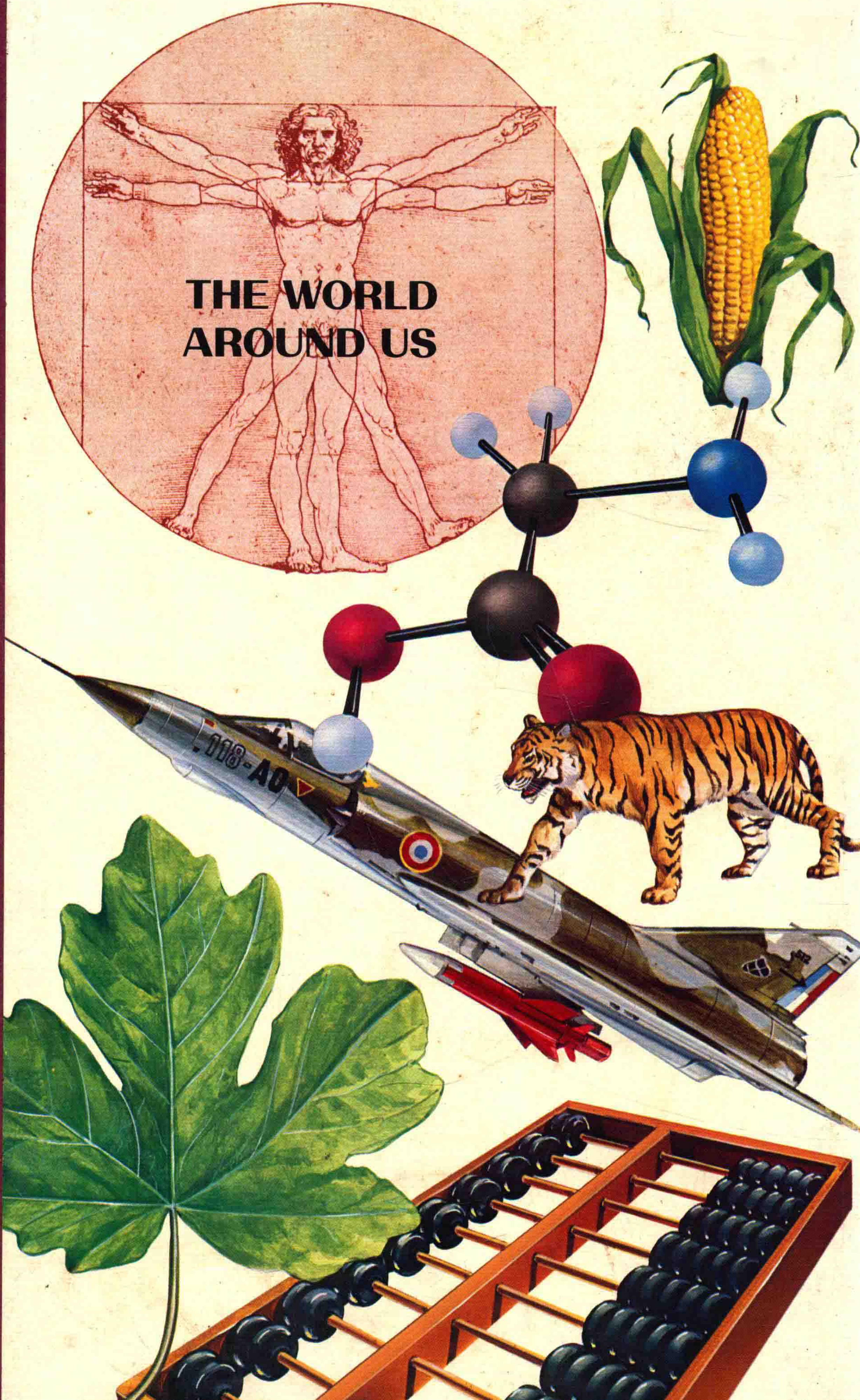
SCIENCE AND TECHNOLOGY ILLUSTRATED

# THE WORLD AROUND US



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# Science and Technology Illustrated

*The World Around Us*

# Science Technology

*The World Around Us*

# *Volume* 16

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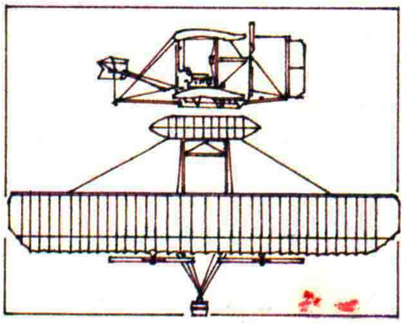


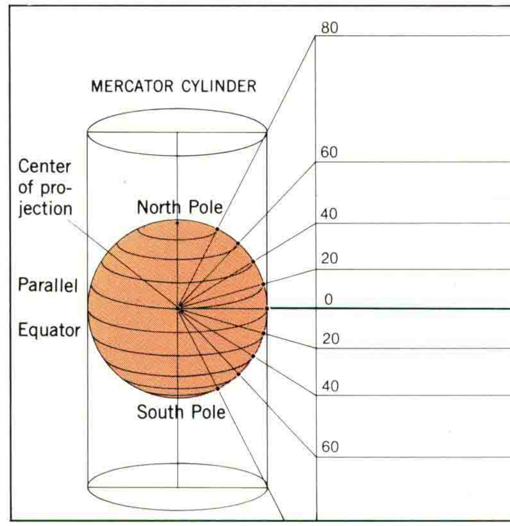


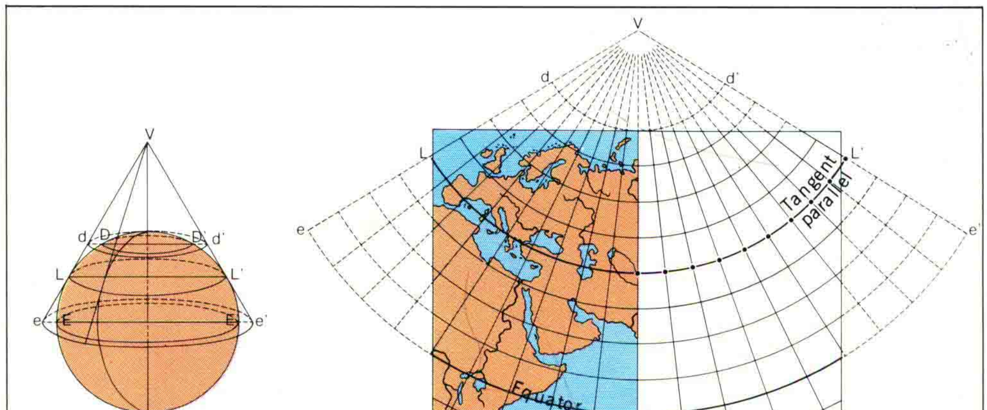
# Maps and Mapmaking

When we look at a map, we think we are seeing a precise representation of the world or some part of it. Like a painting of a human face, however, a map is liable to interpretation or caricature. The great advantage of maps, in fact, is that they are abstract and distorted, and can be manipulated to perform a variety of functions. Satellite photographs show the world more closely as it really is, but they are often confusing in their detail. Maps drawn by skilled cartographers graphically organize this geographic information with colors, symbols, words, and lines, so that we can understand it better.

