Merit
Students
Encyclopedia

14

VOLUME 14

MERIT STUDENTS ENCYCLOPEDIA

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ALPHABETICAL ARRANGEMENT OF ENTRIES

The entries in the *Merit Students Encyclopedia* are arranged in a simple alphabetical order. The method of arrangement combines elements of the system used in most dictionaries with that used in telephone directories. Each entry begins with a heading in dark type. Some of these headings contain a comma; others do not. The basic principles of arrangement are listed below, including rules for placement of identical headings.

The alphabetical sequence is letter by letter.

air
air conditioning
aircraft
aircraft carrier
aircraft landing system
airedale terrier
airfoil

When headings contain words out of their usual order, a comma is used to indicate the change of order, as in

Alaska, University of
Alba, Duke of
Alger, Horatio

Such entry headings are arranged in alphabetical sequence only up to the comma.

Bryansk
Bryant, William Cullen
Bryant College

When words preceding a comma are the same in two or more consecutive entries, the order is determined by the arrangement of the letters following the comma.

Brooks, Phillips
Brooks, Van Wyck

When two or more entries have the same heading, the entries are placed in the following order: persons, places, things.

Hannibal (person)	**Hercules** (person)	**Phoenix** (place)
Hannibal (place)	**Hercules** (constellation)	**phoenix** (bird)

Rulers with identical names are listed alphabetically by the name of the territory ruled. Rulers with the same name and same realm are listed according to dates of reign.

Frederick IX (of Denmark)
Frederick I (of Holy Roman Empire)
Frederick II (of Holy Roman Empire)
Frederick II (of Prussia)

Popes are listed by dates of reign, and they precede rulers of the same name.

Paul VI (Pope)
Paul I (Emperor of Russia)

Other persons with identical names are listed according to date of birth.

Butler, Samuel (born 1612)
Butler, Samuel (born 1835)

Places with identical names are listed according to the importance of the political unit, in descending order.

New Brunswick (Canadian province)
New Brunswick (U.S. city)

When places of the same political unit have identical names, they are arranged alphabetically by location. Cities in the United States and Canada are always located in reference to states or provinces. Cities elsewhere are usually located in reference to countries.

Abilene (Kansas)	**Abydos** (Egypt)
Abilene (Texas)	**Abydos** (Turkey)

Things with identical names are arranged alphabetically according to the subject in which they are classified.

aberration, in astronomy
aberration, in optics

GUIDE TO PRONUNCIATION

Pronunciations in *Merit Students Encyclopedia* appear in parentheses following entry headings. Heavy and light stress marks are used after syllables to indicate primary and secondary accents. A heavy stress mark is used in words that contain one primary accent, such as **comet** (kom′it). Both heavy and light stress marks are used in words that have secondary as well as primary accents, as in **communication** (kə mū′ nə ka′-shən). When two or more entries have exactly the same pronunciation, as with Paris the mythological hero and Paris the French city, the pronunciation is given only with the entry that appears first. Where possible, letters of the standard alphabet are used as symbols in the pronunciation system in preference to less familiar symbols. The symbols used are shown below with some words in which their sounds appear.

a	hat, cap	j	jam, enjoy	u	cup, butter
ā	age, face	k	kind, seek	u̇	full, put
ã	care, air	l	land, coal	ü	rule, move
ä	father, far	m	me, am	ū	use, music
		n	no, in		
b	bad, rob	ng	long, bring		
ch	child, much			v	very, save
d	did, red	o	hot, rock	w	will, woman
		ō	open, go	y	young, yet
e	let, best	ô	order, all	z	zero, breeze
ē	equal, see	oi	oil, voice	zh	measure, seizure
ėr	term, learn	ou	house, out		
		p	paper, cup		
f	fat, if	r	run, try	ə represents:	
g	go, bag	s	say, yes	a in about	
h	he, how	sh	she, rush	e in taken	
		t	tell, it	i in April	
i	it, pin	th	thin, both	o in lemon	
ī	ice, five	ŦH	then, smooth	u in circus	

In pronunciations for entries describing foreign persons and places it is sometimes necessary to represent sounds that are not used in English. Such foreign sounds are represented by four special symbols, which are listed below. Each symbol is accompanied by a brief indication of how the sound it represents is produced.

