorious new Chinese dynasties most notably, had them: they constituted an expression of political triumph, a legitimizing symbol of the first order. Moreover, the architecture was an integral part of Buddhism, and acceptance of this religion in Japan at this time fostered adoption of its building style.

These several confliction factors—the need to modify palace and capital arrangements but the difficulty of doing so, the wish to enjoy grandeur but the reluctance to settle for a single, immobile court—all became evident by the mid-seventh century. Change did come, but slowly, and in the end a compromise system was devised. Traditional shrines of Shinto, the native religion of Japan, and many residential buildings continued to be built in the rottable, replaceable style that accommodated religious concerns and taboos, while city gates, major government buildings, and Buddhist temples were built in the continental fashion that met the need for permanence and grandeur. Moreover, the wish of rulers to maintain multiple palaces fit with the custom of certain continental regimes that maintained summer palaces or other regional capitals where rulers could periodically reside on a temporary basis.

## Vocalization in Frogs

The tu?ngara frog is a small terrestrial vertebrate that is found in Central America. Tu?ngara frogs breed in small pools, and breeding groups range from a single male to choruses of several hundred males. The advertisement call of a male tu?ngara frog is a strange noise, a whine that starts at a frequency of 900 hertz and sweeps downward to 400 hertz in about 400 milliseconds. The whine may be produced by itself, or it may be followed by one or several chucks or clucking sounds. When a male tu?ngara frog is calling alone in a pond, it usually gives only the whine portion of the call, but as additional males join a chorus, more and more of the frogs produce calls that include chucks. Scientists noted that male tu?ngara frogs calling in a breeding pond added chucks to their calls when they heard the recorded calls of other males played back. That observation suggested that it was the presence of other calling males that incited frogs to make their calls more complex by adding chucks to the end of the whine.

What advantage would a male frog in a chorus gain from using a whine-chuck call instead of a whine perhaps the complex call is more attractive to female frogs than the simple call. Michael Ryan and Stanley Rand tested that hypothesis by placing female tu?ngara frogs in a test arena with a speaker at each side. One speaker broadcast a pre-recorded whine call, and the second speaker broadcast a whine-chuck. When female frogs were released individually in the center of the arena, fourteen of the fifteen frogs tested moved toward the speaker broadcasting the whine-chuck call.

If female frogs are attracted to whine-chuck calls in preference to whine calls, why do male frogs give whine-chuck calls only when other males are present Why not always give the most attractive call possible. One possibility is that whine- chuck calls require more energy than whines, and males save energy by only using whine-chucks when competition with other males makes the energy expenditure necessary. However, measurements of the energy expenditure of calling male tu?ngara frogs showed that energy cost was not related to the number of chucks. Another possibility is that male frogs giving whine-chuck calls are more vulnerable to predators than frogs giving only whine calls tu?ngara frogs in breeding choruses are preyed upon by a species of frog-eating bats, Trachops cirrhosus, and it was demonstrated that the bats locate the frogs by homing on their vocalizations.

In a series of playback experiments, Michael Ryan and Merlin Tuttle placed pairs of speakers in the forest and broadcast vocalizations of tu?ngara frogs. One speaker played a recording of a whine and the other a recording of a whine-chuck. The bats responded as if the speakers were frogs: they flew toward the speakers and even landed on them. In five experiments at different sites, the bats approached speakers broadcasting whine-chuck calls twice as frequently as those playing simple whines (168 approaches versus 81). Thus, female frogs are not alone in finding whine-chuck calls more attractive than simple whinesan important predator of frogs also responds more strongly to the complex calls.

Ryan and his colleagues measured the rates of predation intu?ngara frog choruses of different sizes. Large choruses of frogs did not attract more bats than small choruses, and consequently the risk of predation for an individual frog was less in a large chorus than in a small one. Predation was an astonishing 19 percent of the frogs per night in the smallest chorus and a substantial 1.5 percent per night even in the largest chorus. When a male frog shifts from a simple whine to a whine- chuck call, it increases its chances of attracting a female, but it simultaneously increases its risk of attracting a predator. In small choruses, the competition from other males for females is relatively small, and the risk of predation is relatively large. Under these conditions it is apparently advantageous for a male tu?ngara frog to give simple whines. However, as chorus size increases, competition with other males also increases while the risk of predation falls. In that situation, the advantage of giving a complex call apparently outweighs the risks.

## Documenting the Incas

The Incans ruled a vast empire in western South America when the Spaniards encountered them in the sixteenth century. Although the Incas had no writing system of their own, historical information about Incas is available to researchers because early Spaniards wrote documents about them. However, there are drawbacks to use the written record. First, the Spanish writers were describing activities and institutions that were very different from their own, but they often described Inca culture in terms of their own society. As an example, consider the list of kings given by the Incas. As presented in the historical chronology, Spanish sources indicate there were thirteen kings who ruled sequentially. The names were given to them by Inca informants. However, one school of thought in Inca studies suggests that the names were not actual people, but, rather, titles filled by different individuals. Thus, the number of actual kings may have been fewer, and several titles may have been filled at the same time. The early Spanish writers, being unfamiliar with such a system of titles, simply translated it into something they were familiar with (a succession of kings). Given that the Inca empire expanded only during the time of the last four kings, or as a result of the actions of the individuals in those four positions, this question is not deemed significant for an understanding of the Incas. But the example shows that biases and inaccuracies may have been introduced inadvertently from the very beginning of the written Spanish reports about the Incas. Moreover, early writers often copied information from each other---so misinformation was likely to be passed on and accepted as true by later scholars.

Second, both Spanish writers and Incan informants sometimes had motives for being deliberately deceitful. For example, in an effort to gain status in the Spaniards' eyes, Incas might say that they formerly had been more important in the Inca empire than they actually were. Spanish officials as well were occasionally untruthful when it served their purposes. For example, Spaniards might deliberately underreport the productivity of a region under their authority so they could sell the additional products and keep the money, rather than hand it over to the Spanish Crown.

Third, it should be noted that the Spaniards' main sources of information were the Incas themselves, often members of the Inca ruling class. Therefore, what was recorded was the Incas' point of view about their own history and empire. Some modern authorities question whether the history of Incas happened as they said it did. Although some of their history is certainly more myth than truth, many, if not most, scholars agree that the history of the last four Inca kings is probably accurate. The same is true of other things told to the Spanish writers: the more recently an event is said to have occurred, the more likely it is to have actually happened.

A fourth problem relates to the nature of the Inca conquests of the other people in the Americas before the Spanish arrived and how accurate the accounts of those conquests are---whether related by the Spaniards or by the Incas on whom they relied. It was certainly in the Inca's interest to describe themselves as invincible and just. However, lacking accounts by conquered people about their interactions with the Incas, it is unknown how much of the information of the Inca conquest as related by the ruling class is factual.

Finally, there is a certain vagueness in the historical record regarding places and names. Many Spanish writers listed places they had visited within the empire, including both provinces and towns. However, other writers traveling along the same routes sometimes recounted different lists of places. In addition, it is difficult to identify the exact locations of towns and other geographic points of reference because of the widespread movements of people over the past five centuries.

For all these reasons, the historical record must be carefully evaluated to determine whether it is accurate and to verify the locations of past events. One approach is to cross-check information from a number of authors. Another approach is to conduct archaeological research. Regardless of the problems, historical documents review some important information about the Incas.

## Costs and Benefits of Social Life

Many think that the reason so many animals live with others of their species is that social creatures are higher up the evolutionary scale and so are better adapted and leave more offspring than do animals that live solitary lives. However, in each and every species, generation after generation, relatively social and relatively solitary types compete unconsciously with one another in ways that determine who leaves more offspring on average. In some species, the more social individuals have won out, but in a large majority, it is the solitary types that have consistently left more surviving descendants on average.

But how can living alone ever be superior to living together? Under some conditions, a cost-benefit comparison favors solitary life over a more social existence. For example, among most social species, animals have to expend time and energy competing for social status. Those that do not occupy the top positions regularly have to signal their submissive state to their superiors if they are to be permitted to remain in the group. This can take up a major share of a social subordinate's life. In fact, even in small social groups there are both subtle competition and not-so-subtle competition.

Social groups also offer opportunities for reproductive interference. Breeding males that live in close association with more attractive rivals may lose their mates to these individuals. In addition, sociality has two other potential disadvantages. The first is heightened competition for food, which occurs in animals as different as colonial fieldfares (a kind of songbird) and groups of lions, whose females are often pushed from their food by hungry males. The second is increased vulnerability to parasites and disease, which plague social species of all sorts. While it is true that some social animals have evolved special responses designed to combat parasites and disease, those responses can only reduce, but cannot totally eliminate, the damage caused by those threats, and the responses may even carry their own costs. Thus, honeybees warm their hives in response to an infestation by a fungal pathogen, which apparently helps kill the heat- sensitive fungus, but at the price of time and energy expended by the heat-producing workers.

If social living carries a heightened risk of infection, then the larger the group, the greater the risk. This prediction holds for cliff swallows, which pack their nests side by side in colonies composed of anywhere from a handful of birds to several thousand pairs. The more swallows nesting together, the greater the chance that at least one bird will be infested with swallow bugs, which can then readily spread from one nest to another.

The parasites and fungi that make life miserable for swallows and other social creatures demonstrate that if sociality is to evolve, the asorted costs of living together must be outweighed by compensatory benefits. Cliff swallows may join others to take advantage of the improved foraging that comes from following companions to good feeding sites, while other animals, such as male imperial penguins, save thermal energy by huddling shoulder to shoulder during the brutal Antarctica winter. Still others, such as lionesses, join forces to fend off enemies of their own species.

The most widespread fitness benefit for social animals, however, probably is improved protection against predators. Many studies have shown that animals in groups gain by reducing the individual risk of being captured, or by spotting danger sooner, or by attacking their enemies in groups. Males in nesting colonies of bluegill sunfish cooperate in driving egg- eating bullhead catfish away from their nests at the bottom of a freshwater lake. While bluegills have adopted social behavior to avoid predation, closely related species that nest alone have evolved means to protect themselves while nesting alone. Thus, the solitary pumpkinseed sunfish, a member of the same genus as the bluegill, has powerful biting jaws and so can repel egg-eating enemies on its own, whereas bluegills have small, delicate mouths good only for inhaling small, soft-bodied insect larvae. Pumpkinseed sunfish are in no way inferior to or less well adapted than bluegills because they are solitary; they simply gain less through social living, which makes solitary nesting the adaptive tactic for them.

## Consolidated Industry in the United States

Laws of incorporation passed in the United States in the 1830s and 1840s made it easier for business organizations to raise money by selling stock to members of the public. The ability to sell stock to a broader public made it possible for entrepreneurs to gather vast sums of capital and undertake large projects. This led to the emergence of modern corporations as a major force in the United States after 1865. These large, national business enterprises needed more systematic administrative structures. As a result, corporate leaders introduced a set of managerial techniques that relied on systematic division of responsibilities, a carefully designed hierarchy of control, careful cost-accounting procedures, and perhaps above all a new breed of business executive: the middle manager, who formed a layer of command between workers and owners. Efficient administrative capabilities helped make possible another major feature of the modern corporation: consolidation (combining many things into one).

Businessmen created large, consolidated organizations primarily through two methods. One was horizontal integration— the combining of multiple firms engaged in the same enterprise into a single corporation. The consolidation of many different railroad lines into one company was an example. Another method, which became popular in the 1890s, was vertical integration—the taking over of all the different businesses on which a company relied for its primary function. Thus, Carnegie steel controlled mines and railroads as well as steel mills.

The most celebrated corporate empire of the late nineteenth century was John D. Rockefeller's Standard Oil. Shortly after 1865, Rockefeller launched a refining company in Cleveland, Ohio, and immediately began trying to eliminate his competition. Allying himself with other wealthy capitalists, he proceeded methodically to buy out competing refineries. In 1870, he formed the Standard Oil Company of Ohio, which in a few years had acquired twenty of the twenty-five refineries in Cleveland, as well as plants in Pittsburgh, Philadelphia, New York, and Baltimore. He built his own barrel factories, warehouses, and pipelines. Standard Oil owned its own railroad freight cars and developed its own marketing organization. By the 1880s, Rockefeller had established such dominance within the petroleum industry that to much of the nation he served as a leading symbol of monopoly.

Rockefeller and other industrialists saw consolidation as a way to cope with what they believed was the greatest curse of the modern economy. "cutthroat competition." Most businessmen claimed to believe in free enterprise and a competitive marketplace, but in fact they feared that substantial competition could result in instability and ruin for all. As the movement toward consolidation accelerated, new vehicles emerged to facilitate it. The railroads began with so-called pool arrangements—informal agreements among various companies to stabilize rates and divide markets. But if even a few firms in an industry were unwilling to cooperate (as was almost always the case), the pool arrangements collapsed. The failure of the pools led to new techniques of consolidation. At first, the most successful such technique was the creation of the "trust"—pioneered by Standard Oil in the early 1880s and perfected by the banker J. P. Morgan. Under a trust agreement, stockholders in individual corporations transferred their stocks to a small group of trustees in exchange for shares in the trust itself. Owners of trust certificates often had no direct control over the decisions of the trustees, they simply received a share of the profits of the combination. The trustees themselves, on the other hand, might literally own only a few companies but could exercise effective control over many.

In 1889, the state of New Jersey helped produce a third form of consolidation by changing its laws of incorporation to permit companies to buy up the stock of other companies. Other states soon followed. These changes made the trust unnecessary and permitted actual corporate mergers. Rockefeller, for example, quickly relocated Standard Oil to New Jersey and created there what became known as a holding company—a central corporate body that would buy up the stock of various members of the Standard Oil trust and establish direct, formal ownership of the corporations in the trust.

## Newspaper in Western Europe

By the eighteenth century, newspapers had become firmly established as a means of spreading news of European and world affairs, as well as of local concerns, within European society. One of the first true newspapers was the Dutch paper Nieuwe Tijdingen It began publication in the early seventeenth century at about the same time that the overseas trading company called the Dutch East India Company was formed The same ships that brought goods back from abroad brought news of the world, too.

Dutch publishers had an advantage over many other publishers around Europe because the Netherlands' highly decentralized political system made its censorship laws very difficult to enforce Throughout Europe in the seventeenth century, governments began recognizing the revolutionary potential of the free press and began requiring licenses of newspapers—to control who was able to publish news. Another tactic, in France and elsewhere on the continent from the 1630s onward, was for governments to sponsor official newspapers. These state publications met the increasing demand for news but always supported the government's views of the events of the day.

By the eighteenth century, new conditions allowed newspapers to flourish as never before First, demand for news increased as Europe's commercial and political interests spread around the globe—merchants in London, Liverpool, or Glasgow, for example, came to depend on early news of Caribbean harvests and gains and losses in colonial wars Europe's growing commercial strength also increased distribution networks for newspapers. There were more and better roads, and more vehicles could deliver newspapers in cities and convey them to outlying towns Newspaper publishers made use of the many new sites where the public expected to read, as newspapers were delivered to cafes and sold or delivered by booksellers.

Second, many European states had established effective postal systems by the eighteenth century. It was through the mail that readers outside major cities and their environs—and virtually all readers in areas where press censorship was exercised firmly— received their newspapers. One of the most successful newspapers in Europe was a French-language paper (one of the many known as La Gazette,) published in Leiden, in the Netherlands, which boasted a wide readership in France and among elites throughout Europe.

Finally, press censorship faltered in one of the most important markets for news—England— at the turn of the eighteenth century after 1688. debate raged about whether the Parliament or the Crown had the right to control the press, and in the confusion the press flourished. The emergence of political parties further hampered control of the press because political decisions in Parliament now always involved compromise, and many members believed that an active press was useful to that process. British government's control of the press was reduced to taxing newspapers, a tactic that drove some papers out of business.

Eighteenth-century newspapers were modest products by modern Western standards. Many were published only once or twice a week instead of every day, in editions of only a few thousand copies. Each newspaper was generally only four pages long. Illustrations were rare, and headlines had not yet been invented. Hand-operated wooden presses were used to print the papers, just as they had been used to print pamphlets and books since the invention of printing in the fifteenth century.

Yet these newspapers had a dramatic impact on their reading public Regular production of newspapers (especially of many competing newspapers) meant that news was presented to the public at regular intervals and in manageable amounts. Even strange and threatening news from around the world became increasingly easy for readers to absorb and interpret Newspaper readers also felt themselves part of the public life about which they were reading This was true partly because newspapers, available in public reading rooms and in cafes, were one kind of reading that occupied an increasing self-aware and literate audience. Newspapers also were uniquely responsive to their readers. They began to carry advertisements, which both produced revenue for papers and widened readers' exposure to their own communities. Even more important was the inauguration of letters to the editor in which readers expressed their opinions about events Newspapers thus became venues for the often rapid exchange of news and opinions.

## Mating Songs of Frogs

The calling or singing of frogs plays an important role in their reproduction—specifically, in helping individuals find and select mates. Sound has many advantages as a communication signal. When sounds are broadcast, the auditory receptors do not need to be in a particular orientation relative to the sound source in order to receive stimulation. Loud songs, particularly those made by choruses of frogs calling together, can travel long distances and thus attract distant frogs. Sounds travel around large obstacles. These advantages are not found in the visual modality, where the receiver must be attentive and have its visual receptor orientated in the correct direction. Further, most frogs and toads breed at night, when light levels are low but sounds can be easily localized. We can conclude that auditory signals are used by frogs and toads because they can be effective over long distances at night.

Male frogs do most of the courtship calling. Other male frogs can respond by adding their voices to form a calling chorus. Male frogs can also vocalize to each other as part of aggressive displays. Aggressive calls can be distinct from the advertisement calls used to attract females. Females can respond to male songs by moving toward the sound source or by selecting certain males as reproductive partners. In some species females also respond to males by calling: receptive pairs can even perform duets. Predators may also cue in on calling frogs as potential prey.

Frog songs contain several potentially important pieces of information about the calling male. First, sound amplitude can indicate the size of the individual that is Galling. Since many frogs exhibit indeterminate growth (i.e., they keep getting bigger as they get older), size is a good predictor of relative age. In many species, call amplitude is increased by specialized vocal sacs that can enlarge as the animal grows; thus, older frogs produce louder calls. The male's age matters to the female because older frogs have successfully survived the environmental hazards that the offspring they sire will soon be facing. Amplitude can also convey information on how far away the calling frog is or, for choruses, how many frogs are calling together. An intensely vocalizing chorus may indicate a particularly favorable breeding site. Sound amplitude (subjectively: loudness) can be an ambiguous cue for a female, however. A very intense sound can indicate an old male at some distance or a younger male that is close. A close, small chorus could be confused with a louder chorus that is farther away.

Sound frequencies-or pitch-can also convey information about the calling male because the vocal apparatus grows larger as the frog grows older. In some frogs, the pitch of individual sounds varies with so that older and larger males give lower-pitched calls. Sound pitch is affected by temperature; small males can mimic the lower pitch of larger, older males by calling from colder locations. Finally, the length of time that an individual can afford to spend calling is a good indicator of his health. Many frogs invest considerable energy in calling, both because they do not feed and because it is a physically demanding behavior that relies on rapid muscular contractions of the vocalization apparatus. This effort can be debilitating in a male frog that is not in top physical condition. Calling in tree frogs is said to be the most energetically expensive behavior yet measured in any vertebrate.

Sound frequencies and the overall temporal pattern (rhythm and rate) of the song can also reveal the species of the calling male. The frequencies sounds and their temporal patterns are species- specific. The species of a potential mate is extremely important to the female. Females that choose to mate with members of another species risk losing the energy invest in eggs because the hybrid offspring will not survive and reproduce.

Thu complexity of a frog song can also affect how attractive it is to a female. The songs of male tungara frogs, for example, can consist simply of short high-frequency “whines” or by several lower-frequency "chucks." More females approach loudspeakers playing whines plus chucks than whines alone. The addition of chucks, however, also has the disadvantage of attracting bats that eat the frogs.

## The Beringia Landscape

During the peak of the last ice age, northeast Asia (Siberia) and Alaska were connected by a broad land mass called the Bering Land Bridge. This land bridge existed because so much of Earth's water was frozen in the great ice sheets that sea levels were over 100 meters lower than they are today. Between 25,000 and 10,000 years ago, Siberia, the Bering Land Bridge, and Alaska shared many environmental characteristics. These included a common mammalian fauna of large mammals, a common flora composed of broad grasslands as well as wind-swept dunes and tundra, and a common climate with cold, dry winters and somewhat warmer summers. The recognition that many aspects of the modern flora and fauna were present on both sides of the Bering Sea as remnants of the ice-age landscape led to this region being named Beringia.

It is through Beringia that small groups of large mammal hunters, slowly expanding their hunting territories, eventually colonized North and South America. On this archaeologists generally agree, but that is where the agreement stops. One broad area of disagreement in expanding the peopling of the Americas is the domain of paleoecologists, but it is critical to understanding human history: what was Beringia like?

The Beringian landscape was very different from what it is today. Broad, windswept valleys, glaciated mountains, sparse vegetation, and less moisture created a rather forbidding land mass. This land mass supported herds of now-extinct species of mammoth, bison, and horse and somewhat modern versions of caribou, mush ox, elk, and saiga antelope. These grazers supported in turn a number of impressive carnivores, including the giant short-faced bear, the saber-tooth cat, and a large pecies of lion.