By the addition of black borders, for example, a political map can indicate boundaries between nations, states and provinces, counties, townships, districts, and other jurisdictions. By using lines and colors associated with specific elevations, a relief map can visually convey the physical or topographic characteristics of a given area. With standardized symbols such as arrows (wind flow) and isobars (lines that connect points of equal atmospheric pressure), a weather map—an example of a scientific map—depicts natural phenomena. A celestial map is a graphic representation of the stars. With compass points and coordinates, a nautical chart helps a mariner navigate across the open sea. These are just a few examples of the many kinds of maps that are made.

One of the first methods of mapping the surface of the Earth was to draw directly on a sphere. Although this was accurate for an overview, it was inefficient for displaying detail and, in addition, inconvenient for storage and transportation. All successive maps are based on the principle of representing the spherical surface of the Earth on a form that can be flattened. *Right:* Mercator method consists of projecting the surface of the Earth onto an imaginary cylinder that is tangent to the equator. The defect of the Mercator projection is that it shows the polar zones as being disproportionately large. However, detailed maps of relatively small areas can be very accurate when drawn in Mercator projection.




TANGENT CONICAL PROJECTION

### Drawn to Size

All maps are drawn to scale, meaning that they are miniaturized versions of the areas they represent. Scale is typically expressed as a numerical ratio, such as 1:1,000,000. This means that one unit of map measure equals one million units of that measure in nature—(an inch, for example is about 16 miles in this case, or 1 millimeter equals a little over 10 km). Maps that cover large areas are said to be small-scale, while maps showing greater detail in a smaller area are said to be large-scale. The numerical ratio is always in the opposite sense.

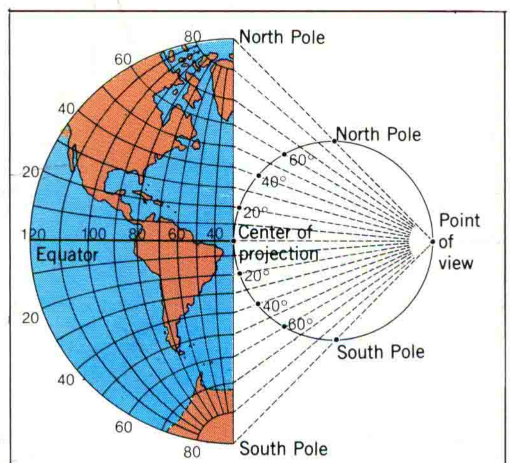
Early in the history of mapmaking, scholars concluded that the Earth was a sphere; this theory provided the mathematical foundation for cartography, the art and science of drawing maps. A sphere can be divided into precise geometrical segments by means of a grid. Those lines—meridians, or longitudes, and parallels, or latitudes—are the basis of all maps, whether they represent a large or small part of the globe. The grid system works like this:

Because the Earth is a sphere, it is possible to draw a circle around the middle of the sphere, dividing it into two equal parts. The ancients called this circle the equator. Like any other circle, the equator can be divided into 360 degrees. One point on the equator, by international convention, marks the location of the prime meridian. This is a line that runs from the North Pole to the South Pole, passes through the Royal Observatory in Greenwich, England, and intersects the equator perpendicularly at 0°.

### From Degrees to Grids

Each degree east or west of the prime meridian marks a measure of longitude, up to 180° east or 180° west. Each degree of any meridian circle north or south of the equator marks a measure of latitude, from 0° at the equator to 90° north and 90° south. The latitude line 40° north, for example, runs through Philadelphia, Pennsylvania, and Beijing, China, among other places, girdling the globe in a circle that is always parallel to the equator. Each of these circles of latitude is smaller than the equatorial ring. When these measurements are depicted on a globe as lines, the world is covered by a grid, and any location on the globe can be pinpointed by its latitudinal and longitudinal coordinates.

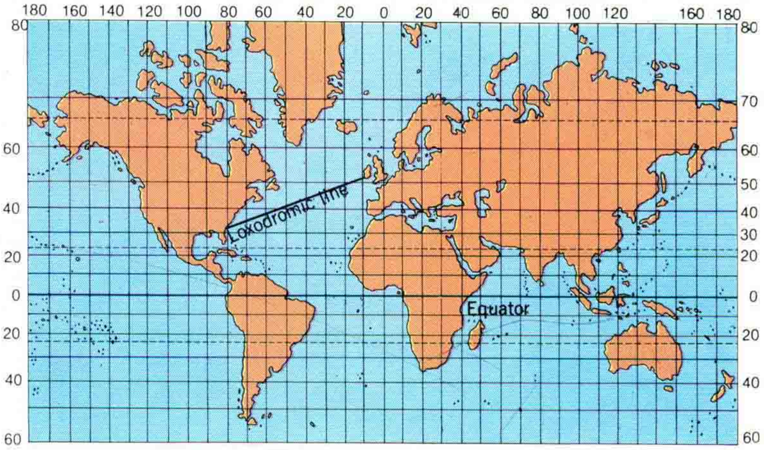
When this grid is transferred to a piece of paper—a process known as projec-



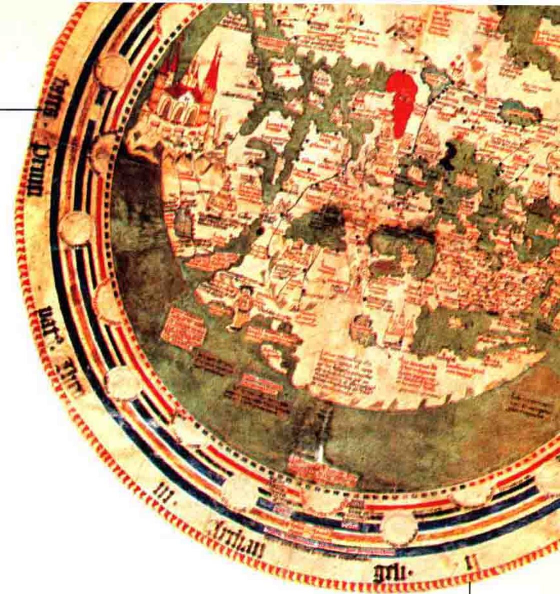

STEREOGRAPHIC EQUATORIAL PROJECTION

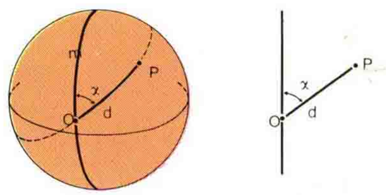
*Above, center:* Conical projection. The map is drawn on a cone whose axis coincides with that of the Earth and whose base is tangent with a given parallel. Conical projection is most accurate along the given parallel, progressively less so as one moves north or south.

*Directly above:* Map drawn on stereographic equatorical projection.