Y	as in French *du*. Pronounce ē with the lips rounded as for English ü in rule.	N	as in French *bon*. The N is not pronounced but shows that the vowel before it is nasal.
œ	as in French *peu*. Pronounce ā with the lips rounded as for ō.	H	as in German *ach*. Pronounce k without closing the breath passage.

OASIS to PHOEBE

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oasis (ō ā′sis), a place in the desert made fertile by a permanent or nearly permanent supply of water. Oases vary in size. Some are mere green specks in the desert. Others, such as the lower valley of the Nile River, are large enough to sustain millions of people.

Most desert soils are rich in plant nutrients and need only water to be productive. Water in an oasis may fall as rain hundreds of miles away, then flow underground to emerge in a well or spring. Water in an oasis may also come from a stream that originates in a rainy area, then flows through an arid region. The Nile is a good example.

In many oases in the Sahara and in Arabia nearly every square inch of land is used. Three layers of agricultural production may exist side by side, consisting of an upper layer of date palms, a middle one of olive trees or grapevines, and an assortment of vegetables at ground level. **Frank Ahnert*

Oates, Titus (ōts, tī′təs), *English conspirator. Born Oakham, England, 1649. Died London, England, July 12, 1705.*

Oates was a clergyman in the Church of England. Nevertheless, in 1677 he began to pose as a Roman Catholic convert in order to sell information on Catholic activities. In 1678 he and a confederate, Israel Tonge, invented the Popish Plot. They claimed that there was a scheme to assassinate King Charles II and to replace him with his Roman Catholic brother, James. The government arrested many prominent Catholics. On testimony by Oates, they were convicted of treason and were executed. In 1685, when James II succeeded to the throne, Oates was charged with perjury, found guilty and severely flogged, and condemned to prison for life. In 1689, William III released him. Oates' later years passed in obscurity.

**Samuel J. Miller*

oats (ōts), a cereal grain that probably originated in Eurasia or Africa and has been cultivated since ancient times. Oats are most widely raised as feed for animals, especially horses and cattle. The portion of the plant remaining after threshing is generally used as bedding for livestock but is sometimes worked into the soil as fertilizer.

The oat plant ranges from 2 to 4 feet (60–120 cm) in height. Its flat, grasslike leaves are bluish green and may reach a foot (30 cm) in length. Along

Gabès, one of the largest oases in Tunisia, lies on the northern rim of the Sahara. The oasis supports about 350,000 date palms.