The presence of mammal species that require grassland vegetation has led Arctic biologist Dale Guthrie to argue that while cold and dry, there must have been broad areas of dense vegetation to support herds of mammoth, horse, and bison. Further, nearly all of the ice-age fauna had teeth that indicate an adaptation to grasses and sedges; they could not have been supported by a modern flora of mosses and lichens. Guthrie has also demonstrated that the landscape must have been subject to intense and continuous winds, especially in winter. He makes this argument based on the anatomy of horse and bison, which do not have the ability to search for food through deep snow cover. They need landscapes with strong winds that remove the winter snows, exposing the dry grasses beneath. Guthrie applied the term "mammoth steppe" to characterize this landscape.

In contrast, Paul Colinvaux has offered a counterargument based on the analysis of pollen in lake sediments dating to the last ice age. He found that the amount of pollen recovered in these sediments is so low that the Beringian landscape during the peak of the last glaciation was more likely to have been what he termed a "polar desert," with little or only sparse vegetation. In no way was it possible that this region could have supported large herds of mammals and thus, human hunters. Guthrie has argued against this view by pointing out that radiocarbon analysis of mammoth, horse, and bison bones from Beringian deposits revealed that the bones date to the period of most intense glaciation.

The argument seemed to be at a standstill until a number of recent studies resulted in spectacular suite of new finds. The first was the discovery of a 1,000-square-kilometer preserved patch of Beringian vegetation dating to just over 17,000 years ago—the peak of the last ice age. The plants were preserved under a thick ash fall from a volcanic eruption. Investigations of the plants found grasses, sedges, mosses, and many other varieties in a nearly continuous cover, as was predicted by Guthrie. But this vegetation had a thin root mat with no soil formation, demonstrating that there was little long-term stability in plant cover, a finding supporting some of the arguments of Colinvaux. A mixture of continuous but thin vegetation supporting herds of large mammals is one that seems plausible and realistic with the available data.

## From Fish to Terrestrial Vertebrates

One of the most significant evolutionary events that occurred on Earth was the transition of water-dwelling fish to terrestrial tetrapods (four-limbed organisms with backbones). Fish probably originated in the oceans, and our first records of them are in marine rocks. However, by the Devonian Period (408 million to 362 million years ago), they had radiated into almost all available aquatic habitats, including freshwater settings. One of the groups whose fossils are especially common in rocks deposited in fresh water is the lobe-finned fish.

The freshwater Devonian lobe-finned fish rhipidistian crossopterygian is of particular interest to biologists studying tetrapod evolution. These fish lived in river channels and lakes on large deltas. The delta rocks in which these fossils are found are commonly red due to oxidized iron minerals, indicating that the deltas formed in a climate that had alternate wet and dry periods. If there were periods of drought, any adaptations allowing the fish to survive the dry conditions would have been advantageous. In these rhipidistians, several such adaptations existed. It is known that they had lungs as well as gills for breathing. Cross sections cut through some of the fossils reveal that the mud filling the interior of the carcass differed in consistency and texture depending on its location inside the fish. These differences suggest a saclike cavity below the front end of the gut that can only be interpreted as a lung. Gills were undoubtedly the main source of oxygen for these fish, but the lungs served as an auxiliary breathing device for gulping air when the water became oxygen depleted, such as during extended periods of drought. So, these fish had already evolved one of the prime requisites for living on land: the ability to use air as a source of oxygen.

A second adaptation of these fish was in the structure of the lobe fins. The fins were thick, fleshy, and quite sturdy, with a median axis of bone down the center. They could have been used as feeble locomotor devices on land, perhaps good enough to allow a fish to flop its way from one pool of water that was almost dry to an adjacent pond that had enough water and oxygen for survival. These fins eventually changed into short, stubby legs. The bones of the fins of a Devonian rhipidistian exactly match in number and position the limb bones of the earliest known tetrapods, the amphibians. It should be emphasized that the evolution of lungs and limbs was in no sense an anticipation of future life on land. These adaptations developed because they helped fish to survive in their existing aquatic environment.

What ecological pressures might have caused fishes to gradually abandon their watery habitat and become increasingly land-dwelling creatures? Changes in climate during the Devonian may have had something to do with this if freshwater areas became progressively more restricted. Another impetus may have been new sources of food. The edges of ponds and streams surely had scattered dead fish and other water-dwelling creatures. In addition, plants had emerged into terrestrial habitats in areas near streams and ponds, and crabs and other arthropods were also members of this earliest terrestrial community. Thus, by the Devonian the land habitat marginal to freshwater was probably a rich source of protein that could be exploited by an animal that could easily climb out of water. Evidence from teeth suggests that these earliest tetrapods did not utilize land plants as food; they were presumably carnivorous and had not developed the ability to feed on plants.

How did the first tetrapods make the transition to a terrestrial habitat? Like early land plants such as rhyniophytes, they made only a partial transition; they were still quite tied to water. However, many problems that faced early land plants were not applicable to the first tetrapods. The ancestors of these animals already had a circulation system, and they were mobile, so that they could move to water to drink. Furthermore, they already had lungs, which rhipidistians presumably used for auxiliary breathing. The principal changes for the earliest tetrapods were in the skeletal system—changes in the bones of the fins, the vertebral column, pelvic girdle, and pectoral girdle.

## Surface Fluids on Venus and Earth

Afluid is a substance, such as a liquid or gas, in which the component particles (usually molecules) can move past one another. Fluids flow easily and conform to the shape of their containers. The geologic processes related to the movement of fluids on a planet's surface can completely resurface a planet many times. These processes derive their energy from the Sun and the gravitational forces of the planet itself. As these fluids interact with surface materials, they move particles about or react chemically with them to modify or produce materials. On a solid planet with a hydrosphere and an atmosphere, only a tiny fraction of the planetary mass flows as surface fluids. Yet the movements of these fluids can drastically alter a planet. Consider Venus and Earth, both terrestrial planets with atmosphere.

Venus and Earth are commonly regarded as twin planets but not identical twins. They are about the same size, are composed of roughly the same mix of materials, and may have been comparably endowed at their beginning with carbon dioxide and water. However, the twins evolved differently, largely because of differences in their distance from the Sun.  With a significant amount of internal heat, Venus may continue to be geologically active with volcanoes, rifting, and folding. However, it lacks any sign of a hydrologic system (water circulation and distribution): there are no streams, lakes, oceans, or glaciers. Space probes suggest that Venus may have started with as much water as Earth, but it was unable to keep its water in liquid form. Because Venus receives more heat from the Sun, water released from the interior evaporated and rose to the upper atmosphere where the Sun's ultraviolet rays broke the molecules apart. Much of the freed hydrogen escaped into space, and Venus lost its water. Without water, Venus became less and less like Earth and kept an atmosphere filled with carbon dioxide. The carbon dioxide acts as a blanket, creating an intense greenhouse effect and driving surface temperatures high enough to melt lead and to prohibit the formation of carbonate minerals. Volcanoes continually vented more carbon dioxide into the atmosphere. On Earth, liquid water removes carbon dioxide from the atmosphere and combines it with calcium, from rock weathering, to form carbonate sedimentary rocks. Without liquid water to remove carbon from the atmosphere, the level of carbon dioxide in the atmosphere of Venus remains high.

Like Venus, Earth is large enough to be geologically active and for its gravitational field to hold an atmosphere. Unlike Venus, it is just the right distance from the Sun so that temperature ranges allow water to exist as a liquid, a solid, and a gas. Water is thus extremely mobile and moves rapidly over the planet in a continuous hydrologic cycle. Heated by the Sun, the water moves in great cycles from the oceans to the atmosphere, over the landscape in river systems, and ultimately back to the oceans. As a result, Earth's surface has been continually changed and eroded into delicate systems of river valleys—a remarkable contrast to the surfaces of other planetary bodies where impact craters dominate. Few areas on Earth have been untouched by flowing water. As a result, river valleys are the dominant feature of its landscape. Similarly, wind action has scoured fine particles away from large areas, depositing them elsewhere as vast sand seas dominated by dunes or in sheets of loess (fine-grained soil deposits). These fluid movements are caused by gravity flow systems energized by heat from the Sun. Other geologic changes occur when the gases in the atmosphere or water react with rocks at the surface to form new chemical components with different properties. An important example of this process was the removal of most of Earth's carbon dioxide from its atmosphere to form carbonate rocks. However, if Earth were a little closer to the Sun, its oceans would evaporate. If it were farther from the Sun, the oceans would freeze solid. Because liquid water was present, self-replicating molecules of carbon, hydrogen, and oxygen developed life early in Earth's history and have rapidly modified its surface, blanketing huge parts of the continents with greenery. Life thrives on this planet, and it helped create the planet's oxygen- and nitrogen-rich atmosphere and moderate temperature.

## Human Impacts on Biogeography

Biologists, who commonly study the distribution of plant and animal species in different environments—their biogeography—strive to develop interpretations or explanations of the patterns of species distribution, but these may be incorrect if the effects of human beings are not taken into consideration. In some cases, these effects may be accidental; for example, some species of rat were unintentionally transported aboard ships from Europe to the islands of the South Pacific. In other cases, species distributions may have been deliberately modified by human beings. The Polynesians in the South Pacific intentionally moved the kumara (sweet potato) to islands in that region to provide the population with a new food crop.

The relocation of species by humans (and more recently the imposition of restrictions on movement by way of national controls and world conventions) has been primarily for economic reasons and for environmental protection. For example, humans introduced Sitka spruce trees into Scotland and England from North America to use them as a timber crop. Similarly the Monterey pine tree was introduced into New Zealand in the nineteenth century from California and has become the most widely used species in the timber production industry in that country. The potato has been carried from its native home in the high Andes of South America, modified and developed into many varieties, and transported around the world because it can be used as a food crop. The plant formerly known as the Chinese gooseberry was relocated from its native China to New Zealand where an industry was established around the renamed kiwifruit.

We have extended the distribution of some species because of certain useful traits that make the species desirable beyond their former known range For example, willows have extensive root systems, can grow relatively quickly, and are now used in several countries worldwide to stabilize river margins as a flood protection measure. The distribution of willows has therefore been influenced considerably by human use in river bank management.

The effects of introduced species can be many and varied and can include effects on the distribution of other species. For example, the North American gray squirrel was introduced into England and has now largely displaced the native red squirrel. The accidental introduction of organisms to new areas may have major pest implications. The South African bronze butterfly, the larva (immature insect forms) of which feed on buds and other parts of geraniums and similar flowers, was accidentally introduced into the Balearic Islands via imported geraniums. In its native South Africa, the distribution and abundance of the butterfly are affected in part by a native wasp that parasitizes (feeds on) the larvae. In the absence of the parasite wasp on the Balearic Islands off the coast of Spain, the butterfly has now spread to mainland Spain where its rapid spread has been accentuated by trade in garden plants and modem transport. The species has become a major pest due to the lack of a natural predator and is now causing great problems for the horticultural industry in Spain.

Human-driven changes in the distribution of some species may result in hybridization (interbreeding) with other species and so have a genetic effect. For example, the North American cord grass was accidentally introduced to the south coast of England in the early nineteenth century. It hybridized with the European cord grass and resulted in the production of a new species, which in this case is also a major pest plant of estuaries in England where it became dominant and extensive.

Information about a species distribution (prior to human modification) maybe applied in pest control programs for the introduced species. Studies of the species in its native habitat may yield information about the factors that limit or influence its distribution and population dynamics. That information may then be applied in the development of strategies to contain and control the spread of pest species. For example, information about the role of the parasitic wasp in the ecology of the bronze butterfly may be utilized in the process of finding control strategies for that species on mainland Spain.

## Agricultural Society in Eighteenth-Century British America

In the northern American colonies, especially New England, tight-knit farming families, organized in communities of several thousand people, dotted the landscape by the mid-eighteenth century. New Englanders staked their future on a mixed economy. They cleared forests for timber used in barrels, ships, houses, and barns. They plumbed the offshore waters for fish to feed local populations. And they cultivated and grazed as much of the thin-soiled, rocky hills and bottomlands as they could recover from the forest.

The farmers of the middle colonies-Pennsylvania, Delaware, New Jersey, and New York-set their wooden plows to much richer soils than New Englanders did. They enjoyed the additional advantage of setting an area already partly cleared by Native Americans who had relied more on agriculture than had New England tribes. Thus favored, mid-Atlantic farm families produced modest surpluses of corn, wheat, beef, and pork. By the mid-eighteenth century, ships from New York and Philadelphia were carrying these foodstuffs not only to the West Indies, always a primary market, but also to areas that could no longer feed themselves-England, Spain, Portugal, and even New England.

In the North, the broad ownership of land distinguished farming society from every other agricultural region of the Western world. Although differences in circumstances and ability led gradually toward greater social stratification, in most communities, the truly rich and terribly poor were few and the gap between them small compared with European society. Most men other than indentured servants (servants contracted to work for a specific number of years) lived to purchase or inherit a farm of at least 50 acres. With their family's labor, they earned a decent existence and provided a small inheritance for each of their children. Settlers valued land highly, for owning land ordinarily guaranteed both economic independence and political rights.

By the eighteenth century, amid widespread property ownership, a rising population pressed against a limited land supply, especially in New England. Family farms could not be divided and subdivided indefinitely, for it took at least fifty acres(of which only a quarter could usually be cropped) to support a single family. In Concurd, Massachusetts, for example, the founders had worked farms averaging about 250 acres. A century later, in the 1730s, the average farm had shrunk by two thirds, as farm owners struggled to provide an inheritance for the three or four sons that the average marriage produced.

The decreasing fertility of the soil compounded the problem of dwindling farm size in New England. When land had been plentiful, farmers planted crops in the same field for three years and then let it lie fallow (unplanted) in pasture seven years or more until it regained its fertility. But on the smaller farms of the eighteenth century, farmers had reduced fallow time to only a year or two. Such intense use of the soil reduced crop yields, forcing farmers to plow marginal land or shift to livestock production.

The diminishing size and productivity of family farms forced many New Englanders to move to the frontier or out of the area altogether in the eighteen century. "Many of our old towns are too full of inhabitants for husbandry, many of them living on small shares of land," complained one writer. In Concurd, one of every four adult males migrated from town every decade from the 1740s on, and in many towns migration out was even greater. Some drifted south to New York and Pennsylvania. Others sought opportunities as artisans in the coastal towns or took to the sea. More headed for the colonies, western frontier or north into New Hampshire and the eastern frontier of Maine. Several thousand New England families migrated even farther north to the Annapolis Valley of Nova Scotia. Throughout New England after the early eighteenth century, most farmers' sons knew that their destiny lay elsewhere.

Wherever they took up farming, northern cultivators engaged in agricultural work routines that were far less intense than in the south. The growing season was much shorter, and the cultivation of cereal crops required incessant labor only during spring planting and autumn harvesting. This less burdensome work rhythm let many northern cultivators to fill out their calendars with intermittent work as clockmakers, shoemakers, carpenters, and weavers.

## Feeding Strategies in the Ocean

In the open sea, animals can often find food reliably available in particular regions or seasons (e.g., in coastal areas in springtime). In these circumstances, animals are neither constrained to get the last calorie out of their diet nor is energy conservation a high priority. In contrast, the food levels in the deeper layers of the ocean are greatly reduced, and the energy constraints on the animals are much more severe. To survive at those levels, animals must maximize their energy input, finding and eating whatever potential food source may be present.

In the near-surface layers, there are many large, fast carnivores as well as an immense variety of planktonic animals, which feed on plankton (small, free-floating plants or animals) by filtering them from currents of water that pass through a specialized anatomical structure. These filter-feeders thrive in the well-illuminated surface waters because oceans have so many very small organisms, from bacteria to large algae to larval crustaceans. Even fishes can become successful filter- feeders in some circumstances. Although the vast majority marine fishes are carnivores, in near-surface regions of high productivity the concentrations of larger phytoplankton (the plant component of plankton) are sufficient to support huge populations of filter-feeding sardines and anchovies. These small fishes use their gill filaments to strain out the algae that dominate such areas. Sardines and anchovies provide the basis for huge commercial fisheries as well as a food resource for large numbers of local carnivores, particularly seabirds. At a much larger scale, baleen whales and whale sharks are also efficient filter-feeders in productive coastal or polar waters, although their filtered particles comprise small animals such as copepods and krill rather than phytoplankton.

Filtering seawater for its particulate nutritional content can be an energetically demanding method of feeding, particularly when the current of water to be filtered has to be generated by the organism itself, as is the case for all planktonic animals. Particulate organic matter of at least 2.5 micrograms per cubic liter is required to provide a filter-feeding planktonic organism with a net energy gain. This value is easily exceeded in most coastal waters, but in the deep sea, the levels of organic matter range from next to nothing to around 7 micrograms per cubic liter. Even though mean levels may mask much higher local concentrations, it is still the case that many deep-sea animals are exposed to conditions in which a normal filter-feeder would starve.

There are, therefore, fewer successful filter-feeders in deep water, and some of those that are there have larger filtering systems to cope with the scarcity of particles. Another solution for such animals is to forage in particular layers of water where the particles may be more concentrated. Many of the groups of animals that typify the filter-feeding lifestyle in shadow water have deep-sea representatives that have become predatory. Their filtering systems, which reach such a high degree of development in shallow-water species, are greatly reduced. Alternative methods of active or passive prey capture have been evolved, including trapping and seizing prey, entangling prey, and sticky tentacles.

In the deeper waters of the oceans, there is a much greater tendency for animals to await the arrival of food particles or prey rather than to search them out actively (thus minimizing energy expenditure). This has resulted in a more stealthy style of feeding, with the consequent emphasis on lures and/or the evolution of elongated appendages that increase the active volume of water controlled or monitored by the animal. Another consequence of the limited availability of prey is that many animals have developed ways of coping with much larger food particles, relative to their own body size, than the equivalent shallower species can process. Among the fishes there is a tendency for the teeth and jaws to become appreciably enlarged. In such creatures, not only are the teeth hugely enlarged and/or the jaws elongated but the size of the mouth opening may be greatly increased by making the jaw articulations so flexible that they can be effectively dislocated. Very large or long teeth provide almost no room for cutting the prey into a convenient size for swallowing; the fish must gulp the prey down whole.

## Environmental Impact of the Anasazi

A major question in the archaeology of the southwestern region of the United States is why so many impressive settlements, and even entire regions, were abandoned in prehistoric times. Archaeologist Tim Kohler has suggested that the nature of human-environmental interaction was an important reason in the case of the Anasazi people. The actual case study that Kohler relies on is from the Dolores River basin of southwest Colorado, where the Anasazi seem to have moved in about A.D. 600. Over the following couple of centuries, the population increased, and they aggregated (or gathered) into villages, but by about A.D. 900 the area began to be abandoned. Other archaeologists have identified the immediate cause of this abandonment to be a series of short growing seasons that would have put pressure on corn production at that high an altitude. Kohler, however, assets that a growing population led to human-environmental interactions that caused people to live in villages, intensify agrarian food production, deforest the region, deplete the local soils, and ultimately abandon the area.

Kohler uses several kinds of evidence to show that human effects, not solely climatic factors, were important factors in the abandonment of settlements. One key indicator of change in the environment surrounding these prehistoric settlements is the wood that was used there. Archaeological study of wood charcoal found in hearths dating to the various episodes of occupation indicated that the species use changed in a patterned way. Over time there was a decline in the use of juniper and pinon (native, slow-growing species of trees) and an increase in woody shrubs and fast-growing cottonwood. The species of wood used in the construction of buildings also changed. Fewer pinon were being used, and those that were used seem to be from increasingly old trees, while juniper continued to be from young trees. The implication is that the forest that did remain was changing to relatively more junipers, a tree that is more fire resistant, better able to reproduce in open settings, and less desirable for construction than pinon. Kohler argues that pinon was disappearing from the locale of settlements and that this put an additional nutritional strain on the population, which used nuts from the tree as well as its wood. The relative proportion of different species of animals hunted by people in the region also changed progressively. A final source of evidence was the seeds found in the archaeological deposits, which had blown or been brought to the settlement. As time went on, there was a substantial increase in seeds from pioneer plants, attesting both to agricultural intensification and to an increasingly disturbed local environment.

This evidence has convinced Kohler of the importance of human impact in degrading the local environment. His interpretation of the situation is that by about A.D. 840, people had aggregated into villages in favorable settings because of their competitive organizational advantages over smaller units in the face of growing population and depletion of local wild resources. Hence, the very nature of the initial slash-and-burn agriculture encouraged a further dependence on agriculture and the aggregation of people into denser settlements. However, there are costs to aggregation, such as the increasing distance to usable fields, the heavier pressure on local soils, and the accompanying increase in agricultural risk. The Anasazi responded to this by further intensification, such as water-control mechanisms, to feed the increasing population. Such a trajectory is fraught with risks, but it is also pushed forward by advantages it bestows on its participants who organize and cooperate. Advantages might include sharing food across groups in a village, investment in facilities to improve the processing and storage of food, and cooperative labor pools and social groupings larger than villages, which would enable organized long-distance hunts and participation in trading networks. Larger and larger villages became possible, but this also made the system vulnerable to collapse. A reliance on the management of resources through cooperative action reduced their flexibility of action, so that when poor seasons occurred, people were seriously hurt. Thus an expectable aberration in the climatic regime may have been enough to cause the collapse of the village system in the Dolores area.