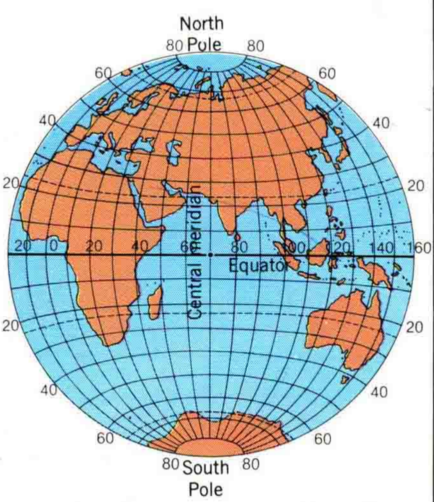



CYLINDRICAL ISOGONIC MERCATOR PROJECTION

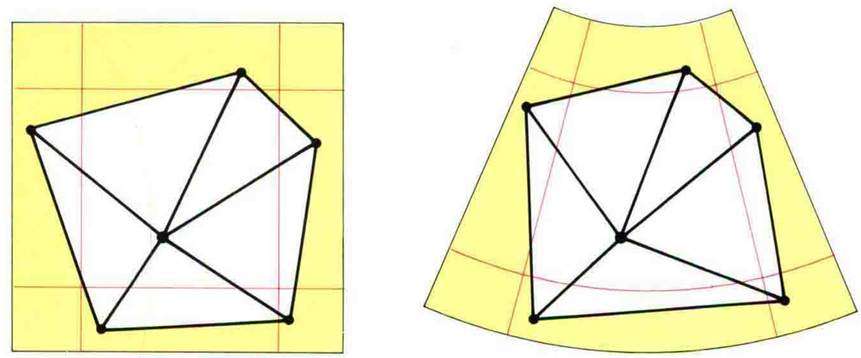





PRINCIPLE OF AZIMUTHAL PROJECTION




EQUIVALENT AZIMUTHAL EQUATORIAL PROJECTION



*Above:* Azimuthal projection. As shown in the diagram above the projection, a point of origin (*O*) is selected on the globe and a meridian line is established (*m*). To locate a second point (*P*), a great circle is drawn passing through both *O* and *P*. The angle of the great circle with the meridian and the distance from *O* to *P* are measured and transferred to the flat map.

*Right:* At top, antique map drawn in stereographic projection. At center, example of how areas appear different depending upon the projection used to make the map. On a globe, these 2 areas would be identical.

tion—any location on the curving globe can be plotted on the flat paper. There are hundreds of different styles of projections, but the three that are most commonly used are cylindrical, conical, and azimuthal. To get a basic idea of projection, imagine the Earth as a glass globe with a light located precisely in its center. If the globe is painted with dark lines to represent latitude, longitude, and continents, these lines appear as shadows when the globe is placed near a piece of paper. The shape of the shadows (and the type of projection) depends on the way the paper is positioned relative to the globe.

## Types of Projection

Cylindrical projection can be pictured by imagining this glass globe as being inside a cylinder of paper. This projection, also known as the Mercator projection, has the effect of turning the curving meridian lines of the globe into straight, parallel shadow lines on the paper. The Mercator projection is used in nautical charts.

Similarly, a conical projection can be pictured from the shadows cast on a cone of paper placed over a section of our hypothetical glass globe. A common example is a map showing the Earth viewed from the North Pole. The third type of projection, azimuthal, can be pictured when the piece of paper stands flat against the glass globe. Different types of azimuthal projection result, depending on the location of the light source within the globe, on its surface, or behind the globe. All projections are mathematical solutions to visual problems; the glass globe is merely an aid to help imagine this crucial transfer process.

No projection presents a completely uniform picture. Some ensure that all lines from the center of the map accurately reflect distance (equidistant projection), some are true to the amount of area shown (equal-area projection), and some are faithful to the shapes of the land masses depicted (conformal projection). Once the system of projection is worked out, mapmakers can plot geographical features, select color tints, add lettering, draw in boundaries, and send the finished manuscript off to the printer.

*See also* CARTOGRAPHY.

# Margarine

Margarine may seem like a newfangled substitute for butter, but in fact, it was invented in 1869 by a French chemist, Hyppolyte Mège-Mouriés, who thereby won Napoleon III's contest for the invention of an inexpensive butter substitute.

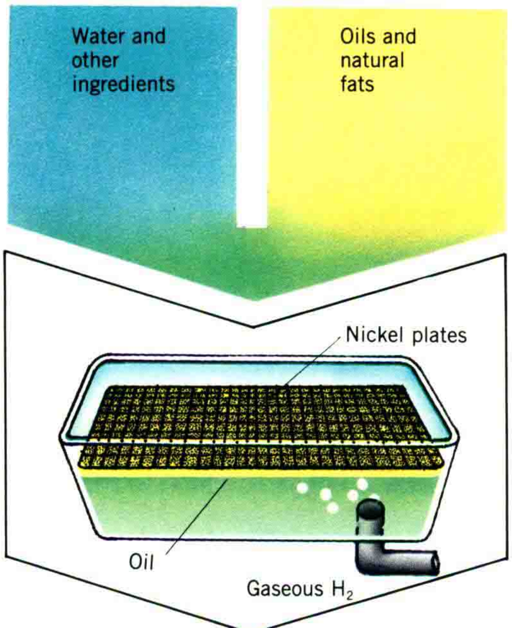
## Ingredients

Margarine consists of fats or oils dispersed in an aqueous phase (a waterlike base), containing milk products dispersed in fats or oils, and flavoring. In its early years, margarine was often made with animal fats—Mège-Mouriés's concoction contained lard—but the great interest in polyunsaturated fats and oils for health reasons has popularized the American shift to vegetable oils such as corn, safflower, soybean, cottonseed, and peanut oils. In Europe, however, lard and whale oil are still used.

According to U.S. regulations, margarine must contain not less than 80 percent fat, except for the low-calorie types on the market. The aqueous phase can be water, milk, or a vegetable-protein solution, and it must be pasteurized. Vitamin A, which is soluble in fats and oils, is added so that the finished product contains no less than 15,000 international units per pound (0.45 kg). Sometimes salt (or, for those on low-sodium diets, potassium chloride), nutritive sweeteners, emulsifiers for proper blending, preservatives, colorings, and flavorings are added (*also see* PROCESSED FOODS and FOOD ADDITIVES).

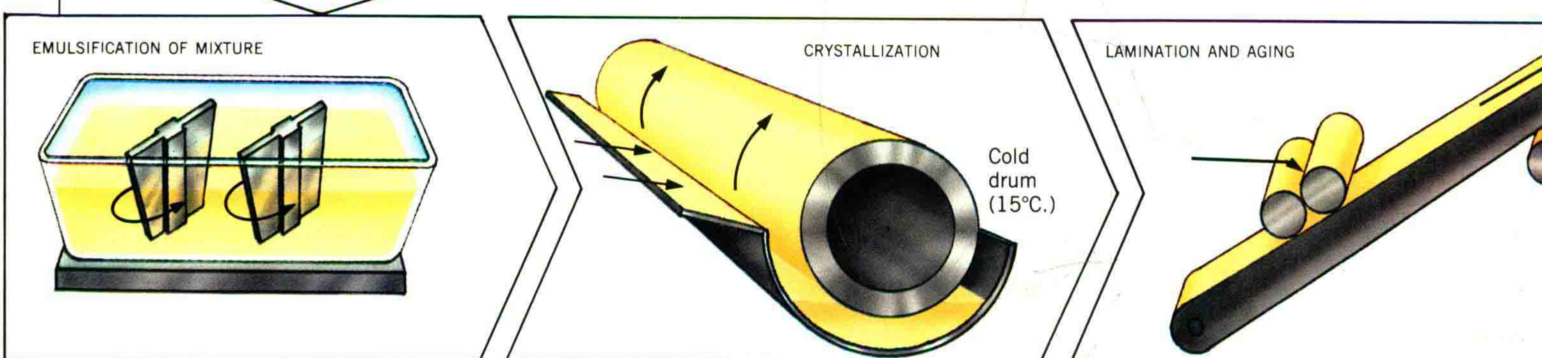
During World War I butter was in short supply, and in the United States blocks of white margarine were sold with small packets of yellow dye that home cooks stirred together in the kitchen.