RAWSON/PHOTO RESEARCHERS

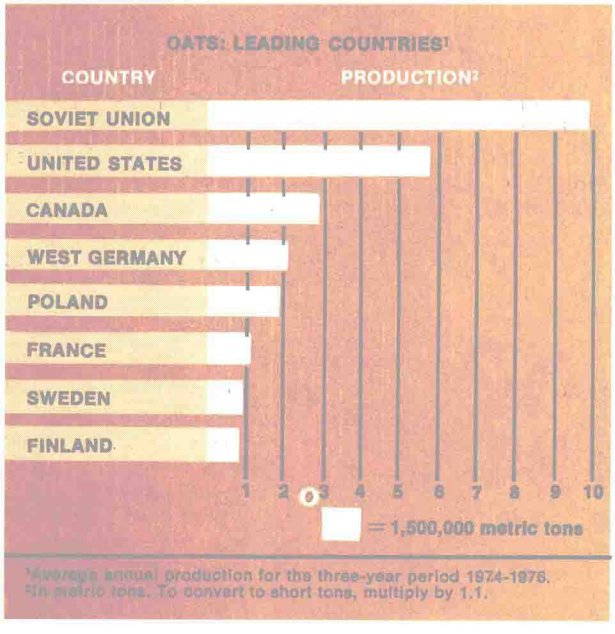
GRANT HEILMAN

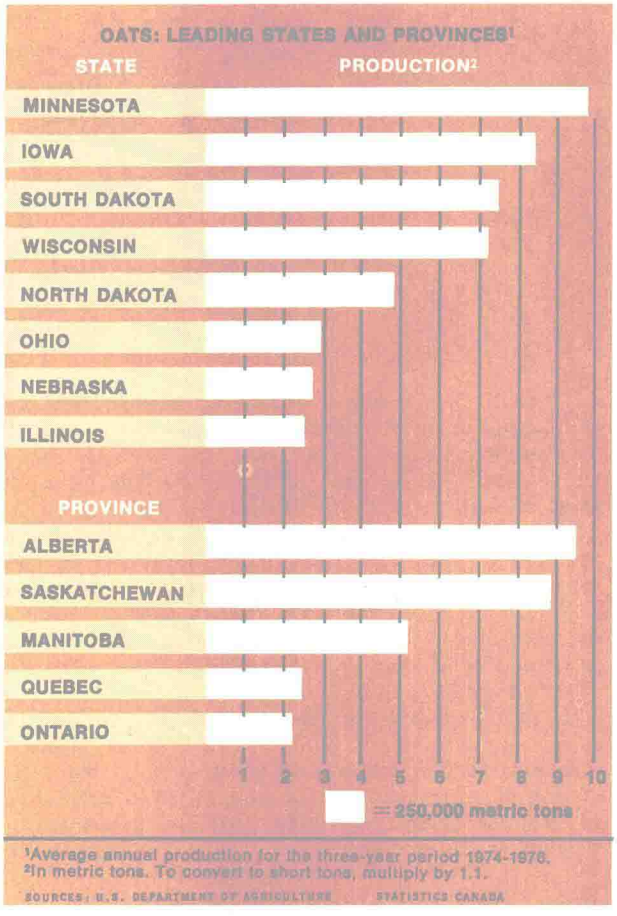
Oat grains grow on thin branches near the top of the stem.

the top of the stem are many short thin branches. These end in spreading clusters of tiny flowers, each of which ripens into an oat grain. In most varieties the grain is encased in a thick hull. Oat hulls may be red, white, yellow, gray, or black, and oats are often classified according to the color of their hulls.

In the United States only 3 or 4 percent of the total oat crop is used as food for people, generally in the form of rolled oats—oats that have been hulled, steamed, and passed through rollers. Rolled oats are used in cakes, biscuits, cookies, and oatmeal. Oats are rich in protein and fat and are high in vitamin E and the B vitamins thiamine and riboflavin.

Oats can be raised under a wide variety of soil and climatic conditions, but they grow best in rich heavy soil and in cool moist climates. In northern regions, oats are planted in spring. In southern areas they are usually planted in late October. Planting is normally done by machine in straight rows. Sometimes, however, the seed is scattered evenly by hand. Generally the seed is first treated with fungicides.





Spring oats are harvested the same year they are planted, usually in July or August. Winter oats are harvested the following summer. Generally, harvesting is by combine—a machine that reaps, threshes, and drops the straw back onto the field.

The oat plant, *Avena sativa,* is classified in the family Gramineae (grass). Annual. **Firman E. Bear*

Oaxaca (wə hä′kə), *a state in southern Mexico; on the Pacific Ocean. Area about 36,375 square miles (94,211 sq km). Pop. (1970) 2,171,700.*

Oaxaca consists largely of mountains of the Sierra Madre del Sur ranges. Most of the people farm or raise livestock in the fertile mountain valleys. Corn is the main crop, but coffee, sugarcane, and tropical fruits are also grown. Silver, gold, and copper are mined. The state, which has the largest Indian population in the country, is also known as Oaxaca de Juárez in honor of Benito Juárez, the Mexican Indian hero who was born there in 1806. **Preston E. James*

Oaxaca, *a city in southern Mexico; the capital of the state of Oaxaca. Pop. (1970) 116,800.*

Located in a mountain valley at an elevation of more than 5,000 feet (1,500 meters), Oaxaca is a commercial and religious center for southern Mexico. Economic activities include lumber and flour milling, food processing, and the manufacture of textiles, leather goods, and handicrafts such as the handwoven woolen capes known as serapes. The city is officially called Oaxaca de Juárez in honor of Benito Juárez, born near Oaxaca in 1806. **Preston E. James*

Obadiah (ō′bə dī′ə), a Hebrew prophet and a book of the Old Testament traditionally ascribed to him. The name, also spelled Abdias, means "worshiper of God" or "servant of God" in Hebrew. Nothing is known of Obadiah except his book. Consisting of only one chapter, it is the shortest book in the Bible. It was probably written in the late 6th century B.C., shortly after Jerusalem was destroyed and its people were carried off to captivity in Babylonia. Obadiah prophesied the subjugation of the Edomites as God's punishment for their part in the Babylonian attack on Jerusalem.