## Plant and Animal Life of the Pacific Islands

There are both great similarities and considerable diversity in the ecosystems that evolved on the islands of Oceania in and around the Pacific Ocean. The islands, such as New Zealand, that were originally parts of continents still carry some small plant and animal remnants of their earlier biota (animal and plant life), and they also have been extensively modified by evolution, adaptation, and the arrival of new species. By contrast, the other islands, which emerged via geological processes such as volcanism, possessed no terrestrial life, but over long periods, winds, ocean currents, and the feet, feathers, and digestive tracts of birds brought the seeds of plants and a few species of animals. Only those species with ways of spreading to these islands were able to undertake the long journeys, and the various factors at play resulted in diverse combinations of new colonists on the islands. One estimate is that the distribution of plants was 75 percent by birds, 23 percent by floating, and 2 percent by wind.

The migration of Oceanic biota was generally from west to east, with four major factors influencing their distribution and establishment. The first was the size and fertility of the islands on which they landed, with larger islands able to provide hospitality for a wider range of species. Second, the further east the islands, generally the less the species diversity, largely because of the distance that had to be crossed and because the eastern islands tended to be smaller, more scattered, and remote. This easterly decline in species diversity is well demonstrated by birds and coral fish. It is estimated that there were over 550 species of birds in New Guinea, 127 in the Solomon Islands, 54 in Fiji, and 17 in the Society Islands. From the west across the Pacific, the Bismarck Archipelago and the Solomon Islands have more than 90 families of shore fish (with many species within the families), Fiji has 50 families, and the Society Islands have 30. Third, the latitude of the islands also influenced the biotic mix, as those islands in relatively cooler latitudes, notably New Zealand, were unsuited to supporting some of the tropical plants with which Pacific islands are generally associated.

Finally, a fourth major factor in species distribution, and indeed in the shaping of Pacific ecosystems, was wind. It takes little experience on Pacific islands to be aware that there are prevailing winds. To the north of the equator these are called north-easterlies, while to the south they are called south-easterlies. Further south, from about 30°south, the winds are generally from the west. As a result on nearly every island of significant size there is an ecological difference between its windward and leeward (away from the wind) sides. Apart from the wind action itself on plants and soils, wind has a major effect on rain distribution. The Big Island of Hawaii offers a prime example; one can leave Kona on the leeward side in brilliant sunshine and drive across to the windward side where the city of Hilo is blanketed in mist and rain.

While such localized plant life and climatic conditions are very noticeable, over Oceania as a whole there is relatively little biodiversity, and the smaller the island and the further east it lies, the less there is likely to be. When humans moved beyond the islands of Near Oceania (Australia, New Guinea, and the Solomon Islands), they encountered no indigenous mammals except for flying foxes, fruit bats, and seals on some islands. Other vertebrate species were restricted to flying animals and a few small reptiles. However, local adaptations and evolution over long periods of isolation promoted fascinating species adaptations to local conditions. Perhaps most notable, in the absence of mammals and other predators, are the many species of flightless and ground-nesting birds. Another consequence of evolution was that many small environments boasted their own endemic (native) species, often small in number, unused to serious predation, limited in range, and therefore vulnerable to disruption. In Hawaii, for example, the highly adapted 39 species and subspecies of honeycreepers, several hundred species of fruit flies, and more than 750 species of tree snails are often cited to epitomize the extent of localized Oceanic endemism (species being native to the area).

## The Cosmological Principle

Cosmologists attempt to understand the origin and structure of the universe as a whole. They begin their search with an assumption about the nature of the universe—namely, that in looking out from our vantage point in the cosmos, we see essentially the same kind of universe that an observer stationed in any other part of it, no matter how remote, would see. As far as our telescopes can reach, we see galaxies and clusters of galaxies distributed in more or less the same way in every direction. This assumption that the universe is uniform on a large scale is called "the cosmological principle."

One thing that is certain is that the universe is expanding. In every direction we look, distant galaxies are moving away from each other. Until the 1960s, the expansion of the universe was the primary fact of cosmological significance that cosmological theories had to accommodate. There were two general classes of cosmological theories that fit with the expanding universe: the evolutionary (Big Bang) theory and the steady-state theory.

The essential idea of the evolutionary cosmology is that there was a beginning—a moment of creation at which the universe came into existence in a hot, violent explosion—the Big Bang. In the beginning, the universe was very hot, very dense, and very tiny. As the explosion evolved, the temperature dropped, the distribution of matter and energy thinned, and the universe expanded. From the current observed rate of expansion, we conclude that the creation event occurred between ten and twenty billion years ago.

The steady-state theory is based on an idea called the "perfect cosmological principle." It is "perfect" in that it maintains that the universe is uniform not only in space but in time. Thus it is the hypothesis that the large-scale universe has always been the way it is now and will be this way forever in the future. This view is consistent with philosophical approaches that reject the notion of an absolute beginning of the universe as unacceptable. The steady-state universe would have no beginning and no end.

In an expanding universe, the galaxies move away from each other, spreading matter more thinly over space. On the other hand, the perfect cosmological principle requires that the density of matter in the universe remain constant over time. To make the steady-state theory compatible with the expanding universe, its proponents introduced the notion of continuous creation. As the universe expands and the galaxies move farther apart, new matter—in the form of hydrogen—is introduced into the universe. The rate at which the hypothesized new matter is created is far too small for this creation to be detected with available instruments, but continuous creation provides just enough matter to form new stars and galaxies that fill in the space left by the old ones. Thus in the steady-state universe there is evolution of stars and galaxies, but the general character and the overall density of the universe remains unchanged over time. In this special sense, the steady- state universe itself does not evolve.

Both of these views—steady-state and Bing Bang—allow for cosmic expansion. However, the discovery in the 1960s of a comparatively small star-like objects called quasars tipped the scales in favor of the Big Bang cosmology. Astronomers determined that almost all quasars are very distant. Given how bright quasars appear even at such great distances, astronomers concluded that quasars typically have an output of light that is 1,000 times greater than that of a whole spiral galaxy composed of billions of stars.

Quasars are such distant objects that the light now reaching us from quasars left them billions of years ago. This means that when we observe quasars today we are seeing that state of the universe billions of years ago. Thus the fact that almost all quasars are very far away implies that earlier in the history of the universe quasars were developing more frequently than they are now. This evolution is consistent with the Big Bang theory. But it violates the perfect cosmological principle, and so it is inconsistent with the steady-state view.

## Bird Colonies

About 13 percent of bird species, including most seabirds, nest in colonies. Colonial nesting evolves in response to a combination of two environmental conditions: (1) a shortage of nesting sites that are safe from predators and (2) abundant or unpredictable food that is distant from safe nest sites. First and foremost, individual birds are safer in colonies that are inaccessible to predators, as on small rocky islands. In addition, colonial birds detect predators more quickly than do small groups or pairs and can drive the predators from the vicinity of the nesting area. Because nests at the edges of breeding colonies are more vulnerable to predators than those in the centers, the preference for advantageous central sites promotes dense centralized packing of nests.

The yellow-rumped cacique, which nests in colonies in Amazonian Peru, demonstrates how colonial birds prevent predation. These tropical blackbirds defend their closed, pouchlike nests against predators in three ways. First, by nesting on islands and near wasp nests, caciques are safe from arboreal mammals such primates. Second, caciques mob predators (work together as a group to attack predators). The effectiveness of mobbing increases with group size, which increases with colony size. Third, caciques hide their nests from predators by mixing active nests with abandoned nests. Overall, nests in cluster on islands and near wasp nests suffer the least predation.

Coordinated social interactions tend to be weak when a colony is first forming, but true colonies provide extra benefits. Synchronized nesting, for example, produces a sudden abundance of eggs and chicks that exceeds the daily needs of local predators. Additionally, colonial neighbors can improve their foraging by watching others. This behavior is especially valuable when the off-site food supplies are restricted or variable in location, as are swarms of aerial insects harvested by swallows. The colonies of American cliff swallows, for example, serve as information centers from which unsuccessful individual birds follow successful neighbors to good feeding sites.Cliff swallows that are unable to find food return to their colony, locate a neighbor that has been successful, and then follow that neighbor to its food source. All birds in the colony are equally likely to follow or to be followed and thus contribute to the sharing of information that helps to ensure their reproductive success. As a result of their enhanced foraging efficiency, parent swallows in large colonies return with food for their nestlings more often and bring more food each trip than do parents in small colonies.

To support large congregations of birds, suitable colony sites must be near rich, clumped food supplies. Colonies of pinyon jays and red crossbills settle near seed-rich conifer forests, and wattled starlings nest in large colonies near locust outbreaks. The huge colonies of guanay cormorants and other seabirds that nest on the coast of Peru depend on the productive cold waters of the Humboldt Current. The combination of abundant food in the Humboldt Current and the vastness of oceanic habitat can support enormous populations of seabirds, which concentrate at the few available nesting locations. The populations crash when their food supplies decline during El Nino years.

Among the costs, colonial nesting leads to increased competition for nest sites and mates, the stealing of nest materials, and increased physical interference among other effects. In spite of food abundance, large colonies sometimes exhaust their local food supplies and abandon their nests. Large groups also attract predators, especially raptors, and facilitate the spread of parasites and diseases. The globular mud nests in large colonies of the American cliff swallow, for example, are more likely to be infested by fleas or other bloodsucking parasites than are nests in small colonies. Experiments in which some burrows were fumigated to kill the parasites showed that these parasites lowered survivorship by as much as 50 percent in large colonies but not significantly in small ones. The swallows inspect and then select parasite-free nests in large colonies, they tend to build new nests rather than use old, infested ones. On balance, the advantages of colonial nesting clearly outweigh the disadvantages, given the many times at which colonial nesting has evolved independently among different groups of birds. Still lacking, however, is a general framework for testing different hypothesis for the evolution of coloniality.

## The Climate of Japan

At the most general level, two major climatic forces determine Japan's weather. Prevailing westerly winds move across Eurasia, sweep over the Japanese islands, and continue eastward across the Pacific Ocean. In addition, great cyclonic airflows (masses of rapidly circulating air) that arise over the western equatorial Pacific move in a wheel-like fashion northeastward across Japan and nearby regions. During winter months heavy masses of cold air from Siberia dominate the weather around Japan. Persistent cold winds skim across the Sea of Japan from the northwest, picking up moisture that they deposit as several feet of snow on the western side of the mountain ranges on Honshu Island. As the cold air drops its moisture, it flows over high ridges and down eastern slopes to bring cold, relatively dry weather to valleys and coastal plains and cities.

In spring the Siberian air mass warms and loses density, enabling atmospheric currents over the Pacific to steer warmer air into northeast Asia. This warm, moisture-laden air covers most of southern Japan during June and July. The resulting late spring rains then give way to a drier summer that is sufficiently hot and muggy, despite the island chain's northerly latitude, to allow widespread rice cultivation.

Summer heat is followed by the highly unpredictable autumn rains that accompany the violent tropical windstorms known as typhoons. These cyclonic storms originate over the western Pacific and travel in great clockwise arcs, initially heading west toward the Philippines and southern China, curving northward later in the season. Cold weather drives these storms eastward across Japan through early autumn, revitalizing the Siberian air mass and ushering in a new annual weather cycle.

This yearly cycle has played a key role in shaping Japanese civilization. It has assured the islands ample precipitation, ranging irregularly from more than 200 centimeters annually in parts of the southwest to about 100 in the northeast and averaging 180 for the country as a whole. The moisture enables the islands to support uncommonly lush forest cover, but the combination of precipitous slopes and heavy rainfall also gives the islands one of the world's highest rates of natural erosion, intensified by both human activity and the natural shocks of earthquakes and volcanism. These factors have given Japan its wealth of sedimentary basins, but they have also made mountainsides extremely susceptible to erosion and landslides and hence generally unsuitable for agricultural manipulation.

The island chain's mountains backbone and great length from north to south produce climatic diversity that has contributed to regional differences. Generally sunny winters along the Pacific seaboard have made habitation there elatively pleasant. Along the Sea of Japan, on the other hand, cold, snowy winters have discouraged settlement. Furthermore, although annual precipitation is high in that region, much of it comes as snow and rushes to the sea as spring runoff, leaving little moisture for farming.

Summer weather patterns in northern Honshu, and especially along the Sea of Japan, have also discouraged agriculture. The area is subject to the yamase effect, when cool air from the north sometimes lowers temperatures sharply and damages farm production. The impact of this effect has been especially great on rice cultivation because, if it is to grow well, the rice grown in Japan requires a mean summer temperature of 20° centigrade or higher. A drop of 2°-3° can lead to a 30-50 percent drop in rice yield, and the yamase effect is capable of exceeding that level. This yamase effect does not, however, extend very far south, where most precipitation comes in the form of rain and the bulk of it in spring, summer, and fall, when most useful for cultivation. Even the autumn typhoons, which deposit most of their moisture along the southern seaboard, are beneficial because they promote the start of the winter crops that for centuries have been grown in southern Japan.

In short, for the past two millennia, the climate in general and patterns of precipitation in particular have encouraged the Japanese to cluster their settlements along the southern coast, most densely along the sheltered Inland Sea, moving into the northeast. There the limits that topography imposed on production have been tightened by climate, with the result that agricultural output has been more modest and less reliable, making the risk of crop failure and hardship commensurately greater.

## The Multiplier Effect

The causes behind the rapid development of the Minoan and Mycenaean civilizations in the Aegean during the late third and second millennia B.C.E. have intrigued scholars for years. Until recently, most explanations attributed Aegean development to outside influence. Civilization had emerged in Mesopotamia by 3000 B.C.E, and, some archeologists argued, Mesopotamian trade introduced civilized ideas and technological innovations into nearby, less advanced areas. Others hypothesized that civilization was brought to the Aegean by invasion from some adjacent region, of which Anatolia in modern Turkey seemed the most plausible.

In a work published in 1972, Professor Colin Renfrew approached the problem from a different viewpoint. He argued that the scanty available evidence for invasion or immigration from Anatolia into Greece in the early Bronze Age (about 3300- 2200 B.C.E.) showed that, at most, such incursion was limited, and that it could not be regarded as responsible for the transformation of society there. Trade, though clearly documented, was also an inadequate explanation in itself. To understand the major changes in social organization and complexity that took place, it was necessary, said Renfrew, to determine the impact that new variables emerging in the early Bronze Age may have had on every interrelated aspect of the local social system. The two new major developments he considered were changes in the subsistence economy and the introduction of bronze metallurgy.

The economy of Neolithic Greece was based on growing grains and raising sheep. Early in the third millennium B.C.E., cultivation of grape vines and olive trees also became important in southern Greece and the Aegean Islands. Both crops were eminently suitable for trade and storage in the form of olive oil and wine. They were grown on land that was not suitable for grain farming. Their cultivation required work at a different time of year from that needed by grain crops, and much of this work, such as harvesting, was relatively light. As a result, agricultural yields were substantially increased without disrupting established agricultural practice. That increase in turn allowed, or stimulated, population growth. For the first time there was enough demand for specialized crafts and services to justify the existence of full-time craftspeople, who could be supported from the extra agricultural output.

Some copper artifacts were made during the fourth millennium B.C.E, but there were not many of them and they had little economic or social significance. When, in the third millennium, copper began to be mixed with tin to produce the relatively hard alloy bronze, demand for metal goods grew. Bronze could be used to make a range of useful new tools and weapons and a variety of impressive ornaments. The demand for metalwork stimulated further specialization in crafts such as toolmaking and jewelry making. The new tools promoted the development of other crafts, like carpentry and shipbuilding. Competition for prestigious or useful craft products and for control of their producers helped to heighten both social differences within communities and conflicts between them, resulting in the emergence of local chieftains, who were also in many instances warriors. These chieftains regulated agricultural and craft production, operating a distribution system through which the farmers could obtain tools or ornaments they needed or wanted. The organizational demands of controlled distribution made it necessary to develop methods of measurement and recording, which led to the development of writing.

Renfrew argued that any single innovation would have had a limited or negligible effect on social organization because the inherently conservative nature of societies acts to minimize change. However, the interaction of several simultaneous developments created a multiplier effect. In the Aegean, increased agricultural productivity provided the means to support craft specialization, while bronze metallurgy provided the technology for producing highly valued new products. These factors set in motion a series of changes in other subsystems of society. Those changes in turn resulted in what, in a term borrowed from electronics, are called positive feedback loops—alterations in the workings of a social system that serve to reinforce themselves. Thus Aegean society was transformed from one consisting of basically self-sufficient and egalitarian farming villages to one of prosperous, hierarchical chiefdoms, with palace-dwelling rulers, actively competing with one another both at home and in international trade.

## Two Kinds of Lizards

Lizards can be divided into two types according to the way they look for food: sit-and-wait foragers and active foragers. Sit-and-wait lizards normally remain in one spot from which they can survey a broad area. These motionless lizards detect the movement of an insect visually and capture it with a quick run from their observation site. Sit-and-wait lizards may be most successful in detecting and capturing relatively large insects like beetles and grasshoppers. Active foragers, on the other hand, spend most of their time on the ground surface, moving steadily and poking their heads under fallen leaves and into crevices in the ground. These lizards apparently rely largely on chemical cues to detect insects, and they probably seek out local concentrations of prey such as termites. Active foragers appear to eat more insects than do lizards that are sit-and-wait predators. Thus, the different foraging behaviors of lizards lead to differences in their diets, even when the two kinds of lizards occur in the same habitat.

The different foraging modes also have different consequences for lizards regarding their exposure to predators. A lizard that spends 99 percent of its time resting motionless is relatively inconspicuous, whereas a lizard that spends most of its time moving is easily seen. Sit-and-wait lizards are probably most likely to be discovered and captured by predators that are active searchers, whereas widely foraging lizards are likely to be caught by sit-and-wait predators. Because of this difference, foraging modes may alternate at successive levels in the food chain: insects that move about may be captured by lizards that are sit-and-wait foragers, and those lizards may be eaten by active predators, whereas insects that are sedentary are more likely to be discovered by lizards that are active foragers, and those lizards may be caught by sit-and- wait predators.

The body forms of sit-and-wait foragers may reflect selective pressures different from those that act on active foragers. Sit-and-wait lizards are often stout bodied, short tailed, and colored to match their background. Many of these species have patterns of different-colored blotches that probably obscure the outlines of the lizard's body as it rests motionless on a rock or a tree trunk. Active foragers are usually slim and elongated with long tails, and they often have patterns of stripes that may produce optical illusions as they move. However, one predator-avoidance mechanism, the ability to break off their tails when they are seized by predators, does not differ among lizards with different foraging modes.

What physiological characteristics are necessary to support different foraging modes. The energy requirements of a quick motion that lasts for only a second or two are quite different from those of locomotion that is sustained nearly continuously for several hours. Sit-and-wait lizards and active foragers differ in their relative emphasis on the two ways that most animals use adenosine triphosphate (ATP) a molecule that transports energy within cells for activity and in how long that activity can be sustained. Sit-and-wait lizards move in brief spurts, and they rely largely on anaerobic metabolism to sustain their movements, namely the kind of metabolism that does not use oxygen. Anaerobic metabolism uses glycogen stored in the muscles and produces lactic acid as its end product. It is a way to synthesize ATP quickly (because the glycogen is already in the muscles), but it is not good for sustained activity because the glycogen is quickly exhausted and lactic acid inhibits cellular metabolism. Lizards that rely on anaerobic metabolism can make brief sprints but become exhausted when they are forced to run continuously. In contrast, aerobic metabolism uses glucose that is carried to the muscles by the circulatory system, and it produces carbon dioxide and water as end products. Aerobic exercise can continue for long periods because the circulatory system brings more glucose and carries carbon dioxide away. As a result, active foragers can sustain activity for long periods without exhaustion. Active species of lizards have larger hearts and more red blood cells in their blood than do sit-and-wait species. As a result, each beat of the heart pumps more blood, and that blood carries more oxygen to the tissues of an active species than a sit-and-wait species.

## Distribution of Seaweeds

Seaweeds are multicellular algae that inhabit the oceans. Despite their evolutionary distance from each other, seaweeds— such as brown algae, red algae, and green algae—have in common many aspects of their biology and contributions to the ecology of the seas.

Most species of seaweed are benthic (living on the seafloor); they grow on rock, sand, mud, and coral on the sea bottom. Other species live on other organisms and as part of fouling communities (plants and animals that live on pilings, boat bottoms, and other artificial surfaces). Some seaweeds attach to very specific surfaces, whereas other seaweeds are rather nonselective. In general, seaweeds inhabit about 2 percent of the seafloor. The presence of benthic seaweeds defines the inner continental shelf, where the marine community largely depends on the food and protection that seaweeds provide. Life on the outer continental shelf and in the deep sea is quite different in the absence of seaweeds. The distinction between the inner and outer shelves is based on the compensation depth of algae. The compensation depth is the depth of water at which there is just enough light for algae to survive. At that depth all the oxygen produced by photosynthesis is consumed by the algae's respiration, so that no further growth can occur.

The environmental factors that are most influential in governing the distribution of seaweeds are light and temperature. Some other abiotic (nonliving) factors critical in governing the distribution of seaweeds are duration of tidal exposure and desiccation (drying out), wave action and surge, salinity, and availability of mineral nutrients. The areas of the world most favorable to seaweed diversity include both sides of the North Pacific Ocean, Australia, southwestern Africa, and the Mediterranean Sea.