The "polyunsaturated" vegetable oils in margarine are hydrogenated, so called because hydrogen is bubbled through them,



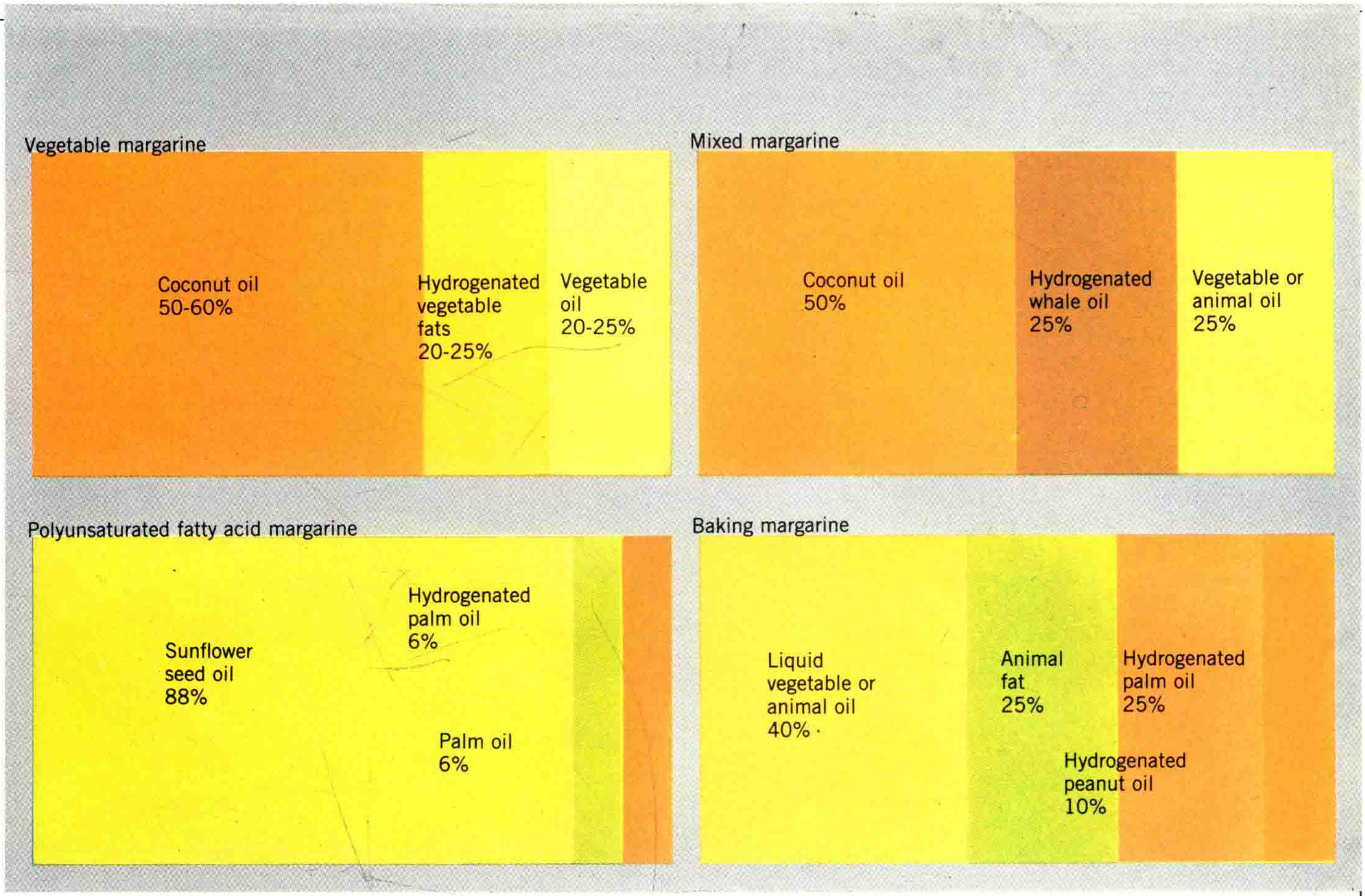

Hydrogenation of oil
200-220°C. 150 mmHg

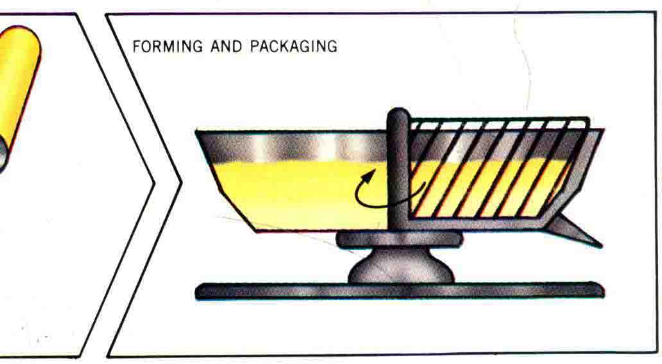
*Left and below:* Stages in the production of margarine. The most important phase is hydrogenation, which occurs in closed containers. This involves the addition of gaseous hydrogen in the presence of catalysts (usually nickel) that do not react directly with the principal ingredient, vegetable oil. The process also reduces the tendency toward oxidation of the lipids. The structure of the unsaturated fatty acids is changed, too—the normally occurring *cis*-form is changed to a trans-isomer.




AVERAGE FATTY ACID COMPOSITION OF VARIOUS MARGARINES

| TYPES OF SOLID MARGARINE | UNSATURATED FATTY ACIDS: Mono-un saturated | UNSATURATED FATTY ACIDS: 2 double bonds | UNSATURATED FATTY ACIDS: Polyunsaturated | SATURATED FATTY ACIDS |
|---|---|---|---|---|
| Vegetable | 35-66 | 12-48 | 0.5-4 | 17-25 |
| Mixed vegetable and animal | 52-57 | 2-11 | 0-0.5 | 36-41 |
| Semisolid | 22-48 | 25-65 | 0.5-3 | 15-23 |
| Spreadable | 14-36 | 42-75 | 0.5-5 | 10-17 |




The lipid phase of margarine preparation involves mixing natural ingredients in proportions that depend upon the consistency or nutritive value desired. The water phase mixture consists of water, food coloring, preservatives, and flavoring. The 2 phases are mixed together with emulsifiers, which ensure proper dispersion of the water phase throughout the lipid phase. The mixture then passes around a cold rotating drum and solidifies. It is scraped off in a sheet, allowed to age, and formed and packaged. There are several different types of margarine, based on the initial ingredients used and the degree of hydrogenation. Besides the traditional margarine prepared from hydrogenated fats and vegetable oils such as coconut and palm, many commercial margarines are highly unsaturated, containing over 80% unsaturated fatty acids.

filling the unused carbon bonds with hydrogen atoms, which raises the melting point closer to that of butter and prevents the margarine from going rancid by leaving fewer unoccupied spots to which oxygen atoms in the air can attach.