**Rev. Holt H. Graham, *Rev. Thomas H. McBrien, O.P., *Cecil Roth*

obelisk (ob′ə lisk), a tall four-sided column, often made from a single block of stone. An obelisk narrows gradually to a pyramidal top. The earliest obelisks were short rectangular structures that were used as gravestones and as garden monuments. Later examples were taller and tapered more sharply toward the peak. Well-known examples are the obelisks in the Place de la Concorde in Paris, France, in the Piazza of St. Peter's in Rome, Italy, and Cleopatra's Needles, either of a pair of Egyptian obelisks, now in London and New York City. (*See also* CLEOPATRA'S NEEDLE.) Monuments in the United States that are in the form of obelisks include the Washington Monument in Washington, D.C., and the Bunker Hill Monument in Boston, Mass.

Obelisks originated in Egypt during the Old Kingdom (about 2700–2200 B.C.). Dedicated to the sun-god and symbolizing a single ray of the rising sun, they bore hieroglyphic inscriptions that recorded the titles and achievements of the pharaohs. The larger Egyptian obelisks were made from slabs of red granite and were placed at temple entrances. Of the many obelisks erected in Heliopolis, the ancient Egyptian city of sun worship, only that of Senusret I (1971–1928 B.C.) remains. **Percival Goodman*

Oberammergau (ō′bər äm′ər gou), *a village in the southern part of West Germany; in the state of Bavaria; about 40 miles southwest of Munich. Pop. (1970) 4,661.*

Oberammergau is a popular resort and tourist center in the Ammer river valley of the Bavarian Alps. The famous Oberammergau Passion Play is performed there every ten years by the villagers. It has been presented since 1634, in accordance with a vow the villagers made for having been spared from a plague in the previous year. Oberammergau is also noted for its fine wood carvings. **Norman J. G. Pounds*

Oberhausen (ō′bər hou′zən), a city in the northwestern part of West Germany, in the state of North Rhine-Westphalia, just northwest of Essen. Oberhausen is one of the iron and steel and commercial centers in the Ruhr industrial region. Pop. (1974 est.) 239,300.

**Norman J. G. Pounds*

Oberlin College, Oberlin, Ohio, a private, accredited, coeducational college. It has a college of arts and sciences and a conservatory of music.

The institution was established in 1833 as Oberlin Collegiate Institute. In 1837 women were admitted as candidates for degrees, and Oberlin became the first coeducational college in the United States. It adopted its present name in 1850. *See also* SCHOOLS, COLLEGES, AND UNIVERSITIES. **J. Robert Williams*

obesity (ō bēs′ə ti), a condition in which an excessive amount of fat is stored in the body. The fat accumulates in all parts of the body, but usually excessive amounts are deposited in certain areas, such as the abdomen. Obesity is very common. Many people more than 30 years old weigh from 10 to 15 percent more than they should and are considered to be slightly obese. At least 20 million Americans exceed their ideal weight by 20 percent or more.

Obesity, if it is considerable, is a serious condition. The extra fat in the body puts a strain on the heart and other organs and on the skeletal system, which must support the weight of the body. Obese people also have a tendency to develop at relatively young ages the diseases that commonly occur with old age. Such diseases include hardening of the arteries, high blood pressure, diabetes, and arthritis. Statistics show that people who are obese do not have as long a life span as do people who are thin.

Occasionally, obesity is due to a disorder of an endocrine gland, such as the thyroid or the pituitary, or to a disorder of the part of the brain called the hypothalamus. In most cases, however, there is no physiological reason for the excess fat, and people are obese simply because they consistently eat too much. As a result, more calories are taken in than are required by the individual for energy and the excess food is stored by the body as fat.

Exercise also plays an important role in obesity. The less active a person is the less food he requires. People who get little exercise may eat only moderate amounts of food, but they will still gain weight if their food contains more calories than are needed.