The vertical and horizontal distributions of seaweeds are limited in part by the availability of sunlight and, therefore, vary by depth, latitude, sea conditions, and season. It was once thought that the vertical distribution of red, brown, and green algae could be explained by their accessory photosynthetic pigments (photosynthetic pigments other than chlorophyll a), the presence of which gives the seaweeds their characteristic colors, a concept known as chromatic adaptation. Because green light penetrates deepest in coastal waters and the accessory pigments of red algae absorb mostly green wavelengths, red algae were thought to extend to the greatest depth. It followed that green algae, which have pigments absorbing mostly blue and red wavelengths that are diminished rapidly in seawater, should be found at the shallowest depths. Because accessory pigments of brown algae absorb intermediate wavelengths of light, brown algae would be expected to be most abundant at intermediate depths. Indeed, some recent evidence would seem to support the hypothesis of chromatic adaptation because the depth record (295 meters, or 973 feet) for seaweeds is held by a yet undescribed species of red algae from the Bahamas. However, the green alga Rhipiliopsis profunda is close behind this record at 268 meters (884 feet).

The concept of chromatic adaptation was proposed in 1883, and the hypothesis was accepted for about 100 years, until it was realized that such zonation did not necessarily occur and that the distribution of seaweeds depended more on herbivory (the consumption of plant material), competition, varying concentration of the specialized pigments, and the ability of seaweeds to alter their forms of growth.

Temperature affects the distribution of seaweeds. The greatest diversity of algal species is in tropical waters. Farther north or south of the equator, the number of species decreases, and the species themselves are different. Many marine algae in colder latitudes are perennials, meaning that they live longer than two years. During the colder seasons only part of the alga remains alive, sometimes only a few cells, but most often a mass of stemlike structures. When the temperature warms up in the spring, this body part initiates new growth. Temperature is not usually a limiting factor for algae that live in tropical and subtropical seas, although temperatures in intertidal areas (those areas between high and low tides) may become too warm and contribute to seasonal mass mortality of many seaweeds and the animals they shelter. At high latitudes, freezing and scouring by ice may eliminate seaweeds from the intertidal and shallow subtidal zones.

## Urban Development in the United States in the Nineteenth Century

In discussing the growth of cities in the United States in the nineteenth century, one cannot really use the term “urban planning,” as it suggests modern concerns for spatial and service organization which, in most instances, did not exist before the planning revolution called the City Beautiful Movement that began in the 1890s. While there certainly were urban areas that were “planned” in the comprehensive contemporary sense of the word before that date, most notably Washington, D.C., these were the exception. Most “planned” in the nineteenth century was limited to areas much smaller than a city and was closely associated with developers trying to make a profit from a piece of land. Even when these small-scale plans were well designed, the developers made only those improvements that were absolutely necessary to attract the wealthy segment of the market. Indeed, it was the absence of true urban planning that allowed other factors to play such an important role in shaping the nineteenth-century American city.

Three forces particularly affected the configuration of urban and suburban areas in the nineteenth century: economics, transportation technology, and demographics. Added to these was the characteristic American preference both for independent living, usually associated with having an individual, free-standing home for one’s family, and for rural living. Economics affected urbanization in two ways. First, economic considerations influenced location decisions for business and industry, which often preempted choice sites. Second, industrial growth generated higher incomes for large segments of the population, which in turn provided more money for larger homes and commuter transportation. Related to economics (since costs to individuals always played a role) were improvements in transportation, from the first horse- drawn buses of the 1820s to electrified street railways at the end of the century. Each transport innovation extended the distance that a person could reasonably travel as a commuter or shopper, while constant system improvements and increased ridership lessened costs.

Demographic patterns also affected urbanization in two ways: first, urban populations grew steadily throughout the century due to immigration from rural areas, principally by those seeking factory work, and emigration from abroad. Therefore cities expanded as new housing had to be provided. Secondly, at the same time that new residents were surging into cities, many urbanites, particularly those of the middle classes, began to leave. While a preference for rural living explained part of this exodus, it was also due to the perception that various urban problems were becoming worse.

Many nineteenth-century urban problems were those that continue to plague cities today— crime, pollution, noise—but others were the direct result of lack of planning and regulation, such as threat of fire, poor sanitation, and shoddy building construction. Fire was a significant problem in urban areas of North America from the time of the first European settlement. Construction with combustible materials coupled with close placement of buildings and the use of open flames in heating, cooking, and lighting meant that the potential for raging fires was ever present. Lack of sanitation, and the ensuring public health problems it created, was a more constant, if less dramatic, urban issue. It was not until the 1860s that any serious, concerted effort was made to develop proper systems for water delivery and sewage removal. In spite of remarkable strides made in the 1870s and 1880s by the newly established profession of sanitary engineering, the common nineteenth-century pattern of individual unprofessionally planned and installed cesspools (underground tanks for holding household sewage) continued. This led to water contamination and the spread of disease by rodents and insects.

Problems of fire and poor sanitation were inextricably linked with the last major urban problem of the nineteenth century—lack of coordination in the physical expansion of cities and their infrastructure systems (systems for providing services such as water, gas, electricity, and sewage). Typically, development was both unplanned and unrestricted, with landowners making all choices of lot size, services, and street arrangement based only on their individual needs in the marketplace. Distortions of streets and abrupt changes in the distance of houses from the street in urban areas, which so clearly delineate where one development ended and another began, were just the most obvious problems that this lack of coordination created.

## Economic Decline in Europe During the Fourteenth Century

After three hundred years of impressive gains in wealth and population, Europe's economy began to slow around 1300. Several factors accounted for the decline. One the most important, though perhaps the least dramatic to relate, was a shift in climate. The remarkably fair weather of the twelfth and thirteenth centuries took a decided turn for the worse in the fourteenth. Chronicler's comments, tree-ring examination, and pollen analysis all indicate that over the course of the fourteenth century Europe's average annual temperature declined approximately two degrees Celsius—which may sound like very little at first, but if one considers current projections about the possible effects of global warming, in which the average annual temperature shift is only one degree Celsius, a rather different impression emerges. As the temperature dropped, shortening the summer growing season and affecting the resilience of certain vegetable species, the wind and rain increased. This meant that crop yields declined precipitously and the agricultural economy began to contract. As food supplies dwindled, costs rose accordingly and cut into the amount of capital that people had available for other purchases or investments. This in turn added to the gradual construction of the commercial economy.

Just as significant were changes in the geopolitics of the Mediterranean world. The decline of the Byzantine Empire, which had dominated the eastern Mediterranean, meant the interruption or trade routes to central and eastern Asia. The rise of new political powers signaled a new era in Mediterranean connections, one in which religious loyalty and ethnic fidelity mattered more than commercial ties. Consequently the movement of goods and services between east and west began to slow. European interest in circumnavigating Africa and exploring westward into the Atlantic Ocean, in fact, originated in the desire to avoid the roadblock in the eastern Mediterranean and to tap directly into the trade with eastern Asia that had long sustained Europe's economic growth.

A more immediate cause of the sputtering economy was an observable absence: since the eleventh century there had been few significant changes in the technology of agriculture. Developments like the wheeled plow, the rotation of crops, and the use of natural fertilizer that had made possible the agricultural revolution of the past two hundred years had had no follow-up. Farming was still conducted in 1300 roughly the same way it had been done in 1100, but with a considerably larger population to feed, there was little surplus left to generate fresh capital. As a consequence, food production fell perilously close to subsistence level. Although the failure of agriculture to keep up with the growing population did not become a crisis until the fourteenth century, clear signs of the problem had already emerged by the middle of the thirteenth century, when occasionally low yields due to bad weather or social disruption revealed how perilous the balance between Europe's population and its food supply had become. Apart from territories beset by war, the tentativeness of the food supply became evident first on the farmlands most recently brought under cultivation during the economic depression of the twelfth century. The less established farmers of these lands frequently did not have the means to survive successive poor harvests. Tenant farmers unable to pay their rents thus began to slip into debt, landlords who depended on rents for their income began to rely increasingly on urban financiers for credit.

Even whole governments became entangled in the credit crisis, England being the most notable example. The cycle of indebtedness was hardly inevitable, but the string of bank failures and commercial collapses in the first half of the fourteenth century was striking. The famed Bardi and Peruzzi banks of Florence (the two largest financial houses of Europe) collapsed spectacularly in the 1340's. They were soon followed by the Riccardi bank of Lucca, whose massive loans had kept the English government afloat for years. Many more houses collapsed in turn.

An important demographic trend resulted from and contributed to the economic malaise: large-scale migration of rural populations into the cities. Europe's overall population growth from 1050 to 1300 had been primarily due to an increase in the number of rural folk. But as economic forces made agrarian life more perilous around 1300, hard-pressed farmers and their families began to migrate to the cities in large numbers in search of work. Many cities doubled in size, and some even tripled, over the course of just one or two generations. Few were capable of absorbing such large numbers of people.

## Saving Soil and Cropland

The world's farmers are literally losing ground on two fronts the loss of soil from erosion and the conversion of cropland to nonfarm uses. Both are well-established trends that reduce agricultural output, but since both are gradual processes, they are often not given the attention they deserve.

The 1930s that threatened to turn the United States Great Plains into a vast desert was a traumatic experience that led to revolutionary changes in American agricultural practices, such as the planting of tree shelterbeltsrows of trees planted beside fields to slow wind and thus reduce wind erosion. Perhaps the most lasting change is strip cropping, the planting of crops on alternate strips with fallowed (not planted) land each year. This permits soil moisture to accumulate on the fallowed strips, while the planted strips reduce wind speed and hence the wind erosion on the idled strips. The key to controlling wind erosion is to keep the land covered with vegetation as much as possible and to slow wind speed at ground level.

One of the time-tested methods of dealing with water erosion is terracing creating hill-side ridges to reduce runoff. Another newer, highly effective tool in the soil conservation tool kit is conservation, which includes both no tillage and minimum tillage. In conventional farming, land is plowed, disked, or harrowed to prepare the seedbed, seed is drilled into the soil with a planter, and row crops are cultivated with a mechanical cultivator two or three times to control weeds. With minimum tillage, farmers simply drill seeds directly into the soil. The only tillage is a one-time disturbance in a narrow band of soil where the seeds are inserted, leaving the remainder of the soil undisturbed, covered by crop residues and thus resistant to both water and wind erosion.

In the United States, where farmers during the 1990s were required to implement a soil-conservation plan on erodible cropland to be eligible for crop price supports, the no-till area went from 7 million hectares in 1990 to nearly 21 million hectares (51 million acres) in 2000, tripling within a decade. An additional 23 million hectares were minimum-tilled, for a total of 44 million hectares of conservation tillage. This total included 37 percent of the corn crop, 57 percent of soybeans, and 30 percent of the wheat. Outside the United States, data for crop year 1998-1999 show Brazil using conservation tillage on 11 million hectares and Argentina on 7 million hectares. Canada, using conservation tillage on 4 million hectares, rounds out the big four. And now no-till farming is catching on in Europe, Africa, and Asia. In addition to reducing soil losses, minimum-till and no-till practices also help retain water and reduce energy use.

Another example of an effort to control soil erosion is the Conservation Reserve Program (CRP). Created in the United States in 1985, the CRP aimed to convert 45 million acres of highly erodible land into permanent vegetative cover under ten-year contracts. Under this program, farmers were paid to plant grass or trees on fragile cropland. The retirement of 35 million acres under the CRP, together with the adoption of conservation practices on 37 percent of all cropland, reduced soil erosion in the United States from 3.1 billion tons in 1982 to 1.9 billion tons in 1997.

Saving cropland is sometimes more difficult than saving the topsoil on the cropland. This is particularly the case when dealing with urban sprawl, where strong commercial forces have influence. With cropland becoming scarce, efforts to protect prime farmland from urban spread are needed everywhere. Japan provides a good example of such efforts. It has successfully protected rice paddies even within the boundaries of Tokyo, thus enabling it to remain self-sufficient in rice, its staple food. In the United States, Portland, Oregon, provides another example. The state adopted boundaries to urban growth twenty years ago, requiring each community to project its growth needs for the next two decades and then, based on the results, draw an outer boundary that would accommodate that growth. This has worked in Oregon because it has forced development back to the city.

## Honeybee Society

Honeybee colonies are essentially societies of females. In a hive of perhaps 20,000 bees, only a few hundred will be male bees, called drones. They are around only in the spring or summerlong enough to rise to treetop level in a comet-like swarm, chasing after one of the queen bees that have assembled from various hives at a mating site. Of the many drones assembled, only 10 to 15 will actually mate with a queen during one of her mating flights. Each drone that is successful dies in the process, however, and a similar fate awaits drones that aren't successful; once mating is done, they will be expelled from their hives or killed.

The week of mating flights prepares the queen for a lifetime of prodigious egg laying; she will produce up to 2,000 fertile eggs a day for years. Nearly all of the offspring that hatch from these eggs are female; they are the hive's worker bees; and they are well named, for it is they who will maintain the hive, forage for food, store the food away, care for newly laid eggs, and more. It is they who will do everything for the colony, in other words, except lay eggs and mate with the queen.

Over their brief adult lives of perhaps six weeks, every worker bee takes on, in a predictable order, nearly all the worker tasks that the hive has to offer. For the first three days of her life, a worker is primarily a cleaner of the cells that the bee larvae (immature, wormlike bees) are stored in. As the days pass, she becomes primarily a larvae feeder, then a hive construction worker, then an entrance guard and food storer, and finally a forager, going out to secure nectar, pollen, and water for the colony. Within this structure, however, a worker's life is one of surprising flexibility. After becoming a construction worker, for example, she still engages in some cell cleaning; and throughout her life, she spends a good deal of time resting and patrolling the hive.

Importantly, there is no chain of command in a colony no group of workers communicating the message more food needed now or cell cleaning needed over here. How, then, does all this work get organized among tens of thousands of bees. Bees are prompted to act either because of environmental conditions (the temperature of the hive, for example) or because of signals or cues they receive from other bees. The signals are explicit acts of communication, as with the famous waggle dance that bees perform to inform their fellow workers of the location of food sites.

Quite often, however, bees are reacting to cues they get from other bees that simply imply a given condition. Take, as an example, a cue that researcher Thomas Seeley confirmed that has to do with unloading time at the hive. In a well-fed hive, forager bees gather food only from flower patches that have lots of nectar. When a hive is near starvation, however, the foragers aren't so choosy; then low-yield flower patches will do. So, how does a forager know whether to be choosy or not  How is she informed of the nutritional status of the colony, in other words Her informational source is the length of time it  takes her to unload her food. Providing the cues are the food-storer bees, which receive the food the foragers bring back and then process it into honey and pack it away in the hive. It takes a returning forager a relatively long time to make contact with a food-storer bee in a well-fed hive, but a relatively short time in a starving hive. Why because in a well-fed hive, the food storers have plenty to keep them busy there is plenty of food to store away. If, however, a forager can make contact with a food storer within 15 seconds of entering the hive, the forager knows the colony is low on food and will start paying visits to low-yield sites. This is but one example of how life in the colony is self-organizing; each bee's behavior is shaped by the behavior of other bees.

## The Upper Paleolithic Revolution

The transition from the historical period known as the Middle Paleolithic to the Upper Paleolithic around 40 to 35 thousand years ago (kya) represents one of the major developments in the prehistory of humankind. The basic features of this transition include more versatile stone implements and the use of antler, bone, and ivory for tools, figurative art, music, and personal decoration. So striking were the strides in human achievement during this period that it is sometimes referred to as the Upper Paleolithic Revolution.

Until recently it had been argued that the Upper Paleolithic Revolution was an archaeological phenomenon found only in Eurasia. The apparent lack of equivalent evidence in other regions suggested that a fundamental change had occurred in human intellectual development around 40 kya in Europe. The recent discovery in the Blombos Cave in South Africa of a block of decorated ochre and then sets of shell beads, dated to around 77 kya, opened up the debate. This supports other evidence of more versatile stone implements and bone tools found in Africa from the same period. Now the Upper Paleolithic Revolution is being seen as simply the most visible example of the evolving process of modern human behavior that had been developing over a much longer timescale.

This raises two further questions. First, what was happening to the human cognitive process during the 40,000 years or so between the creations in the Blombos Cave and the flourishing of human creativity in Europe around 35 kya, and second, was climate change a component Climate change is associated with the sudden occurrence of creative activity in Europe at the beginning of the Upper Paleolithic.

The question of whether the sudden transition seen in Europe was built on earlier developments in Africa has been addressed at length by anthropologists Sally McBrearty and Alison Brooks. They argue that the whole issue of the Upper Paleolithic Revolution stems from a profound Eurocentric bias and a failure to appreciate the depth and breadth of the African archaeological record. In fact, many of the components of this revolution are found earlier in the African Middle Paleolithic tens of thousands of years before they appeared in Europe. These features include blade and microlithic technology, bone tools, increased geographic range, specialized hunting, exploitation of aquatic resources, long-distance exchange networks, systematic processing and use of pigment, and art and decoration. These items do not occur suddenly together as predicted by the revolutionary model, but at sites that are widely separated in space and time. This suggests a gradual assembling of the package of modern human behaviors in Africa and its later export to other regions of the Old World.

The extraordinary range of rock art in Australia adds great weight to the idea that artistic creativity was part and parcel of the intellectual capacity of modern humans that migrated out of Africa around 70 kya. The fact that these people almost certainly arrived in Australia before 60 kya and were, in any case, completely isolated from any evolutionary events that may have occurred in Europe around 40 kya makes this argument compelling.

The consequence of this analysis is that the question of the sudden emergence of creative activity that appears to constitute the Upper Paleolithic Revolution falls to the ground. The obvious explanation is that the gap between African developments and the subsequent better-known European events is a matter of the limitations of the archaeological record. This does not altogether cover the question of why there was the sudden flowering of creativity at the beginning of the Upper Paleolithic in Europe. It may be that earlier creative efforts have either been lost in or have yet to emerge from the mists of time. Recent finds of decorative pierced shells dating from 43 kya or even earlier in caves in parts of western Asia near Europe may be examples of a process extending the evidence back in time. The creative flowering may also be a result of the climatic conditions at the time that governed the movement of modern humans into Europe. Following a period of extreme cold around 39 kya, a period of warming around 35 kya rendered the region more hospitable. As the ancestors of today's Europeans moved into a largely depopulated region, their presence in the archaeological record appeared revolutionary.

## Ocean's Role in Global Warming

To predict what the climate will be like in the future, scientists must rely on sophisticated computer models. These models use mathematical equations to represent physical processes and interactions in the atmosphere, ocean, and on land. A starting point is usually based on current measurements or estimates of past conditions. Then, using a spherical grid laid out over the entire globe, thousands of calculations are performed at grid intersections to represent and assess how conditions in the air, in the sea, and on land will change over time. Because of their complexity and size, supercomputers are used to run full-scale climate models. Much of the uncertainty in their outputs comes from the way that various aspects of the climate are represented by different models, and even more so, because there are aspects of climate that are not well understood a significant decrease in snow one of which is how the ocean impacts climate.

The ocean's role in global warming stems principally from its huge capacity to absorb carbon dioxide and to store and transport heat. In the sea, photosynthesis by marine plants and algae, especially phytoplankton, removes great quantities of carbon dioxide from the atmosphere. Hence, the greater the growth (productivity) of phytoplankton in the sea, the greater the removal of carbon dioxide. But what controls the ocean's productivity. There are several limiting factors, but results from a recent experiment suggest that in areas of the ocean where other nutrients are plentiful, iron may be one of the most important and, until recently, unrecognized variables controlling phytoplankton production. Some have proposed a radical, highly controversial, and uncertain means to counteract global warming adding iron to the oceans to induce phytoplankton blooms. Perhaps increased phytoplankton growth would use up a significant amount of carbon dioxide in the atmosphere, but perhaps not, and there might well be side effects that could be detrimental to the ocean ecosystem.

Within the ocean, the production of limestone, in the form of calcium carbonate skeletons or shells, also reduces atmospheric carbon dioxide. However, when deposits of limestone become exposed and weathered on land or are recycled in the sea, carbon dioxide is released back into the atmosphere. What is not well understood is how much carbon dioxide resides in the sea and at what rate it is taken up and recycled. Relatively new research has also discovered beneath the sea a new and potentially significant threat to skyrocketing Earth temperatures: gas hydrates. Gas hydrates are a solid, crystalline form of water, like ice, except that they contain additional gas, typically methane, and are often found stored in ocean sediments. Increased ocean temperatures could cause gas hydrates to dissociate, releasing massive amounts of methane gas into the atmosphere and cause undersea landslides in the process. Consequently, hydrates may, if released, significantly increase global warming as well as create a geologic hazard to offshore drilling operations.