There is a growing concern about another change that takes place when polyunsaturated fats are hydrogenated—the phenomenon is the formation of mirror-image forms of molecules known as isomers. These molecules are large and complex in shape. They must have a specific configuration to fit into the body's machinery. Just as a pair of gloves share certain identical features but cannot be interchanged, the healthy *cis*-form of a fat can be converted to the look-alike *trans*-shape, which cannot properly fit into the body's biochemical processes and therefore may "gum up the works," contributing to degenerative diseases like hardening of the arteries.

## Manufacture

Mège-Mouriés's margarine was produced in the butter-churning equipment of his day. In the United States, the process was simplified so that the melted-fat mixture was churned with milk and salt, chilled with cold water until it solidified, then kneaded and packaged. Today, the process is not very different. In one supply tank are the oil components—oil and oil-soluble ingredients like vitamins—while the aqueous solution is in another (the water or milk, salt, and emulsifying agent). The two parts are each premixed in the right proportions, then blended together and pumped through a chilling machine. The mixture is cooled rapidly until it is cold but still liquid, then is allowed to rest until it is firm enough to be shaped in bars and wrapped.

If the margarine is destined either for 50-pound (22.7 kg) cans to be used in bakeries or for 1-pound (0.45 kg) tubs to be sold as "soft margarine," it is whipped. Another new form of margarine—which has no real counterpart to butter—is fluid margarine, produced according to a different oil formula and designed to be dispensed from a "squeeze" bottle.

# Marine Biology

Since ancient times, man has been inspired and fascinated by the world below the surface of the ocean. Although archaeologists have found Assyrian bas-reliefs of men swimming underwater breathing through goatskin bellows and Leonardo da Vinci made sketches of diving lungs, it was not until the 17th century that the invention of the diving bell enabled man to spend more than a few minutes at a time underwater. One of the earliest, and still indisputable, findings of the relatively young science of marine biology—the study of life in the ocean—is that the sea is one of the most complex ecosystems in the Universe. The most recent deep-sea explorations, though, have yielded surprising discoveries that challenge not only long-standing theories regarding the conditions necessary for life on Earth, but also offer evidence that life here may not have begun in the shallows, as scientists have generally believed, but may well have its source in deep-sea vents located nearly 2 miles (3,000 m) beneath the surface.

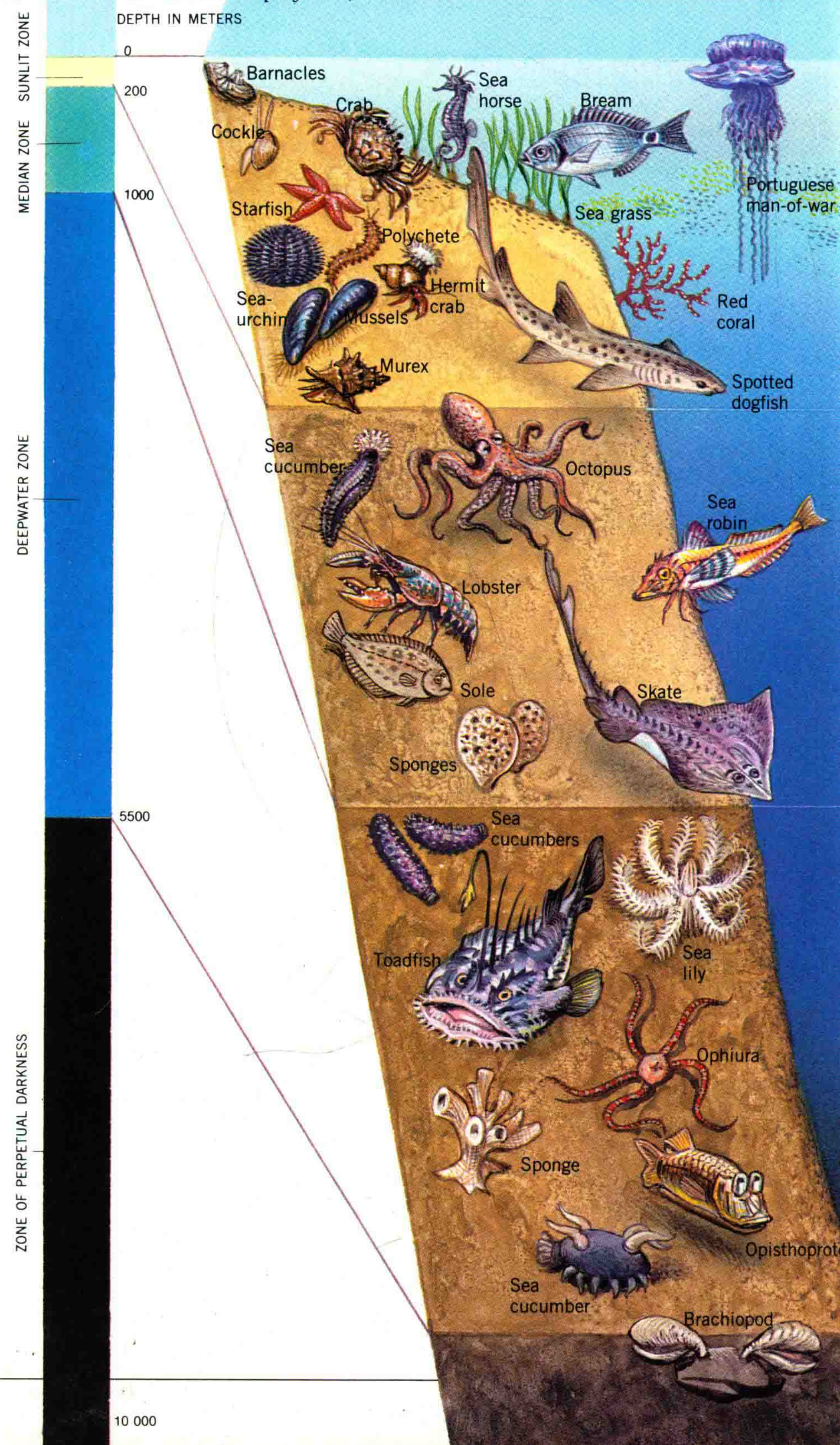
### Plumbing the Depths

The first diving suit to make it from the "drawing board" into the water required the diver to remain attached to his ship, from which his air supply was fed to him through a long rubber hose. Then, in the 1940s, Jacques Cousteau and Émile Gagnan developed the first SCUBA (self-contained underwater breathing apparatus), designed to allow the diver to go down without cables and to breathe with the minimal encumbrance of an air tank (which becomes weightless underwater) strapped to his back and the head of an air hose in his mouth. Cousteau and his crew knew that the scuba would revolutionize marine biology. Serendipity hastened to prove their point, however, for on one of their earliest expeditions, they discovered a school of monk seals supposedly extinct since 1690.