The ocean is also a great reservoir and transporter of heat. Heat from the ocean warms the atmosphere and fuels tropical storms. Heat is transported by currents from the equator to the poles. Ocean circulation is strongly controlled by wind and by the sea's balance of salt and heat. Scientists think that climate warming may slow down circulation, while cooling may speed it up, but these responses are not well understood. Evaporation from the ocean also supplies the precipitation that creates fields of snow and ice at high latitudes. Snow and ice coverage change the reflectivity of Earth's surface and are an important influence on how much incoming radiation is either absorbed or reflected. Furthermore, clouds and water vapor in the atmosphere come mainly from the sea and strongly influence climate. Surprisingly, clouds are one of the least understood and most poorly modeled parts of the climate change equation. Most climate modeling grids fail to take into account common-sized cloud formations. Aerosols, tiny particles of soot, dust, and other materials, are thought to seed cloud formation, scatter incoming radiation and promote cooling, but this effect, which would counteract warming, is also only superficially understood. Computer models of climate change must take into account all of the processes within the ocean, over land, and in the sky that potentially influence warming. No wonder there is such uncertainty.

## Live Performance

Unlike video and cinema (although sometimes employing elements of both), the theater is a living, real-time event, with both performers and audience mutually interacting, each aware of the other's immediate presence. This turns out to be an extremely important distinction. Distinguished film stars, particularly those with theater backgrounds (as most have), routinely return to the live dramatic stage despite the substantially greater financial rewards of film work and invariably prefer stage acting because of the immediate audience response theater provides, with its corresponding sensations of excitement and presence.

The first of these is the rapport existing between actor and audience. Both are breathing the same air; both are involved at the same time and in the same space with the stage life depicted by the play. Sometimes their mutual fascination is almost palpable; every actor's performance is affected by the way the audience yields or withholds its responses: its laughter, sighs, applause, gasps, silences. Live theatrical performance is always a two-way communication between stage and house.

Second, theater creates a relationship among the audience members. Having arrived at the theaters as individuals or in groups of two or three, the audience members quickly find themselves fused into a common experience with total strangers: laughing at the same jokes, empathizing with the same characters, experiencing the same revelations. This broad communal response is never developed by television drama, which is played chiefly to solitary or clustered viewers who (because of frequent commercial advertisements) are only intermittently engaged, nor is it likely to happen in movie houses, where audience members essentially assume a one-on-one relationship with the screen and rarely (except in private or group screenings) break out in a powerful collective response, much less applause. By contrast, live theatrical presentations generate audience activity that is broadly social in nature: the crowd arrives at the theater at about the same time, people mingle and chat during intermissions, and all depart together, often in spirited conversation about the play. Moreover, they communicate during the play: laughter and applause build upon themselves and gain strength from the recognition that others are laughing and applauding. The final ovation unique to live performance inevitably involves the audience applauding itself, as well as the performers, for understanding and appreciating the theatrical excellence they have all seen together. And plays with political themes can even generate collective political response. In a celebrated example, 1935s Waiting for Lefty was staged as if the audience were a group of union members; by the play's end the audience was yelling Strike! Strike! in response to the play's issues. Obviously, only a live performance could evoke such a response.

Finally, live performance inevitably has the quality of immediacy. The action of the play is taking place right now, as it is being watched, and anything can happen. Although in most professional productions the changes that occur in performance from one night to another are so subtle that only an expert would notice, the fact is that each night's presentation is unique, and everyone present the audience, the cast, and those behind the scenes knows it. This awareness lends an excitement that cannot be achieved by theatrical events that are wholly in the can. One reason for the excitement, of course, is that in live performance, mistakes can happen; this possibility occasions a certain abiding tension, perhaps even an edge of stage fright, which some people say creates the ultimate thrill of the theater. But just as disaster can come without warning, so too can night, each actor is trying to better his or her previous performance, and no one knows when this collective effort will coalesce into something sublime. The actors' constant striving toward self-transcendence gives the theater a vitality that is missing from performances fixed unalterably on videotape or celluloid. But perhaps most appropriately, the immediacy of live performance embodies the fundamental uncertainty of life. One prime function of theater is to address the uncertainties of human existence, and the very format of live performance presents a moment-to-moment uncertainty right before our eyes. Ultimately, this immediate theater helps us define the questions and confusions of our lives and lets us grapple, in the present, with their implications.

## Olmec Art

The earliest Mesoamerican art and architecture to combine ideological complexity, craft, and permanence was that of the Olmecs, whose civilization flourished between about 1500 B.C. and 100 B.C. The early Olmecs established major ceremonial centers along the rich lowlands of the modern Mexican states of Veracruz and Tabasco. At distant Teopantecuanitlan, the Olmecs established a sacred precinct, the first monumental evidence of the Olmecs in the highlands. But the Olmecs had an advanced social and economic system, with networks for commerce extending far to the west and south. The fertile gulf plain probably allowed for an agricultural surplus, controlled by only a handful of individuals. From the art and architecture of their ceremonial centers (we know too little about Olmec domestic life to call their sites cities), it is clear that for the Olmecs, social stratification was sufficiently advanced for their society to place great importance on the records of specific individuals, particularly in the form of colossal heads (enormous stone sculptures of human heads and faces).

Long before modern radiocarbon dating testified to the antiquity of this culture, archaeologists and art historians had become aware of the power of Olmec art through individual objects. Some even identified the Olmec culture as the oldest of Mesoamerican civilizations, perhaps a mother culture from which all others derived, as the art historian Miguel Covarrubias once thought. Eventually the antiquity of Olmec culture was confirmed, and today many important elements of Mesoamerican art and architecture can be seen to have had a probable Olmec origin: ball courts, pyramids, portraiture, and mirrors. Some later Mesoamerican deities probably derive from Olmec gods, and even the famous Maya calendar was already in use by peoples in the Olmec area at the dawn of Maya civilization.

One of the first important Olmec objects to come to modern attention was the Kunz axe, acquired in the 1860s in Oaxaca, Mexico. The ceremonial axe puzzled and intrigued investigators for years because on the one hand, it was clearly neither Aztec nor Maya, the best-known ancient Mesoamerican cultures, and in fact it had no features that could be linked with any known civilization, while on the other hand, it had surely been made in Mesoamerica in antiquity.

The axe exhibits many qualities of the style we now call Olmec: precious blue-green translucent jade, worked to reveal a figure in both two and three dimensions. More than half the axe is devoted to the creature's face, an open, toothless mouth, and closely set, slanting eyes which has often been likened to the face of a howling human infant. The creature's hands are worked in lower relief, and in them he grasps a miniature version of himself. Feet and toes are indicated only by incision (carved lines), and incision also marks the face, ears, and upper body, perhaps to suggest tattooing, ear ornaments, and a tunic. For over two millennia this large, precious axe was presumably kept as a treasure or heirloom. It was not until 1955, after several seasons of excavation at La Venta had produced many fine jade objects and a convincing series of radiocarbon dates in the first millennium B.C., that objects such as the Kunz axe were at last understood by scholars to embody the principles of the first great art style of Mesoamerica.

Early scholars of the Olmec style noticed a pattern of imagery repeated on many of the carved stone objects. Many howling baby faces were found, and other faces seemed to combine the features of humans and jaguars (large cats). Today, while the presence of jaguar imagery is still acknowledged, scholars have discovered that aspects of many other tropical rainforest fauna can be identified in the carvings. The caiman (a kind of alligator), eagle, toad, jaguar, and snake all appear in the Olmec supernatural repertoire. Anthropologist Peter David Joralemon has suggested that most of the motifs and images can be allocated to a few Olmec deities. The paw-wing motif, for example, can be shown to be an element of the winged dragon, itself perhaps derived from the eagle and caiman. This whole intricate symbolic code appears to have been in use from the first appearance of the Olmecs, and to have been employed consistently for a thousand years.

## Extinctions at the End of the Cretaceous

It has long been recognized that the dinosaurs disappeared from the fossil record at the end of the Cretaceous period (65 million years ago), and as more knowledge has been gained, we have learned that many other organisms disappeared at about the same time. The microscopic plankton (free-floating plants and animals) with calcareous shells suffered massively. The foundation of the major marine food chain that led from the minute plankton to shelled animals to large marine reptiles had collapsed.

On land it was not only the large animals that became extinct. The mammals, most of which were small, lost some 35 percent of their species worldwide. Plants were also affected. For example, in North America 79 percent did not survive, and it has been noted that the survivors were often deciduous. They could lose their leaves and shut down while others could survive as seeds. As in the sea, it seems that on the land one key food chain collapsed: the one with leaves as its basic raw material. These leaves were the food of some of the mammals and of the herbivorous dinosaurs, which in turn were fed on by the carnivorous dinosaurs. Furthermore, it is most likely that these large dinosaurs had slow rates of reproduction, which always increases the risk of extinction. Crocodiles, tortoises, birds, and insects seem to have been little affected. The two first named are known to be able to survive for long periods without food, and both can be scavengers (feed on dead material). Indeed, with the deaths of so many other animals and with much dead plant material, the food chain based on detritus would have been well-supplied. Many insects feed on dead material; furthermore, most have at least one resting stage in which they are very resistant to damage. In unfavorable conditions some may take a long time to develop: there is a record of a beetle larva living in dead wood for over 40 years before becoming an adult. Some birds were scavengers, but the survival of many lineages is a puzzle.

What happened in the biological story just after these extinctions what is found in and just above the boundary layer between the deposits of the Cretaceous and those of the Tertiary (65¨C2.6 million years ago), termed the K/T boundary For a very short period the dominant microorganisms in marine deposits were usually diatoms and dinoflagellates (both single-celled types of plankton). The important feature for the survival of both these groups was the ability to form protective cysts (sacs around organisms) that rested on the sea floor. Above these, in the later deposits, are the remains of other minute plankton, but the types are quite different from those of the Late Cretaceous. In terrestrial deposits a sudden and dramatic increase in fern plant spores marks the boundary in many parts of the world; ferns are early colonizers of barren landscapes. The fern spike (sudden increase), as it is termed, has been found also in some marine deposits (such was the abundance of fern spores blown around the world), and it occurs in exactly the same layer of deposit where the plankton disappear. We can conclude that the major marine and terrestrial events occurred simultaneously.

Many theories have been put forward for the extinction of the dinosaurs, but most of them can be dismissed. Since 1980 there have been more focused, but still controversy-ridden, investigations. In that year Louis and Walter Alvarez and colleagues from the University of California published their research on the amounts of various metals in the boundary between Cretaceous and Tertiary rocks (K/T boundary) in Italy, Denmark, and New Zealand. They had found, accidentally, that a rare metal, iridium, suddenly became very abundant exactly at the boundary and then slowly fell away. This phenomenon, known as the iridium spike, has now been identified in K/T boundary deposits in over a hundred other sites in the world. Iridium occurs in meteorites and volcanic material, but in the latter case it is accompanied by elevated levels of nickel and chromium. These other metals are not especially abundant at the K/T boundary. The Alvarezes concluded that the iridium spike was due to a large asteroid that struck Earth 65 million years ago.

## The Geographical Distribution of Gliding Animals

Southeast Asia has a unique abundance and diversity of gliding animals flying squirrels, flying frogs, and flying lizards with wings of skin that enable them to glide through the tropical forest. What could be the explanation for the great diversity in this region and the scarcity of such animals in other tropical forests Gliding has generally been viewed as either a means of escaping predators, by allowing animals to move between trees without descending to the ground, or as an energetically efficient way of traveling long distances between scattered resources. But what is special about Southeast Asian rain forests

Scientists have proposed various theories to explain the diversity of gliding animals in Southeast Asia. The first theory might be called the tall-trees hypothesis. The forests of Southeast Asia are taller than forests elsewhere due to the domination of the dipterocarp family: a family of tall, tropical hardwood trees. Taller trees could allow for longer glides and the opportunity to build up speed in a dive before gliding. The lower wind speeds in tall-tree forests might also contribute by providing a more advantageous situation for gliding between trees. This argument has several flaws, however. First, gliding animals are found throughout the Southeast Asian region, even in relatively short-stature forests found in the northern range of the rain forest in China, Vietnam, and Thailand. Some gliders also thrive in low secondary forests, plantations, and even city parks. Clearly, gliding animals do not require tall trees for their activities. In addition, many gliding animals begin their glides from the middle of tree trunks, not even ascending to the tops of trees to take off.

A second theory, which we might call the broken-forest hypothesis, speculates that the top layer of the forest. The tree canopy has fewer woody vines connecting tree crowns in Southeast Asian forests than in New World and African forests. As a result, animals must risk descending to the ground or glide to move between trees. In addition, the tree canopy is presumed to be more uneven in height in Asian forests, due to the presence of the tall dipterocarp trees with lower trees between them, again favoring gliding animals. Yet ecologists who work in different regions of the world observe tremendous local variation in tree height, canopy structure, and abundance of vines, depending on the site conditions of soil, climate, slope elevation, and local disturbance. One can find many locations in Southeast Asia where there are abundant woody vines and numerous connections between trees and similarly many Amazonian forests with few woody vines.

A final theory differs from the others in suggesting that it is the presence of dipterocarp trees themselves that is driving the evolution of gliding species. According to this view, dipterocarp forests can be food-deserts for the animals that live in them. The animals living in dipterocarp forests that have evolved gliding consist of two main feeding groups: leaf eaters and carnivores that eat small prey such as insects and small vertebrates. For leaf-eating gliders the problem is not the absence of any leaves but the desert-like absence of edible leaves. Dipterocarp trees often account for 50 percent or more of the total number of canopy trees in a forest and over 95 percent of the large trees, yet dipterocarp leaves are unavailable to most vertebrate plant eaters because of the high concentration of toxic chemicals in their leaves. Many species of gliding animals avoid eating dipterocarp leaves and so must travel widely through the forest, bypassing the dipterocarp trees, to find the leaves they need to eat. And gliding is a more efficient manner of traveling between trees than descending to the ground and walking or else jumping between trees.

Many carnivorous animals also may need to search more widely for food due to the lower abundance of insects and other prey. This is caused by dipterocarps' irregular flowering and fruiting cycles of two- to seven-year intervals, causing a scarcity of the flowers, fruits, seeds, and seedlings that are the starting point of so many food chains. The lower abundance of prey in dipterocarp forests forces animals such as lizards and geckos to move between tree crowns in search of food, with gliding being the most efficient means.

## Thermal Stratification

Physical characteristics of aquatic environments at different depths such as salt level, light, inorganic nutrients, degree of acidity, and pressure all play key roles in the distribution of organisms. One of the most important physical features is thermal stratification.

When solar radiation strikes water, some is reflected, but most penetrates the surface and is ultimately absorbed. Although water may appear transparent, it is much denser than air and absorbs radiation rapidly. In clear water, 99 percent of the solar radiation is absorbed in the upper 50 to 100 meters. Longer wavelengths of light are absorbed first; the shorter wavelengths (which have more energy) penetrate farther, giving the depths their characteristic blue color.

This rapid absorption of sunlight by water has two important consequences. First, it means that photosynthesis the process by which plants use the energy of sunlight to produce the organic carbon compounds necessary for life can only occur in surface waters where the light intensity is sufficiently high. Species that produce their own organic carbon compounds are called primary producers, and they are the base of the marine food web. Virtually all of the photosynthesis that supports the rich life of oceans and lakes comes from plants living in the upper 10 to 30 meters of water. Along shores and in very shallow bodies of water, some species such as kelp are rooted to the bottom. These plants may attain considerable size and structural complexity, and may support diverse communities of organisms. In the open waters that cover much of the globe, however, the primary producers of organic carbon are tiny, often one-celled algae (called phytoplankton), which are suspended in the water. Zooplankton, tiny invertebrates that feed on phytoplankton, migrate vertically on a daily cycle: up into the surface waters at night to feed and down into the dark, deeper waters during the day to escape predatory fish that rely on light to detect prey.

Second, the rapid absorption of sunlight by water means that only surface water is heated. The density of pure water is greatest at 4??C and declines as the water's temperature rises above or falls below this point. When solar radiation heats the water surface above 4??C, the warm surface water becomes lighter than the cool, deeper water, and so tends to remain on the surface, where it may be heated further and become even less dense. In tropical areas and in temperate climates during the summer, the surfaces of oceans and lakes are usually covered by a thin layer of warm water. Unless these bodies of water are shallow, the deep water below this layer is much colder (sometimes near 4??C). The change in temperature between the warm surface water and the cold, deep water is called the thermocline. Mixing of the surface water by wave action determines the depth of the thermocline and maintains relatively constant temperatures in the water above it.

Tropical lakes and oceans show pronounced permanent stratification of their physical properties, with warm, well- oxygenated, and lighted surface water giving way to frigid, dark, deep water almost devoid of oxygen. Oxygen cannot be replenished at great depths where there are no photosynthetic organisms to produce it, and the stable thermal stratification prevents mixing and reoxygenation by surface water. Only relatively few organisms can live in such extreme conditions. The waste products and dead bodies of organisms living in the surface waters sink to the depths, taking their mineral nutrients with them. The lack of vertical circulation thus limits the supply of nutrients to the phytoplankton above. Consequently, deep tropical lakes are often relatively unproductive and depend on continued input from streams for the nutrients required to support life.

The situation is somewhat different in temperate and polar waters. Deep lakes, in particular, undergo dramatic seasonal changes: they develop warm surface temperatures and a pronounced thermocline in summer, but freeze over in winter. Twice each year, in spring and fall, the entire water column attains equal temperature and equal density; moderate winds may then generate waves that mix deep and shallow water, producing what is called overturn. This semiannual mixing carries oxygen downward and returns inorganic nutrients to the surface. Phosphorus and other nutrients may be depleted during the summer; overturn replenishes these nutrients by stimulating the growth of phytoplankton.

## Gondwana

Among the enduring legacies of the famous European voyages of discovery in the eighteenth and nineteenth centuries are a collection and scientific description of plants and animals from around the world. These form the nucleus of the great collections in modern museums and have been responsible for a radical revision in the way that we perceive the structure of Earth and the forces that have shaped its surface over time. As the fauna and flora from far-flung lands came to be described and incorporated into the body of knowledge about the world, it was noted that there were some striking similarities among living and extinct organisms of the Southern Hemisphere continents. In the 1840s, the English botanist Sir Joseph Dalton Hooker commented on the remarkable fact that the flora of South America and Oceania (mainly Australia, New Zealand, New Guinea, and the Malay Archipelago) shared seven families of flowering plants and 48 genera that were not to be found elsewhere. Later, similar patterns were observed in other groups of plants and animals, such as liverworts, lichens, mayflies, midges, and various types of vertebrates. How could these similarities be explained in view of the enormous stretches of ocean that separate the Southern Hemisphere continents today. One idea developed during the late nineteenth century was that there existed in the remote geological past a vast Southern Hemisphere continent in other words, that the modern continents of the Southern Hemisphere were somehow connected long ago, thus explaining the similarities in fauna and flora. The name given to this hypothetical continent was Gondwana.

One of the most distinctive fossil plants of this hypothetical continent is called Glossopteris. When first described by the French paleobotanist Adolphe Brongniart in 1828, Glossopteris was thought to be a type of fern. Now, however, it is known to be a woody seed-bearing shrub or tree. The trunks of Glossopteris could reach 4 meters in height. Seeds and pollen-containing organs were borne in clusters at the tips of slender stalks attached to the leaves, but some species may have borne seeds in cones. It is thought that Glossopteris lived in a seasonal environment, and this is consistent with the occurrence of growth rings in the wood. Also, there is evidence that the plant was deciduous (that is, that it shed its leaves annually at the end of the growing season) and that it grew under very wet soil conditions, like the modern swamp cypress. The large leaves of Glossopteris which exceeded 30 centimeters in length are common fossils in rocks of the Permian period (299¨C251 million years ago) in India, Africa, South America, Australia, and Antarctica.

At the time the Gondwana hypothesis was conceived, the prevailing theory of Earth saw continents as fixed in their relative positions. The problem of linking up the various elements of Gondwana was solved by hypothesizing the existence of ancient land bridges. This changed in 1912 with the proposal of the theory of continental drift by the German meteorologist and geophysicist Alfred Wegener, an idea that was later developed and championed by the famous South African geologist Alex Logan du Toit. Wegener and du Toit argued that the continents are not fixed; rather, they have moved apart or drifted to their present-day positions. In the past, Gondwana was a single contiguous landmass comprising the present-day Southern Hemisphere continents.

These ideas seemed incredible at the time, but in support of their theory Wegener and du Toit pointed to similarities in fauna and flora, and the distributions of fossils such as Glossopteris provided an important piece of evidence in the assembly of the Gondwana jigsaw puzzle. Wegener and du Toit also drew together other different sources of evidence, such as the remarkable geometric fit of South America and Africa, and similarities between the ages and types of rock found in areas of Southern Hemisphere continents that are now thousands of miles apart. The notion of drifting continents only became widely accepted in the 1960s following the discovery of paleomagnetism (the study of changes in the polarity of Earth's magnetic field through time) and the development of the theory of plate tectonics, which explained the growth and movement of continents and other geological phenomena.

## Mesopotamian and Egyptian Settlement Patterns

On the basis of available evidence, there existed in ancient state-level societies a variety of urban types. These have been classified under a number of different headings, ranging from city-states to territorial- or village-states. Mesopotamia and Egypt, for example, traditionally represent the two opposing extremes along a spectrum of possible settlement distributions and types.

Mesopotamian city-state systems were made up of densely populated urban areas that shared a common language, status symbols, and economic systems, but their elites tended to compete with each other, often militarily, to control territory, trade routes, and other resources. Each city-state controlled a relatively small territory, often only a few hundred square kilometers, and had its own capital city, which in many cases was enclosed by a wall. In addition to its capital, a city-state might govern a number of smaller centers, as well as numerous farming villages and hamlets. Ancient Sumer is a classic example of such a system.