Though the invention of the scuba was a quantum leap for shallow-water biology, it does not permit divers to descend more than a few hundred feet. Auguste Piccard's 1948 invention of the bathyscaphe opened the ocean to a depth of nearly 5,000 feet (1,500 m). Much like an underwater dirigible, the bathyscaphe consists of a pressurized steel cabin, heavier than water, and a float, which is filled with fluid that is lighter than water, and thus can provide lifting power when the craft is underwater. The bathyscaphe descends beneath the surface when its ballast tanks are opened and the air therein is replaced by water.

World War II saw the invention of the two-man submarine, which served as a design model for the first series of diving saucers made in 1959. Resembling "flying saucers," the most advanced of these vehicles (now called submersibles) enables a biologist to work at 10,000 feet (3,000 m) below the ocean's surface.

Important as they are, the bathyscaphe and submersible allow biologists to work underwater for only limited periods of time. A series of "Conshelf" projects (so named because research/living stations were placed on the continental shelf) was directed by Jacques Cousteau during the 1960s and 1970s. Conshelf I, which took place in 1965, enabled two divers to live for a week at a depth of about 35 feet (11 m). By Conshelf II, six "oceanauts" could live for an even longer period of time at a depth of 369 feet (112.47 m). Not only were these scientists able to make the

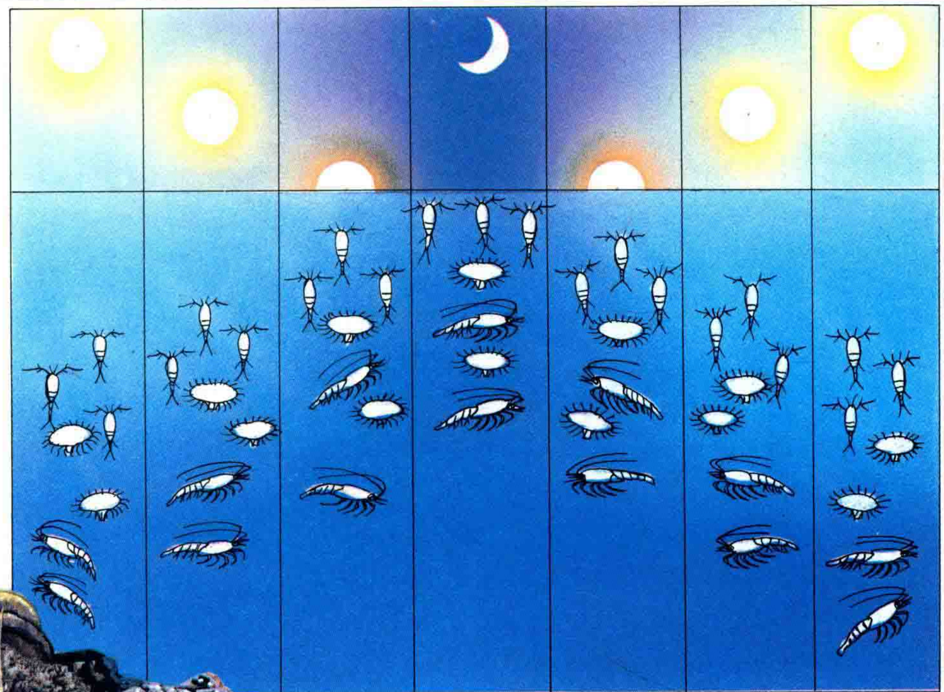


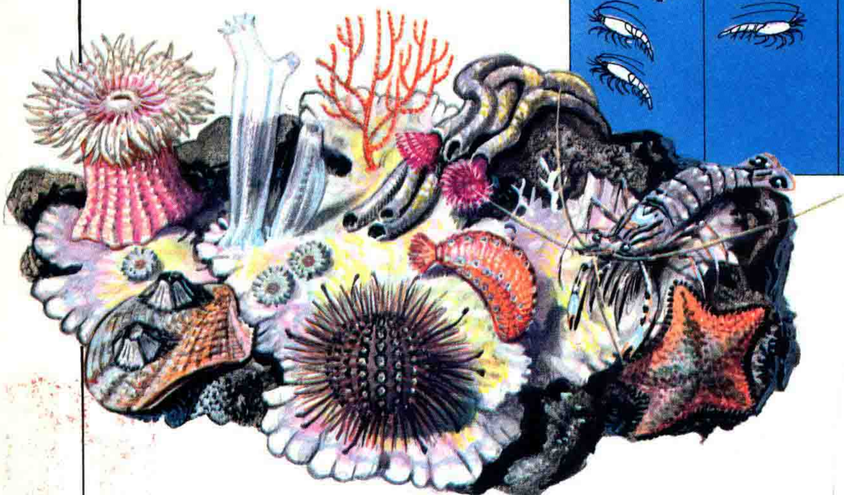
lengthiest observations of underwater life hitherto attempted, but they also were able to live comparatively normally—eating, sleeping, exercising, even playing chess. Since then, submersible design has been refined even further, and though these vehicles are very costly, they are nonetheless employed commercially, especially in the offshore oil industry.

The qualities of the ocean's waters at different depths determine the types of life at each level. The vast majority of all marine life exists relatively near the surface, where sunlight penetrates and the waters are rich with oxygen and nutrients. Below this layer there is no light. Nutrients are present in the form of decomposing elements drifting down from above and as living marine life. The forms of life in this zone of perpetual darkness have evolved strange shapes and capabilities: some even give off their own light, a phenomenon called bioluminescence. *Below:* Some of the marine creatures found at different depths of the ocean.

## Life in the Depths

Documenting the distribution of life in the ocean and observing particular patterns of marine behavior constitute major provinces of marine biology. The 1981 American *Oasis* expedition, manned by scientists from the Scripps Institute of Oceanography, the Woods Hole Marine Biological Laboratory, and several major universities, proved to be a bellwether deep-sea exploration and a turning point not only for marine biology but also for allied disciplines as well. The *Oasis* crew was stationed at the East Pacific Rise (off the coast of California) 21°N of the equator. Scientists who participated in the *Oasis* Expedition have described surface waters that were steely, harshly glaring, and apparently a fitting cover for vast stretches of eerily still, sparsely populated stretches along the bottom. The ocean surface, however, could not have been more deceiving. About 3,300 yards (3,000 m) below the surface, in vents fed on gases (hydrogen sulfide, primarily) emanating from a split in the earth's upper mantle, *Oasis* scientists turned up teeming colonies of giant clams, crabs, mussels, and worms, in addition to species that were hitherto unknown. This would have been surprise enough, but the vents have temperatures of up to 360°F. (182°C.) and pressures greater than 200 times that on the Earth's surface. Before this expedition, scientists believed that such temperatures were invariably lethal to life on Earth. Experts have concluded that the combination of high pressures and high temperature is a crucial factor for survival in the vents, for if the pressure were normal, the water would boil away into vapor.





*Left:* Examples of bottom-dwelling marine life found in shallow tropical waters.

*Above:* Effect of the Sun on distribution of marine shrimp. During the middle of the day, the Sun's radiation is strong, so that light and heat reach deep into the ocean. The shrimp, which require warmth, can descend to greater depths. Conversely, at night, when the waters cool, the shrimp rise closer to the surface. Note that the immature shrimp always remain closer to the surface than the adults.

The vents also contradict the classical notion that not only is temperature low at great depths, but food supply as well, with the result that deep-sea species have metabolic rates much slower than those of surface species. The *Oasis* team found that vent species respire, digest, excrete, and reproduce at rates comparable to those of animals in shallow waters. The explanation is that vent animals, unlike other marine species, do not rely on the bits of food that float downward from shallow waters, where photosynthesis is the driving life force. Rather, vent animals are chemosynthetic, which means that they use chemicals (in this case, hydrogen sulfide), as opposed to light, as the energy source in their production of usable organic compounds. When first advanced, this theory—logical though it seems—befuddled scientists even further, for hydrogen sulfide is a deadly poison to all organisms save those dwelling in the vents. Suspecting that vent species had evolved an adaptation that ensured the production of cytochrome oxidase (the enzyme that consumes oxygen in the metabolic process except in the presence of hydrogen sulfide), scientists began by isolating and studying this enzyme. Their bewilderment was compounded when they found no such adaptation. Later experiments, however, revealed that vent species have a blood protein that regulates the travel of hydrogen sulfide through their systems. This protein—the only one known to perform in this manner—holds the sulfide until cytochrome oxidase has completed its work; it then releases the sulfide to the specific enzymes that utilize it. The presence of this blood protein has made scientists reevaluate their supposition that life on Earth began in the shallows and gradually moved to the depths. This theory seemed correct when predicated on the notion that light is the ultimate energy source of the Earth's food chain. The fact of chemosynthesis in the depths, however, has made scientists think that these vents may have been the "bed" of all life on this planet.

## Sampling Ocean Life

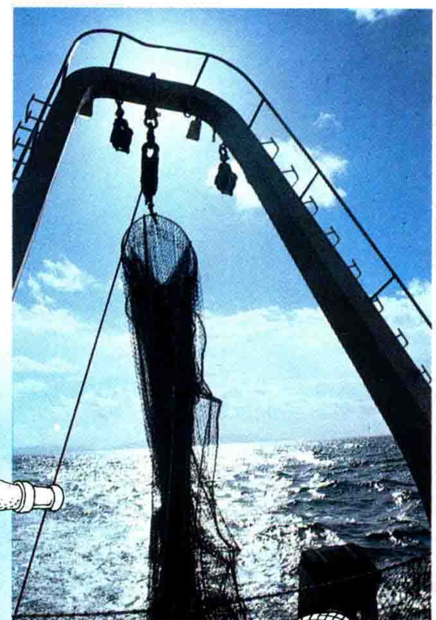
Marine biologists do not do all their ocean-life studies underwater. Especially when they are studying tiny and microscopic animals and plants, they collect water samples and examine them in permanent laboratories either on shore or on shipboard. Several instruments have been designed specifically for taking samples from the ocean floor. One example is the Petersen Grab, a jawlike apparatus that is lowered, in the open position, from the ship to the ocean floor. When it hits bottom, the impact trips a closing catch, and the "mouth" shuts. Samples are strained and separated through a series of sieves of diminishing density before the grab is brought to the surface. Marine biologists also gather bottom samples with a dredge consisting of a mesh bag affixed to a rectangular frame, which has blades for overturning bottom sediment. Because dredges move slowly, they cannot be used to capture darting or quick-swimming organisms. For these, trawls (weighted nets hauled by boats) are used.

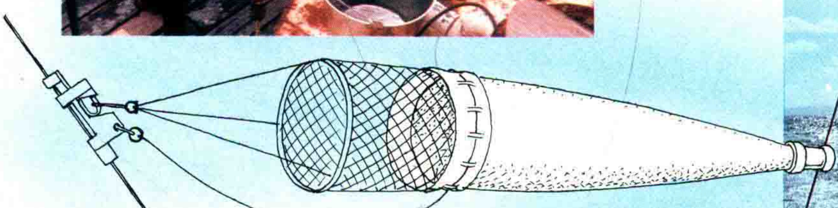
Nets are used closer to the surface to sample zooplankton, or tiny sea animals such as protozoa, worms, and primitive mollusks. These nets can be hauled either vertically or horizontally and can be closed at various depth intervals to enable scientists to determine the relative distribution of a given species.

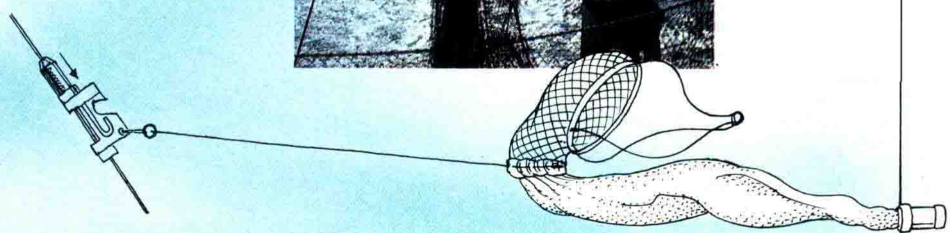
### Applications of Marine Biology

Life in the ocean greatly affects life on land. Since we rely on the sea as a food and energy source, we have an increased responsibility to its ecological integrity. Knowing the distribution of fish is important to the fishing industry as well as to biologists. A serious decline in a given fish population could signal overly zealous fishing activity or an influx of predators, which scientists could then attempt to eliminate to protect a valuable species. Marine biologists can also help to enlarge fishing areas by introducing species into regions that are rich in the nutrients they require. Observing the ways in which fish react to stimuli is helpful in developing new fishing tactics, lures, and traps.