In ancient Mesopotamia, urban centers tended to be relatively large, with populations ranging from less than 1,000 to more than 100,000 inhabitants, depending on the ability of a particular city-state to control and collect payments from its neighbors. Often, a considerable number of farmers lived in these centers to secure greater protection for themselves and their possessions. It is estimated that in southern Mesopotamia (circa 2900¨C2350 BC) more than 80 percent of the total population lived in cities.

These cities also supported craft production, which sought to satisfy the demands of the urban elite and society as a whole. The development of craft specialization and commercial exchanges between town and countryside as well as between neighboring urban centers encouraged the growth of public markets. Although the evidence for actual marketplaces is less than clear for southern Mesopotamia, the remnants of shop-lined streets indicate vigorous commercial activity involving large numbers of people. This activity in turn promoted competition among city-states to obtain supplies of exotic raw materials. As a result of widespread access to goods produced by full-time specialists and the development of more intensive agriculture close to urban centers, Mesopotamian city-states were able to support numerous nonfood producers, possibly as high a proportion as 20 percent of the total population.

In contrast to Mesopotamia, ancient Egypt's population has traditionally been perceived as more evenly dispersed across the landscape, a characteristic of village-states. Topography and the formation of the early state were the major factors contributing to this dispersal. Unlike Mesopotamia, Egypt had relatively secure and defined borders, allowing a single state to dominate the area. Additionally, the villages and towns of Egypt, all of which were situated near the Nile on the river's narrow flood plain, had approximately equal access to the river and did not have to compete among themselves for water as their contemporaries in Mesopotamia were forced to do. As the main highway through Egypt, the Nile offered innumerable harbors for shipping and trading, so there was no strong locational advantage to be gained in one area as opposed to another; hence the Egyptian population generally remained dispersed throughout the valley and delta in low densities. Trade specialists apparently were evenly spread throughout Egypt, supported by both independent workshops in small towns and royal patronage in the territorial capitals. In contrast to the defensive walls of Mesopotamian city-states, the walls of Egyptian towns primarily defined and delineated sections of the town (for example, a temple precinct from a residential area).

Egypt, however, was not without urban centers. At points where goods entered the Nile valley via maritime routes or overland routes from the Red Sea via wadis (stream beds that remain dry except during the rainy season), the right circumstances existed for the growth of larger cities. Egyptian cities and towns shared certain characteristics with other contemporary societies but also displayed unique traits influenced by the culture and environment of the Nile valley. Thus, the geopolitical system that evolved in ancient Egypt was different from that of Mesopotamia; Egypt developed a village or territorial state characterized by dispersed settlements of varying size, a form of urbanism that gave Egypt its distinctive identity.

## Primitive and Advanced Termite Species

Termites are insects that collect vegetation, chew it up, and leave the chemical breakdown to other organisms. There are two strategies. The most primitive termites swallow the chewed vegetation and pass it to a fermentation chamber in their bodies. There, anaerobic bacteria break down the cellulose, an organic compound that forms about 33 percent of all plant matter. The termites are nourished by the ever-growing population of microorganisms in their guts that turn the grass, leaves, and twigs the insects ingest into glucose. Cattle do much the same thing: they allow bacteria to ferment the cellulose in an airtight rumen (digestive chamber), and then digest the bacteria.

Termite evolution has several obvious trends, from primitive species, which live in small hidden colonies, to groups millions strong, the builders of enormous mounds that allow for heat and gas exchange. The less advanced groups digest microorganisms, which do the real work of breaking food down. The culture (colony) of cellulose digesters is passed along through a special exchange. Young termites feed on a special liquid secretion provided by adults, rich in the group's digestive heritage. When reproductive termites those destined to produce offspring leave the nest, they carry in their stomachs the microorganisms essential for the digestive success of their offspring. Treat a colony of these termites with an antibiotic solution, and they will slowly starve to death.

More advanced species have a different feeding strategy. The energy source is still cellulose, but it is digested outside the termite's body. Not having to carry around large chambers of slowly fermenting cellulose solution makes these species more nimble and efficient. Foragers bring twigs and leaves back to special areas and chew them. They then transplant bits of fungus growing on other pieces of nearby vegetation onto the gnawed edges, where the fungi break down the cellulose. Fungi is the only kingdom of organisms able to digest cellulose in air, though they need warmth and humidity to do the job efficiently. This is just what the termites provide. Moreover, these social insects carefully tend the fungus-covered vegetation by treating it with antibiotics they secrete to keep bacterial growth to a minimum. When it is time for the fungus to reproduce, pieces are carried into the open to complete the life cycle. Some species of fungi are found only in termite mounds of a particular species; without their caretakers, these fungi would die. Needless to say, the termites eat the fungi; neither can live without the other. Reproductive termites even carry a chunk of fungi when they leave on mating flights.

The evolutionary trend in termites is to forsake excavated nests in soil or wood, like those of most ants, for carton nests constructed inside excavations or on trees. (When referring to termites, carton means, broadly, nesting material consisting of a mix of adhesive saliva or feces with earth or pulp, and even sand, to create cells, floors, walls, graceful arches, tiered roofs, chimney stacks, and buttressed towers up to twenty feet high.) Primitive termites do not store food; they live from hand to mouth, inside a rotting tree, for instance. Advanced termites have special carton areas for food they hold in reserve; these supplies consist of nonperishable material such as grass clippings, analogous to the hay and straw fed to cattle in the winter, and are kept in a dry carton loft. Primitive species need wet cellulose, such as damp wood; more advanced species can also process dry material.

To expand their niche in this way, dry-diet termites require a source of water. In arid habitats, they excavate vertical tunnels down to the water table, as much as 150 feet below, which fan out at the base to increase the area of contact and thus maximize the rate of subsurface water accumulation. Finally, less advanced termites remain their entire lives in tunnels and cells excavated in or near wood. More complex species, on the other hand, search for food away from a central nest. To ensure that they can work in safety, they burrow shallowly through the earth or build mud-covered tunnels on the surface of the ground or trees and around the food they wish to harvest.

## Individual Performance and the Presence of Others

A person's performance on tasks can be enhanced or impaired by the mere presence of others, and a person's behavior as part of a group can be quite different from the person's behavior when acting alone. In certain cases, individual performance can be either helped or hindered by the physical presence of others. The term social facilitation refers to any effect on performance, whether positive or negative, that can be attributed to the presence of others. Research on this phenomenon has focused on two types of effects: audience effects (the impact of passive spectators on performance) and coaction effects (the effect on performance caused by the presence of other people engaged in the same task).

In one of the first studies in social psychology, psychologist Norman Triplett looked at coaction effects. He had observed in official bicycle records that bicycle racers pedaled faster when they were pedaling against other racers than when they were racing against the clock. Was this pattern of performance peculiar to competitive bicycling Or was it part of a more general phenomenon whereby people work faster and harder in the presence of others than when performing alone Triplett set up a study in which he told 40 children to wind fishing reels as quickly as possible under two conditions: alone or in the presence of other children performing the same task. He found that the children worked faster when other reel turners were present than when they performed alone.

Later studies on social facilitation found just the opposite effect that the presence of others, whether co-acting or just watching, could hurt or diminish individual performance. Social psychologist Robert Zajonc proposed an explanation for these seemingly contradictory effects. He reasoned that we become aroused by the presence of others and that arousal facilitates the dominant response, the one most natural to us. On simple tasks and on tasks at which we are skilled, the dominant response is to perform effectively. However, on tasks that are difficult or tasks we are just learning, the incorrect response (making a mistake or not performing effectively) is dominant. This reasoning accounts for the repeated findings that, in the presence of others, performance improves on tasks that people do easily but suffers on difficult tasks. Other researchers have suggested that concern over the observers' evaluation is what most affects people's performance, particularly if they expect a negative evaluation.

What happens in cooperative tasks when two or more people are working together instead of competing Do they increase their effort or slack off Researcher Bibb Latan¨|used the term social loafing to refer to people's tendency to exert less effort when working with others on a common task than when they work alone Social loafing occurs in situations where no one person's contribution to the group can be identified and individuals are neither praised for a good performance nor blamed for a poor one. In one experiment, Latan¨| and others asked male students to shout and clap as loudly as possible, first alone and then in groups. In groups of two, individuals made only 71 percent of the noise they had made alone; in groups of four, each student put forth 51 percent of his solo effort; and with six students, each made only a 40 percent effort.

Harkins and Jackson found that social loafing disappeared when participants in a group believed that each person's performance could be monitored and evaluated; indeed, even the idea that the group performance may be evaluated against some standard can be sufficient to eliminate the loafing effect. When a group is relatively small and group evaluation is important, some members will even expend extra effort if they know that some of their coworkers are unwilling, unreliable, or incompetent to perform well. Moreover, social loafing is unlikely when participants can evaluate their own individual contribution or when they have a personal stake in the outcome. It is also unlikely when participants feel that the task is challenging or when they are working with close friends or teammates. Some 80 experimental studies have been conducted on social loafing in diverse cultures. Based on evidence these studies have produced, social loafing probably occurs in almost all cultures.

## Features of Tropical Mammals

There are several important features of tropical mammals and their habitats that differentiate them from temperate-zone mammals. First, tropical mammals face different environmental stresses than do temperate-zone mammals, and they respond to stresses in different ways. Many temperate-zone mammals, of course, must endure extreme variation within a year; from cold winters with snow and low food supplies to hot summers with dry weather and abundant food. Many mammals respond with hibernation, staying more or less dormant for several months until conditions improve. Tropical mammals, except in the high-altitude mountains, do not encounter such extreme annual changes, but they do face dry seasons, up to five months long, that sometimes severely reduce food supplies. For some surprising reasons, they cannot alleviate this stress by hibernating, waiting for the rainy season to arrive with its increased food supplies. When a mammal in Canada or Alaska hibernates, many of its predators leave the area. This is not the case in the tropics. A mammal sleeping away the dry season in a burrow would be easy prey to snakes and other predators. Moreover, a big danger to sleeping mammals would be army ants. These voracious insects are very common in the tropics and would quickly eat a sleeping mouse or squirrel. Also, external parasites, such as ticks and mites, which are inactive in extreme cold, would continue to be very active on sleeping tropical mammals, sucking blood and doing considerable damage. Last, the great energy reserves needed to be able to sleep for an extended period through warm weather may be more than any mammal can physically accumulate. Therefore, tropical mammals need to stay active throughout the year. One way they counter the dry season's reduction in their normal foods is to switch food types seasonally. For instance, some rodents that eat mostly insects during the rainy season switch to seeds during the dry season; some bats that feed on insects switch to dry-season fruits.

The abundance of tropical fruit brings up another interesting difference between temperate and tropical mammals: a surprising number of tropical mammals eat a lot of fruit, even among the carnivore group, which, as its name implies, should be eating meat. All the carnivores in Brazil, save pumas, jaguars, and otters, are known to eat fruit on occasion. Upon reflection, however, it makes sense that these mammals consume fruit. Fruit is very abundant in the tropics, available throughout much of the year, and, at least when it is ripe, easily digested by mammalian digestive systems. A consequence of such frugivory (fruit eating) is that many mammals have become, together with frugivorous birds, major dispersal agents of fruit seeds, which they spit out or which travel unharmed through their digestive tracts to be deposited in feces far from the mother tree. Some biologists believe that, even though the carnivores plainly are specialized for hunting down, killing, and eating animal prey, it is likely that fruit has always been a part of their diet.

Finally, there are some differences in the kinds of animals inhabiting tropical and temperate regions. For instance, in tropical regions there are few social rodents like beavers and prairie dogs and very few rabbit species. On the other hand, some groups occur solely in the tropics and do extremely well there. There are about 75 to 100 species of New World monkeys (depending on which primate specialist you consult), all of which occur in tropical areas. Arboreal (tree-living) mammals such as monkeys and sloths are plentiful in tropical forests, probably because there is a rich, resource-filled, dense canopy to occupy and feed in. The closed canopy blocks light to the ground, which allows only an undergrowth that is sparse and poor in resources, and consequently permits few opportunities for mammals to live and feed there. Bats thrive in the tropics, being very successful both in terms of number of species and in their abundances. Nine families of bats occur in Brazil, including more than 140 species; only four families and 40 species occur in the entire United States, an area similar in size to Brazil. While most North American bats feed on insects, the diets of Brazilian bats are more varied and include fruit, nectar, and fish.

## Europe in the High Middle Ages

For 500 years after the fall of the Western Roman Empire in 476 A.D., a period known as the early middle Ages, Europe endured an age of political instability, economic decline, and reduced population. But as the millennium approached, the situation began to improve. Toward the end of the tenth century, an increase in the amount of crop-producing land was accompanied by an increase in population, with the potential for that number to rise even higher. The increase in agricultural production came about as a result of a combination of factors, the most prominent of which were changing methods of field management and improvements in agricultural technology.

For much of the early Middle Ages, peasants continued the Roman practice of dividing their fields in two leaving one fallow, or uncultivated, for a year, and planting their crops in the other half. Fallow land restored its nutrients, but the practice meant that half the land produced nothing every year. In southern Europe with its drier climate this system of two-field crop rotation continued, but in northern Europe, peasants improved on this system by dividing their land into three parts. One they left fallow, another they planted in the spring, and the third they planted with winter crops. This three-field crop rotation, dependent on more rainfall than southern Europe received, meant that two-thirds instead of one- half of a peasant's land was under production in one year.

Related to the changes in crop rotation were improvements in plows and animal harnessing. More land under cultivation spurred experimentation in the construction of plows. Peasants attached wheels to their plows, which made it easier for oxen to pull them through the heavier, wetter soil of northern Europe, and made it possible for a plow to move more quickly down a row provided it had a speedy animal pulling it.

Oxen are slow and unintelligent compared to horses, but peasants could not use horses to pull plows until they devised a different kind of harnessing than the strap that circled an ox's neck. With a harness resting on its shoulders instead of its neck, a horse could be used to plow, and horses could walk more quickly and work longer hours than oxen. They also required less guidance, since they understood verbal signals to turn or to stop. Heavier, wheeled plows pulled by suitably harnessed horses meant that peasants could work more land in a day than ever before. Whether an increase in population across western Europe, but particularly in the north, stimulated innovations or whether such innovations contributed to a rise in population, the cumulative effect of these changes in agriculture was apparent in the tenth century. Conditions in Europe were ripe for an economic and cultural upswing.

Even before trade with the eastern Mediterranean increased starting in the twelfth century, trade and towns were on the rise. Travel was still dangerous, but merchants were willing to risk transporting goods over long distances. By the late thirteenth century, a few merchants from Italy had even reached China. Greater surpluses in crops meant people had more to sell at market. More people and goods led to regularly held markets in the most populated location in a region. It would be impossible to say whether trade gave rise to towns or vice versa. What is clear is that each fostered the other in conditions of greater social stability.

Travel on trade routes increased, and some towns sprang up to provide rest and refreshment to traders. The distance between towns often corresponded to the distance that traders could cover in a day. Merchants kept their eyes open for customers with money to spend. The residences of kings, nobles, and powerful officials became sites of markets for local and long-distance traders. In Champagne, in northeastern France, six large annual markets attracted merchants from all over Europe in the twelfth century. Their different currencies prompted the first development of banking techniques. With the use of coins now the norm, money changers daily posted changing exchange rates so that merchants would know the worth of their coins in relation to the worth of other merchants' coins. By 1300, trade had transformed life for the better throughout western Europe.

## The Origins of Writing

It was in Egypt and Mesopotamia (modern-day Iraq) that civilization arose, and it is there that we find the earliest examples of the key feature of civilization, writing. These examples, in the form of inscribed clay tablets that date to shortly before 3000 B.C.E., have been discovered among the archaeological remains of the Sumerians, a gifted people settled in southern Mesopotamia.

The Egyptians were not far behind in developing writing, but we cannot follow the history of their writing in detail because they used a perishable writing material. In ancient times the banks of the Nile were lined with papyrus plants, and from the papyrus reeds the Egyptians made a form of paper, it was excellent in quality but, like any paper, fragile. Mesopotamia's rivers boasted no such useful reeds, but its land did provide good clay, and as a consequence the clay tablet became the standard material. Though clumsy and bulky it has a virtue dear to archaeologists: it is durable. Fire, for example, which is death to papyrus paper or other writing materials such as leather and wood, simply bakes it hard, thereby making it even more durable. So when a conqueror set a Mesopotamian palace ablaze, he helped ensure the survival of any clay tablets in it. Clay, moreover, is cheap, and forming it into tablets is easy, factors that helped the clay tablet become the preferred writing material not only throughout Mesopotamia but far outside it as well, in Syria, Asia Minor, Persia, and even for a while in Crete and Greece. Excavators have unearthed clay tablets in all these lands. In the Near East they remained in use for more than two and a half millennia, and in certain areas they lasted down to the beginning of the common era until finally yielding, once and for all, to more convenient alternatives.

The Sumerians perfected a style of writing suited to clay. This script consists of simple shapes, basically just wedge shapes and lines that could easily be incised in soft clay with a reed or wooden stylus; scholars have dubbed it cuneiform from the wedge-shaped marks (cunei in Latin) that are its hallmark. Although the ingredients are merely wedges and lines, there are hundreds of combinations of these basic forms that stand for different sounds or words. Learning these complex signs required long training and much practice, inevitably, literacy was largely limited to a small professional class, the scribes.

The Akkadians conquered the Sumerians around the middle of the third millennium B.C.E., and they took over the various cuneiform signs used for writing Sumerian and gave them sound and word values that fit their own language. The Babylonians and Assyrians did the same, and so did peoples in Syria and Asia Minor. The literature of the Sumerians was treasured throughout the Near East, and long after Sumerian ceased to be spoken, the Babylonians and Assyrians and others kept it alive as a literary language, the way Europeans kept Latin alive after the fall of Rome. For the scribes of these non-Sumerian languages, training was doubly demanding since they had to know the values of the various cuneiform signs for Sumerian as well as their own language.

The contents of the earliest clay tablets are simple notations of numbers of commodities—animals, jars, baskets, etc. Writing, it would appear, started as a primitive form of bookkeeping. Its use soon widened to document the multitudinous things and acts that are involved in daily life, from simple inventories of commodities to complicated governmental rules and regulations.

Archaeologists frequently find clay tablets in batches. The batches, some of which contain thousands of tablets, consist for the most part of documents of the types just mentioned: bills, deliveries, receipts, inventories, loans, marriage contracts, divorce settlements, court judgments, and so on. These records of factual matters were kept in storage to be available for reference—they were, in effect, files, or, to use the term preferred by specialists in the ancient Near East, archives. Now and then these files include pieces of writing that are of a distinctly different order, writings that do not merely record some matter of fact but involve creative intellectual activity. They range from simple textbook material to literature—and they make an appearance very clearly, even from the third millennium B.C.E.

## The Collapse of the Mays

The Mayan society of Central America (2000 B.C. – A.D. 1500), like other ancient states, was characterized by populations unprecedented both in their size and density. It was not just the number of people that lived in the Mayan city- states but also the relatively small area into which they were concentrated. To support such populations, societies developed various intensive agricultural methods, including large-scale irrigation and hill-slope terracing (the cutting of horizontal ridges into hillsides so they can be farmed). These were designed both to increase yields from a given area and to increase the absolute amount of land under cultivation. These strategies were in essence very successful: hey made it possible to feed larger populations than ever before and supported the growth of cities. But they also placed considerable strains on the environment and rendered it increasingly fragile and vulnerable to unexpected climatic events, and even to short-term fluctuations. Thus, the argument is that because of their size and ever more intensive agriculture, the Mayan and other ancient state societies were fundamentally unsustainable.

Claims about environmental degradation and disaster have figured prominently in discussions of the collapse of the Mayan city-states of the Central American lowlands. When two explorers came upon the Mayan cities in the 1830s, they were struck by the sight of tall pyramids and elaborately carved stones among luxuriant forest growth. Here was the archetypal picture of a great lost civilization: abandoned cities submerged in vegetation. Theories of catastrophic collapse or apocalyptic overthrow came naturally to mind to explain these dramatic scenes.

Recent studies of the Mayan collapse (beginning around A.D. 900) have emphasized the gradual and progressive nature of the process, beginning in earnest in the South and advancing northward. It was not a single, sudden event, as had once been thought. Warfare and social unrest are thought to have played a part, but these may well have arisen through pressure from other causes. The Mayan cities had, after all, flourished for over 500 years and had frequently been at war with each other.

But what about the possibility of food shortages? These could have come about through either natural or humanly induced changes in the environment. Increasingly fierce competition between Mayan cities led to an upsurge of monument construction during the eighth and ninth centuries A.D., which would have placed added strain on agricultural production and expansion. Interstate rivalry may hence have pushed the Maya toward overexploitation of their fragile ecosystem. Deforestation and soil erosion might ultimately have destroyed the capacity of the land to support the high population levels of the Mayan cities, leading to famine, social unrest, and the collapse of the major Mayan centers.

Yet it may be incorrect to lay the blame entirely on human action. Several of the lowland cities, such as Tikal, appear to have depended heavily on the cultivation of raised fields set in the marshy depressions known as bajos, which today flood intermittently in the rainy season but may originally have been permanent lakes. The raised-field system of intensive cultivation (created by digging surrounding canals and using the soil removed to elevate the fields for planting) allows year-round food production through the constant supply of soil nutrients that erode into the drainage ditches dug around the raised fields, nutrients that are then collected and replaced. Stable water levels were essential to this subsistence system, but evidence from Lake Chichancanab in Yucatán shows that between A.D. 800 and A.D. 1000 this region suffered its driest period of climate in several thousand years. We may expect that as a result water levels fell, and the raised fields in many areas became unusable. But the human response must be viewed through the lens of the social, political, and cultural circumstances. These exerted a powerful mediating effect on the way the Maya endeavored to cope with their difficulties. Had population levels been lower, the impact of the drought may not have been catastrophic, as it was, the Maya were already reaching the limits of the available subsistence capacity, and Mayan elites had espoused certain social and political agendas (including expensive warfare and competition with each other). It was against this specific background that a period of drought led quickly to crisis and collapse.

## Bison and Humans

When human beings first migrated from Asia into North America at the end of the last ice age, they found an enormous, now extinct creature known as the giant long-horned bison (Bison priscus). We know that early Americans hunted these beasts because excavated skeletons of the bison bear stone spear tips. The style of the points dates them to twelve to thirteen thousand years ago, not long after the first wave of human immigrants washed south and east across the continent. These early Americans ate a variety of plants and animals, but judging from the campsite remains, they had a special taste for long-horned bison. It was their favorite prey, perhaps because one animal filled so many stomachs.

The giant horns that gave Bison priscus its common name tell us some important things about its lifestyle. Animals with gigantic weapons on their heads usually live alone or in small groups. Animals that live in herds usually have small horns. Horns and antlers help males in several ways. Animals use these horns and antlers to fight with other members of the same species, to increase their appeal to potential mates, and to protect themselves from predators. Fossil bones suggest that giant bison used their long, outward-facing horns to injure their opponents. An individual with longer horns had a better chance of circumventing its opponents' horns and fatally wounding them than one with shorter horns, and females probably preferred to mate with winners of these contests rather than with losers, either because they liked what they saw in the male or because they liked the territory that the male could defend from competitors.

The giant bison's architecture served it well for thousands of years, but its body shrank and changed shape starting about twelve thousand years ago. The timing gives us an important clue about the cause. Only two major predators, wolves and lions, had hunted giant bison for tens of thousands of years. If they caused the change, it would have happened much earlier. The big change in the bison's environment twelve to thirteen thousand years ago was the arrival of a new predator. This one walked on two feet, hunted in cooperative bands, and carried spears with well-designed stone points. Its remarkable efficiency at hunting seems to have caused a reduction in the body size of other large mammals, too. Over the past ten thousand years, North American sheep, elk, moose, musk ox, bears, antelope, and wolves have all shrunk.

Scholars have offered various explanations for these changes, but it seems likely that these new hunters converted the giant bison's shape and habits from virtues into liabilities. Hunters who needed to get close to their prey, such as wolves and human beings armed with spears, preferred to attack lone individuals rather than many victims at once. Hunting punished solitary, territorial giant bison and rewarded those that stayed close together. Clumps of bison became more common and grew into herds.

Herding is a classic response to heavy predation. It brings a statistical advantage to herd members because the odds that a predator will hone in on any one individual will decrease with the size of the herd. Herds further improved odds for members through cooperative behavior. Members warned each other of danger, and they fought off predators by joining forces (e.g. by forming a circle with vulnerable backsides to the center and dangerous horns facing the periphery).

But bison paid a price for herding. In a given area, the supply of food per individual declined along with the chances of being attacked. Smaller bodies probably resulted from a decline in food availability as bison crowded together. Herding changed the bison's shape as well as size. Now survival depended on the ability to crop grass, bison's main food, quickly. Shifting the head closer to the ground, reducing horn size, and growing a hump to cantilever, or support, the head's weight enabled bison to graze for long periods without strain. Giant horns, which enabled males to defend territory, may also have become a liability as being able to stay close together became more valuable.

## Weak Electric Systems in Fish

Some blind elephantnose fish produce weak electric signals that are used for detecting objects in their surroundings a phenomenon called active electrolocation. These fish have specialized electric organs that discharge either in pulses or in a wave-like fashion, depending on the species. Although discharges follow one another almost continuously throughout the life of the fish, their power level is much too low to be detected by human handlers but potent enough to create a stable electric field around the body of the fish. When an object enters into this electric field, it causes distortions in the current that are detected by electroreceptor organs distributed over the fish's skin.

A weak electric system may have several uses, including the exploration of novel environments. For example, blind elephantnose fish can easily find the only opening that allows them to cross through a newly installed partition within their aquarium, even though they cannot see it with their eyes. Their electric sense must be implicated because when these individuals become electrically silent (unable to use their electric system through denervation of their electric organs), they can no longer find the opening.

During the 1970s, biologists became interested in the role of the weak electric system not only as a means of electrolocation but also as a means of electrical communication between individual fish. Communication is possible because the rate and waveform of the electric discharges can vary between species, between sexes, between individuals, or even between situations in the same individual. Moreover, some fish can temporarily interrupt their normally continuous train of discharges, and these pauses can be full of meaning. The effective range of communication by electric signals can reach a little over 1 meter depending on water resistance.

In terms of functions, electric communication is strikingly similar to acoustical vocalization (vocal sounds). Some of these functions are concerned with reproductive activity. In some species, males switch to new electric calls during courtship, resuming their regular programming only after the mating season is over. In species in which each sex has its own distinctive pattern of discharges, females are attracted to the pattern of males, and males to the pattern of females. Females can even be induced to release their eggs in the vicinity of electrodes that imitate a male signal the spark of love. As expected, through natural selection, both males and females prefer the electric pattern of their own species to that of other species.

Other functions relate to aggression. Aggressive individuals often precede their attacks with an increase in discharge rate, whereas submissive fish may stop emitting altogether. This submissive behavior seems to work. Researchers have found that individuals rendered electrically silent through denervation of their electric organs are seldom attacked by dominant fish. Finally, individual recognition can also be based on electric signatures. In banded knifefish, territory neighbors recognize each other through individually distinctive discharge waveforms.

The fact that weak electric fish can use their electric sense to communicate with one another leads to an interesting question: How can a fish distinguish between its own electric bursts and those from another fish. In blind elephantnose fish, the problem is solved by the presence of two types of electroreceptors. One of these two types is automatically and briefly shut down each time the fish discharges. Therefore, any signal picked up by these electroreceptors has to come from another animal. Elephantnose fish also have the habit of echoing the discharges of other individuals. They discharge their own electric organ a fixed time after sensing the electric signal of another fish. This response time is extremely short approximately 12 milli seconds probably the most rapid form of communication in the animal kingdom.

Knifefish also display a peculiar behavior called the jamming avoidance response. This response allows knifefish to prevent interference with their electric system when they meet other knifefish. In order to avoid confusion, an electric fish must somehow keep track of the discharge rate of another knifefish while remaining aware of its own. If the two rates are too close, each fish alters its frequency of discharge so as to widen the gap between the two. In a sense, they do not want to get their wires crossed. In the laboratory, it is possible, using artificial signals, to force a knifefish to decrease its frequency of firing just by exposing it to a high but slowly decreasing signal rate or to increase its frequency of firing by switching to a low but slowly rising signal rate.

## Gliding and Soaring

Gliding is gravity-powered flight where the movement of the glider has a downward tilt. But many birds are capable of ascending without flapping their wings, and this is called soaring. Birds usually soar by finding air that is rising as fast as or faster than the gliding bird's sinking speed. For example, a turkey vulture might glide with a sinking speed of about 0.8 meters per second. If the vulture can find a place where the air is rising at 0.8 meters per second, it will be able to maintain a constant altitude. If it finds air rising faster than that, it will be able to climb.

Two common processes produce updrafts, or rising air. When heated air rises, it is called a thermal, and when wind blows up a hill or over a large obstacle, it is called ridge lift or slope lift. Thermals occur when the Sun heats some parts of the ground more than others. For example, a freshly plowed field may heat up faster than an adjacent meadow. The warm ground heats the air above it, and the air starts to rise. As the warm air rises, it is replaced by cool air from the surrounding terrain, and this new air is heated until it rises. Thermals may be continuous chimneys of rising air, or a series of discrete, doughnut-shaped bubbles (ring thermals) formed at intervals by the warmed ground.

If they could be made visible, ring thermals would look like giant, rising smoke rings. Some airplane pilots and biologists disagree about the exact form of continuous thermal chimneys. Pilots have traditionally interpreted thermals as large, tall columns of rising air, usually with a cumulus (white, fluffy) cloud marking the top of the column. In contrast, observers of animal flight find only small, localized thermal chimneys, which usually take the form of dust devils, which are small columnar thermals with intense rotation. Colin Pennycuick, a prolific researcher on bird flight, discounts thermal chimneys and recognizes only ring thermals as sources of large-scale, long-lasting updrafts. In any case, thermals can rise 2 or 3 kilometers above the ground. Also, they tend to increase in size and intensity as they rise, sometimes reaching over 1,000 meters in diameter. Thermals are usually capped by a cloud, because the upper limit of a thermal is set by the altitude where the temperature is low enough to condense water vapor in the thermal, which cools the air and forms a cloud.

As long as the upward speed of the thermal is greater than the sinking speed of a glider, the glider will ascend in the thermal. Of course, the glider will quickly fly out of the thermal if it flies in a straight line, so it must circle to stay in the rising air. (A glider should stay on the inside of the ring, because the air on the outer edge of the ring is actually rolling downward.) Imagine a vulture ascending to 1,500 meters above the ground by circling in a ring thermal. From this height, it will be able to fly out of the thermal and glide for about 30 minutes (traveling over 23 kilometers) before it runs out of altitude and needs to either start flapping, find another thermal, or land. Many soaring birds use just this pattern: climbing up in a thermal, gliding a long distance, then finding another thermal in which to soar. This type of flight is an efficient way to cover long distances at a low energy cost, making it a handy way to migrate or search for food.

Slope soaring is useful when wind blows upward along a slope. The speed of the wind's upward motion can be calculated in the same manner that the sinking speed of a glider is calculated. If the upward speed of this wind is greater than or equal to the sinking speed of a glider, the glider will be able to maintain altitude. Such ridge lift has a characteristic that is both an advantage and a disadvantage: ridge lift is usually predictably tied to a particular slope, so it is easy to find. But it is usable only in that fixed, local area.

## Forms of Locomotion

Using metabolic energy as "currency" to measure the "cost" of locomotion—that is, the amount of energy that must be spent to move from one place to another—we can compare the costs of different types of locomotion. Terrestrial locomotion—walking or running—is the most expensive form of locomotion. Given that humans are naturally terrestrial, many people may be surprised to learn that walking is so costly. The cost per kilogram of locomotion for human running is about five times higher than for the flight of a typical bird, and ten times more expensive than for fish swimming.

Just why is locomotion so cheap for a fish? The main reason is that the water supports most of the body weight of such a swimmer, so all the animal needs to do to swim is to produce enough force to overcome the drag of its own body. Most aquatic animals have nearly the same density as the water in which they swim, so they do almost no work to support their weight against gravity. However, swimming is cheap only for those animals well adapted to swimming completely submerged. When animals such as ducks and muskrat swim on the surface, they use two or three times more energy to swim on the surface than when submerged, and as much as twenty times more energy than fish of a similar size. This is because of what is called the "bow wave" any object moving on the surface of water pushes up a bow wave at the front, which streams alongside and trails back. Boat designers have long known that the bigger the bow wave, the harder it is to push a boat through the water. The bow wave produces extra drag on any body moving on the surface of water. An animal swimming on the surface of the water uses extra energy in order to overcome drag. Thus, for our purposes, efficient "swimming" means underwater locomotion by animals with streamlined bodies, not the exhausting, inefficient locomotion of humans in swimming pools.

Flying animals move through air that is less dense and less viscous than water, so why does flying cost more than swimming? First, most flying animals move much faster than a swimmer in order to produce enough lift (the upward force necessary to overcome gravity). This higher speed increases the drag that a flyer must overcome. Furthermore, a flyer has an extra source of drag that a swimmer does not have: the extra drag that comes from lift production. In a way, the extra drag represents the cost of supporting the flyer's weight in air.

Walking (or running or galloping) is so costly because it involves at least three processes that require muscular work. The first is simply supporting the body's weight. The second is overcoming the friction in joints and muscles, and the third is constantly producing accelerations (speeding up) and decelerations (slowing down). The exact proportion of muscular effort that goes into these three processes depends on the anatomy of a given animal, but the third process probably accounts for most of the energy used by the muscles. When a person takes a step, first one foot pushes off, which accelerates the body. Then the other foot swings forward and hits the ground, and as the weight shifts onto that foot, the body decelerates. Some of the leg muscles actively tense to act as shock absorbers during this deceleration. Momentum carries the body over the grounded foot, at which time that foot pushes off to accelerate the body, and the cycle repeats.

In terms of energy, walking is inefficient because of the acceleration and deceleration required with every step. Both the decelerations and accelerations need muscular effort and thus energy use. In swimming and flying, animals accelerate and decelerate relatively little over the course of a tail stroke or a wingbeat, so less energy is consumed by this process. As an analogy, consider riding a bicycle. When a person rides a bicycle, the bicycle does not accelerate or decelerate much with each turn of the petal. Thus, a person can ride a bicycle much faster than he or she could run using the same amount of effort.

## How Plants and Animals Arrived in the Hawaiian Islands

Scientists have attempted to explain how living things that are not native to the Hawaiian Islands were able to reach the islands from distant places. The way in which birds reached the Hawaiian Islands is obvious enough. Some of the plants that probably came with them had seeds that readily attached to feathers, about 7 percent of the Hawaiian nonendemic (nonnative) seed plants probably arrived in this way. The Hawaiian insects, too, arrived by air. Entomologists have used airplanes and ships to trail fine nets over the Pacific at different heights and have trapped a variety of insects, most of which, as would be expected, are light-bodied. These types also predominate in the Hawaiian Islands (an indication of their airborne arrival), although heavier dragonflies, sphinx moths, and butterflies are also found there.

The influence of the winds in providing colonists is shown by the fact that, although flowering plants are far more common than ferns in the world as a whole, their diversity in Hawaii is more evenly balanced: 225 immigrant flowering plants and 135 immigrant ferns. The relatively greater success of the ferns is probably due to the fact that their spores (reproductive structures) are much smaller and lighter than the seeds of flowering plants. Of the nonendemic seed plants of the Hawaiian Islands, about 7.5 percent almost certainly arrived carried by the wind, while another 30.5 percent have small seeds (up to three millimeters in diameter) and thus may also have arrived this way.

One of the most interesting plants that probably arrived as a wind-borne seed is the tree Metrosideros. It is unusual because its seeds are relatively tiny, and this has allowed it to become widely dispersed through the Pacific islands. It is able to form forests on lowland lava with virtually no soil—a great advantage on a volcanic island. Metrosideros shows great variability in its appearance in different environments, from a large tree in the wet rain forest, to a shrub on windswept ridges, to as little as 15 centimeters high in peatlands, and it is therefore the dominant tree of the Hawaiian forest. The different forms are not distinct species, and intermediates are found where two different types are adjacent to one another.

Probably the single most important method of entry of seed plants to the Hawaiian Islands has been as seeds within the digestive systems of birds that have eaten their fruit (e.g. blueberry, sandalwood), about 37 percent of the nonendemic seed plants of the islands probably arrived in this way. Significantly, many plants that succeeded in reaching the islands are those that, unlike the rest of their families, bear fleshy fruits instead of dry seeds, such as the species of mint, lily, and nightshade found in Hawaii.

Dispersed by sea accounts for only about 5 percent of the nonendemic Hawaiian seed plants. As well as the widespread coconut, the islands also contain Scaevola toccata, this shrub has white, buoyant fruits and forms dense hedges along the edge of the beach. Another seaborne migrant is Erythrina, most species of this plant have buoyant, beanlike seeds. On Hawaii, after its arrival on the beach, Erythrina was unusual in adapting to an island environment, and a new endemic species, the coral tree E sandwichensis, has evolved on the island. Unlike those of its ancestors, the seeds of the coral tree do no float—an example of the loss of its dispersal mechanism often characteristic of an island species.

The successful colonists of the Hawaiian Islands are the exceptions, many groups, both plants and animals, have failed to reach the islands by natural processes. There are no truly freshwater fish and no native amphibians, reptiles, or mammals (except for one species of bat), while 21 orders of insect are completely absent. As might be expected, most of these are types that seem in general to have very limited powers of dispersal. For example, the ants, which are an important part of the insect fauna in other tropical parts of the world, were originally absent. They have, however, since been introduced by humans, and 36 different species have now established themselves and filled their usual dominant role in insect faunas. This proves that the obstacle was reaching the islands, not the nature of the Hawaiian environment.

## Disease and History

Epidemiology is the study of the causes, distribution, and control of diseases in populations. Throughout history, there have been general trends in the relationship between diseases and the human species. Anthropologist George Armelogos has outlined these trends and refers to them as three "epidemiological transitions."

For most of our species' history, we lived in small, widely dispersed, nomadic groups.Our ancestors certainly experienced diseases of various sorts and would have come into contact with new diseases as they migrated to new environments. But infectious disease may not have had serious effects on large numbers of people or many different populations, since diseases would have had little chance of being passed on to many other humans.

When some people began to settle down and produce their food through farming and animal domestication—starting about 10,000 years ago—the first epidemiological transition occurred. Infectious diseases increased in impact, as larger and denser concentrations of people provided greater opportunity for disease to be passed from host to host. Animal domestication may have brought people into contact with new diseases previously limited to other species. Working the soil would have exposed farmers to insects and other pathogens. Irrigation in some areas provided breeding places for mosquitoes, increasing the incidence of malaria and other mosquito-borne diseases. Sanitation problems caused by larger, more sedentary populations would have helped transmit diseases in human waste, as would the use of animal dung for fertilizer. In addition, agriculture also led to a narrowing of food sources, as compared to the varied diets of hunters and gatherers. This could have resulted in nutritional deficiencies; moreover, the storage of food surpluses attracted new disease carriers such as insects and rats. Trade between settled communities helped spread diseases over large geographic areas, as in the case of the Black Death in Europe. Epidemics, in the sense of diseases that affect a large number of populations at the same time, were essentially nonexistent until the development of agricultural economies.

Beginning in the last years of the nineteenth century and continuing into the twentieth, we experienced the second epidemiological transition. With modern medical science providing immunizations and antibiotics and with better public health measures and improved nutrition, many infectious diseases were brought under control, or even eliminated. In terms of what ailed and killed us, there was a shift to chronic diseases such as heart and lung diseases. The increase in many of these came not only from the fact that fewer people were dying from infectious disease and were living longer but also from the results of modern lifestyles in developed countries and among the upper classes of developing countries—a more sedentary life leading to less physical activity, more stress, environmental pollution, and high-fat diets. But at least, we thought, many of these problems were things we could potentially control; all those infectious epidemics were of the past.

But on the heels of the second transition had come the third epidemiological transition, and we are in it now. New diseases are emerging, and old ones are returning. Both of these phenomena can be understood in terms of evolutionary theory.

The return of old diseases is the result of the fact that microorganisms are evolving species themselves. For example, new and serious antibiotic-resistant strains of tuberculosis have recently appeared. This evolution may have been encouraged by what some authorities consider our overuse of antibiotics, giving microorganisms a greater chance to evolve resistance by exposing them to a constant barrage of selective challenges. Some bacteria reproduce hourly, and so the processes of genetic mutation and natural selection are speeded up in these species.

Emerging diseases are also the result of human activity in the modern world, which brings more people into contact with more diseases, some of which were unheard of even a few decades ago. As people and their products became more mobile, and as our populations spread into previously little-inhabited areas, cutting down forests and otherwise altering ecological conditions, we contact other species that may carry diseases to which they are immune but that prove deadly to us.

## Habitat Selection

Researchers who study habitat selection have proposed various models for the process. Marine biologist Peter F. Sale hypothesized the existence of a simple mechanism of habitat selection in fish that is based on levels of exploratory behavior. Sense organs monitor specific stimuli in the environment and send a summation of pertinent stimuli back to central-nervous-system centers, which regulate the amount of exploration. As the constellation of cues approaches some optimum level, exploratory behavior ceases and the animal stays where it is.

An alternative hypothesis is that an animal has a cognitive map of the ideal habitat and that its behavior is goal directed. However, working with a species of surgeonfish, Sale tested juveniles in laboratory tanks with various water depths and bottom covers under which fish could hide. Exploration time was least in the tank with shallow water and bottom cover and highest in the tank with shallow water and no bottom cover. In choice tests and field observations, most fish preferred shallow areas with bottom cover. Thus, Sale concluded, there is no need to suggest the inheritance of complex cognitive maps and goal-directed behaviors, rather, the animal simply moves around more in an unsuitable habitat and less in a suitable one.

Sale's model still does not explain how the animal "knows" what is suitable and what is not, or how stimuli from multiple cues are integrated. Nor does it explain the role of photoperiod (the duration of the animal's daily exposure to sunlight) in the response of dark-eyed juncos to photographs of their natural habitat. These wild-caught birds were presented a choice of viewing one of two 35-millimeter color slides showing different habitats. Birds kept in the lab under a winter photoperiod of nine hours of light and fifteen hours of darkness preferred (spent more time in front of) slides of their southern winter habitat. After day length was increased to fifteen hours of light and nine hours of darkness, the birds' viewing preferences shifted to the northern summer habitat.