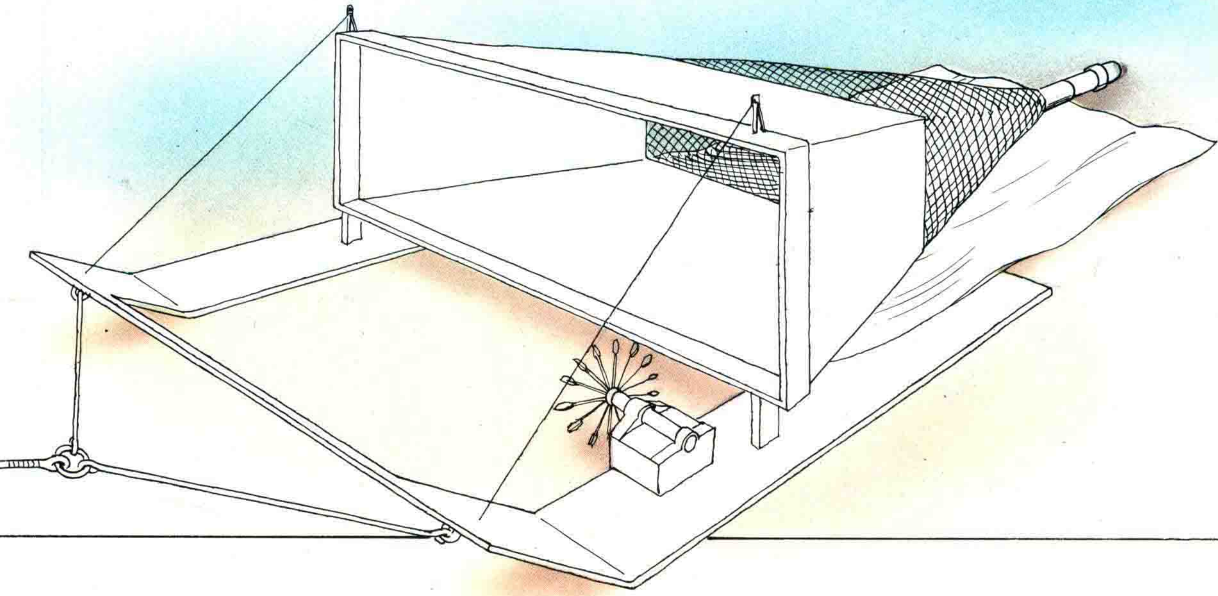
Marine biologists are playing an increasingly active role in conservation and pollution control. Though wastes may be dumped far offshore, marine animals, through migration and food chains (the documentation of which is done by marine biologists), can return the pollutants to the very waters we need to protect.







*Above:* Collecting marine samples with a trawl. When a sample has been taken (right), a weight is allowed to slide down the line, causing the catch to release. This closes the trawl, which is then hauled on board.



*Left:* Dredge used for collecting samples from a flat sea floor. The front structure of the dredge and the rotary paddles stir up the sea bottom. As the dredge moves forward, the sediment is strained through the screen, trapping specimens in the collecting net.

# Mars

To ancient civilizations, it was the blood-red god of war. To author H. G. Wells, it was the home of macabre creatures intent on conquering Earth. To contemporary scientists, it is a place of planetwide dust storms, huge volcanoes, and canyons thousands of miles long.

It is the planet Mars, Earth's neighbor in space.

### Mars and the Earth

Mars, the fourth planet from the Sun, has a highly elliptical orbit that brings it as close to the Sun as 128.4 million miles (206.7 million km) and as distant as 154.9 million miles (249.1 million km). The Martian year is about 687 Earth days, while the Martian day is only slightly longer than the days on our planet—24 hours and 37 minutes.

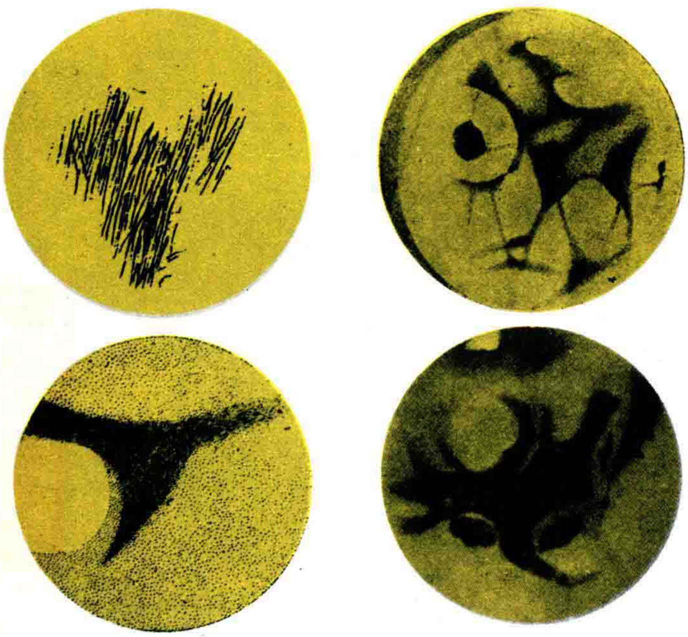
Mars is smaller than Earth, with a diameter of 4,210 miles (6,787 km), and only Mercury and Pluto are smaller. As a consequence, gravity on Mars is one third the intensity of gravity on Earth. This results in a very thin atmosphere—air pressure on the Martian surface is the equivalent of Earth's at an altitude of 15 miles (24 km). The sparse atmosphere makes Mars an extremely dry place and, combined with Mars' distance from the Sun, a very cold one as well. Though temperatures at the equator can reach 70°F. (21°C.) during the summer, the average surface temperature is 19°F. (−7°C.), and the lowest temperature recorded thus far on Mars was a bracing −275°F. (−175°C.).

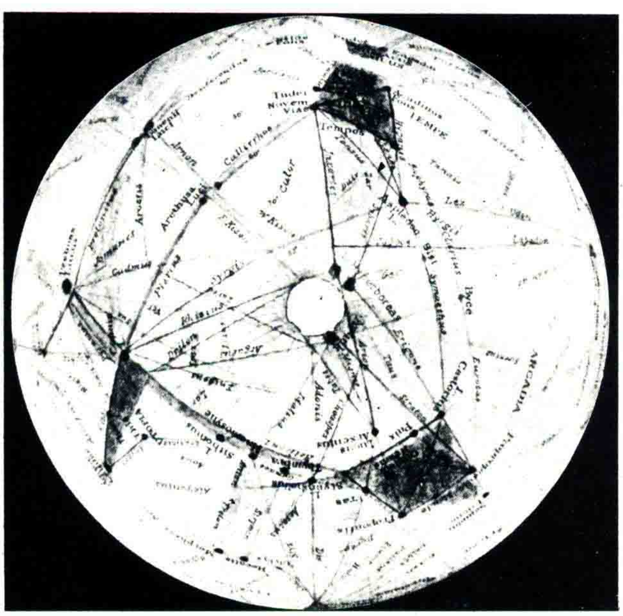
Mars has two moons to Earth's one, but they are very tiny satellites indeed. Phobos measures about 14 miles (22 km) in diameter, and Deimos a mere 8 miles (13 km). Phobos orbits Mars in less than a third of one Martian day, resulting in a phenomenon unique in all the Solar System—from the surface of Mars, it seems to rise in the west and set in the east.

### Mars and the Scientists

One of the seven planets visible to the naked eye, Mars has been known since antiquity, when its red hue earned it the name of the Roman god of war. It was often viewed as an ill omen.

For many centuries, it was believed that Mars and all the other planets circled the Earth (as did the Sun). But there was a problem—from time to time, Mars would seem to reverse direction as it moved against the unchanging background of the





*Left:* Circles record the results of early telescopic observations of Mars, beginning with a sketch by the Dutch mathematician and astronomer Christian Huygens in 1659 (top left).

*Below left:* The confused details of the Martian planetary surface visible through early telescopes fueled speculation that the planet's surface might be covered by a network of canals. As shown in the antique map, these features were even given names.

*Right:* Artist's view of the surface of Mars. Though no human has yet set foot on the planet, it has been carefully studied by a series of sophisticated space probes. Those shown in the illustration are the Soviet Mars 3 and the U.S. Viking and Mariner 4 probes. The satellites visible in the background are Deimos and Phobos, the Martian moons.