Social cues may also affect choice of habitat. Large juncos (usually males) dominate smaller individuals (usually females and juveniles) in wintering flocks. Biologist Ellen Ketterson explained the finding that females usually migrate farther south than males by hypothesizing that subordinate birds are forced to migrate farther to avoid competing with dominants. In their lab study, researchers E. Roberts and Peter Weigl found that during the short days (stimulating winter), small subordinate juncos showed the strongest preference for winter scenes.

Risk of predation and competition are other factors that may affect habitat use. Hairy-footed gerbils live in vegetated islands in a sea of sand in the Namib Desert of southern Africa. Habitat use was determined by tracks in the sand and by how quickly they gave up feeding at stations containing seeds mixed with sand. Gerbils preferred sites around bushes or grass clumps to open areas and were more active on new-Moon nights than on full-Moon nights. They also gave up feeding at seed trays sooner in open areas and on full-Moon nights. These differences were likely caused by greater risk of predation in open areas and when the Moon was full. When striped mice, a close competitor of the gerbil, were removed, gerbils increased foraging activity, especially in the grass clumps.

The immediate cues to which animals respond when selecting a habitat may not be the same as the ultimate factors that have brought about the evolution of the response. For example, the blue tit, a European bird, lives in oak woodlands where most of its preferred food is found. But the blue tit establishes its territory each year before leaves and caterpillars (its staple food) have even appeared, so it must be using some other cue, such as the shape of the trees, to select its habitat. In fact, we know little about the signals that animals respond to when choosing their habitat. And in migratory species, it is not even clear when in the life cycle a choice of habitat is made. One study found that breeding sites may be selected in late summer or fall before migration, rather than in the spring, as is usually assumed.

## Impacts and Mass Extinctions

Meteorites and impact craters bear witness to the fact that large impacts occasionally occur on Earth. Meteor Crater in the northern Arizona desert of the United States formed about 50,000 years ago when a metallic impactor roughly 50 meters across crashed to Earth with the explosive power of a 20-megaton hydrogen bomb. Although the crater is only slightly more than one kilometer across, an area covering hundreds of square kilometers was probably battered by the blast and ejecta—the debris ejected or displaced during the formation of an impact crater. Far bigger impacts have occurred, sometimes with catastrophic consequences for life on Earth.

While collecting geological samples in Italy in 1978, the father-son team of Luis and Walter Alvarez discovered a thin layer of dark sediment that had apparently been deposited 65 million years ago—at about the same time that the dinosaurs and many other organisms suddenly became extinct. Subsequent studies found similar sediment deposited at the same time at many sites around the world. Careful analysis showed this worldwide sediment layer to be rich in iridium, and element that is rare on Earth's surface. But iridium is common in primitive meteorites, which led the Alvarezes to a stunning conclusion: the extinction of the dinosaurs was caused by the impact of an asteroid or comet. This conclusion was not immediately accepted and still generates some controversy, but it now seems clear that a major impact coincided with the death of the dinosaurs. While the dinosaurs were the most famous victims of this mass extinction, it seems that up to 99 percent of all living things were killed and that 75 percent of all species living on Earth were wiped out at that time.

How could an impact lead to mass extinction? The amount of iridium deposited worldwide suggests that the impactor must have been about 10 kilometers across. After a decade-long search, scientists identified what appears to be the impact crater from the event. Located off the coast of Mexico's Yucatan peninsula, it is 200 kilometers across, which is close to  what one would expect for a 10-kilometer impactor, and dates to 65 million years ago. Further evidence that the Yucatan crater is the right one comes from the distribution of small glassy spheres that formed when the molten impact ejecta solidified as it rained back to Earth. More of these glassy spheres are found in regions near the crater, and careful study of their distribution suggests that the impactor crashed to Earth at a slight angle. These pieces of once molten rock are evidence of an explosion powerful enough to instantly melt bedrock and propel it far from its origin. The impact almost immediately sent a shower of debris raining across much of North and South America and generated huge waves that may have sloshed more than 1,000 kilometers inland. Many North American species thus may have been wiped out shortly after impact. For the rest of the world, death may have come more slowly. Heat from the impact and returning ejecta probably ignited wildfires in forests around the world. Evidence of wildfires is found in the large amount of soot (a black powdery form of carbon produced when coal, wood, or oil is burned) that is also present in the indium-rich sediment from 65 million years ago. The impact also sent huge quantities of dust high into the stratosphere, where it remained for several years, blocking out sunlight, cooling the surface, and affecting atmospheric chemistry. Plants died for lack of sunlight, and effects propagated throughout the food chain.

Perhaps the most astonishing fact is not that 75 percent of all species died, but that 25 percent survived. Among the survivors were a few small, rodent-like mammals. These mammals may have survived because they lived in underground burrows and managed to store enough food to outlast the long spell of cold, dark days. Small mammals had first arisen at about the same time as the dinosaurs, more than 100 million years earlier. But the sudden disappearance of the dominant dinosaurs made these mammals dominant.

## Artisans in Sixteenth-Century Europe

For centuries European artisans had operated in small, autonomous handcraft businesses, but by the sixteenth century an evolving economic system—moving toward modern capitalism, with its free-market pricing, new organization of production, investments, and so on—had started to erode their stable and relatively prosperous position. What forces contributed to the decline of the artisan?

In a few industries there appeared technological innovations that cost more to install and operate than artisans—even associations of artisans—could afford. For example, in iron production, such specialized equipment as blast furnaces, tilt hammers, wire-drawing machines, and stamping, rolling, and slitting mills became more familiar components of the industry. Thus the need for fixed capital (equipment and buildings used in production) soared. Besides these items, expensive in their own right, facilities for water, storage, and deliveries were needed. In addition, pig (raw) iron turned out by blast furnaces could not be forged until refined further in a new intermediate stage. In late sixteenth-century Antwerp, where a skilled worker earned 125 to 250 guilders a year, a large blast furnace alone cost 3,000 guilders, and other industrial equipment was equally or more expensive.

Raw materials, not equipment, constituted artisans' major expense in most traders, however. Whereas in 1583 an Antwerp silk weaver paid 12 guilders for a loom (and made small payments over many years to pay off the debt for purchasing the loom), every six weeks he or she had to lay out 24 guilders for the 2 pounds of raw silk required to make a piece of cloth. Thus access to cheap and plentiful primary materials was a constant preoccupation for independent producers. Using local materials might allow even the poorest among them to avoid reliance on merchant suppliers. The loss of nearby sources could therefore be devastating. As silk cultivation waned around the Spanish cities of Cordoba and Toledo, weavers in these cities were forced to become employees of merchants who put out raw silk from Valencia and Murcia provinces. In the Dutch Republic, merchants who imported unprocessed salt from France, Portugal, and Spain gained control of the salt-refining industry once exploitation of local salt marshes was halted for fear that dikes (which held back the sea from the low-lying Dutch land) would be undermined.

Credit was necessary for production but created additional vulnerabilities for artisans. Prices for industrial products lagged behind those of raw materials and foodstuffs, and this, coupled with rising taxes, made it difficult for many producers to repay their creditors. Periodic downturns, when food prices shot up and demand for manufactures fell off, drove them further into debt or even into bankruptcy, from which they might emerge only by agreeing to sell their products exclusively to merchants or fellow artisans who extended them loans. Frequent enough during periods of growth, such credit crises became deeper and lasted longer after about 1570, as did war-related disruptions of raw-material supplies and markets.

Artisans' autonomy was imperiled, too, by restrictions on their access to markets.During the sixteenth century, a situation like this often resulted from the concentration of export trade in a few great storage and distribution centers. The disappearance of regional markets where weavers in Flanders (what is now northern Belgium) had previously bought flax and sold linen left them at the mercy of big-city middlemen, who quickly turned them into domestic workers. In a similar fashion, formerly independent producers in southern Wiltshire in England, who had bought yarn from spinners or local brokers and sold their cloth to merchants in nearby Salisbury, became subject to London merchants who monopolized both wool supplies and woolens exports.

With good reason, finally, urban artisans feared the growth of industries in the countryside. For one thing, they worried that the spread of village crafts would reduce their supply of raw materials, driving up prices. City producers also knew that rural locations enjoyed lower living costs, wages, and taxes, and often employed fewer or simplified processes. These advantages became a major preoccupation as competition intensified in the 1570s and 1580s.

## Birdsong

Birdsong is the classic example of how genes (hereditary information) and environment both have a crucial role to play in the behavioral development of animals. Since the pioneering work of W. H. Thorpe on chaffinches (a common European bird), many species have been studied, and it has become clear both that learning plays an important role for all species and also that there are constraints on what they are able to learn.

Thorpe was able to show that learning from others was involved in chaffinch birds through a series of experiments on hand-reared chicks (young birds). As in most other species, only the males sing. Thorpe found that, if he raised young males in total isolation from all others, the song they produced was quite different from that of a normal adult. It was about the right length and in the correct frequency range. It was also split up into a series of notes as it should be. But these notes lacked the detailed structure found in wild birds, nor was the song split up into distinct phrases as it usually is. This suggested that song development requires some social influence. Later experiments in which researchers played recordings of songs to young birds showed just how precise this influence was: many of them would learn the exact pattern of the recording they had heard. A remarkable feature here was that birds were able to copy precisely songs that they only heard in the first few weeks of life, yet they did not sing themselves until about eight months old. They are thus able to store a memory of the sound within their brain and then match their own output to their recollection of it when they mature.

Young chaffinches normally learn only chaffinch song, though Thorpe found they could be trained to sing the song of a tree pipit (another type of bird), which is very similar to that of their own species. In general, however, the constraints on learning which birds have ensure that they only learn songs appropriate to the species to which they themselves belong.  These constraints may be in their brain's circuitry, the young bird hatching with a rough idea of the sounds that it should copy. The crude song of a bird reared in isolation gives some clues as to what this rough idea may be: the length, the frequency range and the breaking up into notes are all aspects of chaffinch song shared between normal birds and those reared in isolation. In other cases the constraints are more social, young birds only being prepared to learn from individuals with whom they have social interactions. Thus, in a number of species, it has been found that they will not copy from recordings, but will do so from a live tutor. In some cases this may occur when they are young birds, but in others the main learning period is when they set up their territories and interact with neighbors for the first time, enabling them to match their neighbor's songs and so countersing with them.Whatever the nature of the learning rules in a particular species, there is no doubt that they are effective; it is very unusual to hear a wild bird singing a song which is  not typical of its own species despite the many different songs which often occur in a small patch of woodland.

However, not all birds show the same learning pattern as do chaffinches. There are some species which produce normal sounds even if deaf, so that they cannot hear their own efforts, much less copy those of others. The cooing of doves and the crowing of cocks are examples here. In other cases, such as parrots and hill mynahs, birds can be trained to copy a huge variety of sounds, though those they learn in the wild are usually more restricted. The amazing capability of mynahs has apparently arisen simply because birds in an area learn a small number of their calls from each other, males from males and females from females, and these calls are highly varied in structure. The ability to master them has led the birds, incidentally, to be capable of saying "hello" and mimicking a wide variety of other sounds.

## The Use of the Camera Obscura

The precursor of the modern camera, the camera obscura is a darkened enclosure into which light is admitted through a lens in a small hole. The image of the illuminated area outside the enclosure is thrown upside down as if by magic onto a surface in the darkened enclosure. This technique was known as long ago as the fifth century B.C., and Leonardo da Vinci described it in his notebooks in 1490. In 1558 Giovanni Battista Della Porta wrote in his twenty-volume work Magia naturalis (meaning “natural magic”) instructions for adding a convex lens to improve the quality of the image thrown against a canvas or panel in the darkened area where its outlines could be traced. Later, portable camera obscures were developed, with interior mirrors and drawing tablets on which the artist could trace the image. For the artist, this technique allows forms and linear perspective to be drawn precisely as they would be seen from a single viewpoint. Mirrors were also used to reverse the projected images to their original positions.

Did some of the great masters of painting, then, trace their images using a camera obscura? Some art historians are now looking for clues of artists’ use of such devices. One of the artists whose paintings are being analyzed from this point of view is the great Dutch master, Jan Vermeer, who lived from 1632 to 1675 during the flowering of art and science in the Netherlands, including the science of optics. Vermeer produced only about 30 known paintings, including his famous The Art of Painting. The room shown in it closely resembles the room in other Vermeer paintings, with lighting coming from a window on the left, the same roof beams, and similar floor tiles, suggesting that the room was fitted with a camera obscura on the side in the foreground. The map hung on the opposite wall was a real map in Vermeer’s possession, reproduced in such faithful detail that some kind of tracery is suspected. When one of Vermeer’s paintings was X-rayed, it did not have any preliminary sketches on the canvas beneath the paint, but rather the complete image drawn in black and white without any trial sketches. Vermeer did not have any students, did not keep any records, and did not encourage anyone to visit his studio, facts that can be interpreted as protecting his secret use of a camera obscura.

In recent times the British artist David Hockney has published his investigations into the secret use of the camera obscura, claiming that for up to 400 years, many of Western art’s great masters probably used the device to produce almost photographically realistic details in their paintings. He includes in this group Caravaggio, Hans Holbein, Leonardo da Vinci, Diego Velazquez, Jean-Auguste-Dominique Ingres, Agnolo Bronzino, and Jan van Eyck. From an artist’s point of view, Hockney observed that a camera obscura compresses the complicated forms of a three-dimensional scene into two- dimensional shapes that can easily be traced and also increases the contrast between light and dark, leading to the chiaroscuro effect seen in many of these paintings. In Jan van Eyck’s the Marriage of Giovanni Arnolfini and Goivanna Genami, the complicated foreshorteningin the chandelier and the intricate detail in the bride’s garments are among the clues that Hockney thinks point to the use of the camera obscura.

So what are we to conclude? If these artists did use a camera obscura, does that diminish their statue? Hockney argues that the camera obscura does not replace artistic skill in drawing and painting. In experimenting with it, he found that it is actually quite difficult to use for drawing, and he speculates that the artists probably combined their observations from life with tracing of shapes.

Chiaroscuro: artistic term for a contrast between light and dark Foreshortening: a technique for representing an image in art that makes it appear to recede in space

## Sumerian Contributions

Before about 4500 B.C., lower Mesopotamia, the region between the Tigris and Euphrates rivers just north of the Persian Gulf, was much less densely populated than other inhabited regions of the Near and Middle East. Its marshy soil, subject to annual inundations (floods) from the rivers, was not suited to the primitive hoe culture of early agriculture, in which land was cultivated without domestic animals or beasts. Moreover, the land was virtually treeless and lacked building stone and mineral resources. During the next thousand years, however, this unpromising area became the seat of Sumer, the first great civilization known to history, with large concentrations of people, bustling cities, monumental architecture, and a wealth of religious, artistic, and literary traditions that influenced other ancient civilizations for thousands of years. The exact sequence of events that led to this culmination is unknown, but it is clear that the economic basis of this first civilization lay in its highly productive agriculture.

The natural fertility of the rich black soil was renewed annually by the silt left from the spring floods of the Tigris and Euphrates rivers. Harnessing its full productive power, however, required an elaborate system of drainage and irrigation, which in turn required a large and well-disciplined workforce as well as skilled management and supervision. The latter were supplied by a class of priests and warriors who ruled a large population of peasants and artisans. Through taxation and other means the rulers extracted wealth from the population and then used it to construct temples and other public buildings and to create works of art. That gave them (or some of them) the leisure to perfect the other refinements of civilization.

The rise of civilization brought with it a far more complex division of labor and system of economic organization. Full- time artisans specialized in the manufacture of textiles and pottery, metalworking, and other crafts. The professions of architecture, engineering, and medicine, among others, were born. Weights and measures were systematized, mathematics was invented, and primitive forms of science emerged. Since Sumer was virtually devoid of natural resources other than its rich soil, it traded with other people, thereby contributing to the diffusion of Sumerian civilization. The scarcity of stone, for tools as well as for buildings, probably hastened the adoption of copper and bronze. Copper, at least, was already known before the rise of Sumerian civilization, but lack of demand for it among the Stone Age peasant villages inhibited its widespread use. In Sumerian cities, on the other hand, stone imported by sea through the Persian Gulf from Oman and downriver from the mountains of Anatolia and the Caucasus had to compete with imported copper, and the latter proved more economical and effective for a variety of uses. Thereafter metallurgy, the technology of separating metals from their ores and purifying them, was regarded as one of the hallmarks of civilization.

Sumer’s greatest contribution to subsequent civilizations, the invention of writing, likewise grew out of economic necessity. The early cities—Eridu, Ur, Uruk, and Lagash—were temple cities: both economic and religious organizations centered on the temple of the local patron deity, represented by a priestly hierarchy. Members of the hierarchy directed the construction and maintenance of irrigation and drainage systems, oversaw agricultural activities, and supervised the collection of produce as taxation or tribute (money or other wealth given as a sign of submission or in return for protection). The need to keep records of the sources and uses of this tribute led to the use of simple pictographs on clay tablets sometime before 3000 B.C. By about 2800 B.C. the pictographs had been stylized into the system of writing known as cuneiform (using wedge-shaped marks on clay), a distinctive characteristic of Mesopotamian civilization. It is one of the few examples in history of a significant innovation issuing from a bureaucratic organization.

Although writing originated in response to the need for administrative bookkeeping, it soon found multiple religious, literary, and economic uses. In a later phase of development, after the strict temple-centered organization of the economy had given way to greater freedom of enterprise, clay tablets were used for recording the details of contracts, debts, and other commercial and financial transactions.

## Milankovitch Cycles and Glaciation

Although the history of glaciation during the Pleistocene epoch (2 million to 10,000 years ago) is well established, we do not know with complete certainty why glaciation takes place. For over a century, geologists and climatologists have struggled with this problem, but it remains unsolved.

It is long known that Earth's orbit around the Sun changes periodically, cyclically affecting the way solar radiation strikes the Earth, but the idea that these changes affect climate was first advanced by James Croll in the late 1800s. Later, Milutin Milankovitch elaborated the theory with calculations that convincingly argued that the cycles, now known as Milankovitch cycles, could cause climatic variations.

The Milankovitch cycles emerge from the way three cyclic changes in Earth's orbit combine. One characteristic of Earth's orbit is its eccentricity, the degree to which the orbit is an ellipse rather than a circle. Changes in the eccentricity of Earth's orbit occur in a cycle of about 96,000 years. The inclination, or tilt, of Earth's axis also varies periodically, moving between 22 degrees and 24.5 degrees. The tilt of Earth's axis, toward the Sun at some times of the year and away from the Sun at other times, is responsible for the annual cycle of seasons. The greater the tilt, the greater the contrast between summer and winter temperatures. Changes in the tilt occur in a cycle 41,000 years long. Also, Earth wobbles as it spins, like a slightly unsteady top. The wobble cycle is completed once every 21,700 years. Changes in eccentricity, tilt and wobble do not affect the total amount of solar radiation Earth receives in a year, but they do affect how evenly or unevenly this radiation is disturbed over the course of a year. According to the Milankovitch theory, about every 40,000 years the three separate cycles combine in such a way that the difference between summer and winter temperatures is at a minimum. At this point winter temperatures are milder but so too are summer temperatures. As a result, less ice is melted in the summer than is formed in the winter, so glaciers build up and a period of glaciation results.

Milankovitch worked out the ideas of climatic cycles in the 1920s and 1930s, but it was not until the 1970s that a detailed chronology of the Pleistocene temperature changes was determined that could test the predictions of this theory. A correspondence between Milankovitch cycles and climate fluctuations of the last 65 million years seems clear. Furthermore, studies or rock samples drilled from the deep-sea floor and the fossils contained in them indicate that the fluctuation of climate during the past few hundred thousand years is remarkably close to that predicted by Milankovitch.

A problem with Milankovitch's explanation of glaciation arises from the fact that the variations in Earth's orbit, and hence the Milankovitch cycles, have existed for billions of years. Thus we might expect that glaciation would have been a cyclic event throughout geologic time. In fact, periods of glaciation are rare. So there must be another factor acting together with the Milankovitch cycles that causes periods of glaciation. Once this additional factor makes the temperature low enough, the cyclic variations of the Milankovitch cycles will force the planet into and out of glacial epochs with a fixed regularity.

Many hypotheses have been proposed for the additional cooling factor. Some suggest that variations in the Sun's energy output could account for the ice ages. However, our present understanding of the Sun's luminosity holds that it should have progressively increased, not decreased, over the course of Earth's history. Still others argue that volcanic dust injected into the atmosphere shields Earth from the Sun's rays and initiates an ice age. However, no correlation has been found between volcanic activity and the start of the last ice age. An increasingly attractive theory holds that decreases in atmospheric carbon dioxide starts the cooling trend that leads to glaciation. Carbon dioxide traps solar energy reflected from the Earth's surface. If carbon dioxide levels decrease, less heat is trapped and Earth's surface cools. Recent studies of the carbon dioxide content of gas bubbles preserved in the Greenland ice cap do in fact show that high carbon dioxide levels are associated with warm interglacial periods, and low levels with cold glacial periods.