There are many reasons why people overeat. Eating habits are established during childhood, and the pattern of overeating is sometimes related to family or cultural background. Overeating may also have psychological causes. For example, a person may eat more than he needs because he is nervous, insecure, upset, frustrated, or unhappy.

If obesity is caused by a physiological disorder, the disorder should be corrected. Generally, however, the only treatment for obesity is to reduce the number of calories taken in. When more calories are burned during a day than are taken in, the body will start to burn its stored fat and the person will lose weight. To avoid regaining the lost weight, it is important to maintain new eating habits.

For many reasons, it may not be easy for obese people to lose weight. However, it is important for them to do so, since the consequences of obesity may be dangerous. *See also* WEIGHT CONTROL.

Louis J. Vorhaus, M.D.

Oblate College. *See under* SCHOOLS, COLLEGES, AND UNIVERSITIES.

oboe (ō′bō), a high-pitched musical instrument of the woodwind group. It has a penetrating, intense tone and a range of about three octaves. The instrument consists of a cone-shaped tube approximately 2 feet (60 cm) long, with a double-reed mouthpiece at the narrow end. It is played by vibrating the reeds with the breath and using the fingers and a system of keys to open and close the holes along the length of the tube. The English horn is an alto oboe.

Pipes similar to the oboe were used in ancient Egypt

as early as 3700 B.C. Several types of double-reed instruments, including the shawm, curtal, crumhorn, and bagpipe, developed in the Middle Ages. The modern oboe originated in France in the 17th century, when it was known by its French name, *hautbois* ("high wood"). By the end of the 18th century it had replaced many woodwinds with less range and had become an important orchestral and solo instrument. Many compositions have been written with solos for the oboe and members of its family. Some notable examples of such works are Purcell's *Dioclesian,* Bach's *Christmas Oratorio,* Haydn's oboe concerto, and Mozart's Serenade No. 10. The oboe traditionally sounds the note A to which an orchestra tunes at the start of a concert. **Sigmund Spaeth*

Obregón, Álvaro (ō brā gōn′, äl′vä rō), *Mexican statesman. Born near Álamos, Mexico, Feb. 17, 1880. Died San Angel (now Villa Obregón), Mexico, July 17, 1928.*

Obregón, a young rancher, helped overthrow the Mexican dictator Porfirio Díaz in 1911. In the many years of revolution that followed, Obregón proved to be one of Mexico's ablest generals. He was war minister under Venustiano Carranza and helped frame the constitution of 1917. When Carranza opposed his presidential ambitions, Obregón deposed Carranza by force.

Elected President of Mexico in 1920, Obregón brought stable government to his country. He initiated land reform, taxed oil, and supported a rural school system. He chose Plutarco Elías Calles to succeed him in 1924. Obregón was elected president again in 1928. However, two weeks after the elections he was assassinated. **Donald E. Worcester*

A musical tone is produced on an oboe by blowing through a small mouthpiece that consists of two very thin pieces of reed. LINTON

Ob River (ōb), in the Asian part of the Soviet Union, in the region of Siberia. About 2,290 miles (3,685 km) long, the Ob is one of the longest rivers in the Soviet Union. Together with its major tributary, the 2,700-mile (4,345-km)-long Irtysh River, it forms one of the longest river systems in the world. The two rivers and their tributaries drain an area of more than 1,000,000 square miles (2,589,990 sq km).

The Ob River is formed near the city of Biisk in southern Siberia by the junction of the Biya and Katun rivers, which rise in the Altai Mountains. It is a broad, largely navigable river that flows generally northwestward to the Arctic Ocean. The river crosses the vast, sparsely populated area of swamps and forest called the taiga, and farther north it crosses the cold treeless plains of the tundra. At its mouth the river forms a large estuary called Ob Bay.

The Ob is a major water route of western Siberia, although navigation is impeded by ice during the winter. The bulk of the freight transported on the river consists of lumber and grain. Most of the settlements on the Ob lie on the upper course of the river. They include the industrial cities of Barnaul and Novosibirsk. A large hydroelectric plant is located on the river just above Novosibirsk. The river is sometimes called the Obi River. **W. A. Douglas Jackson*

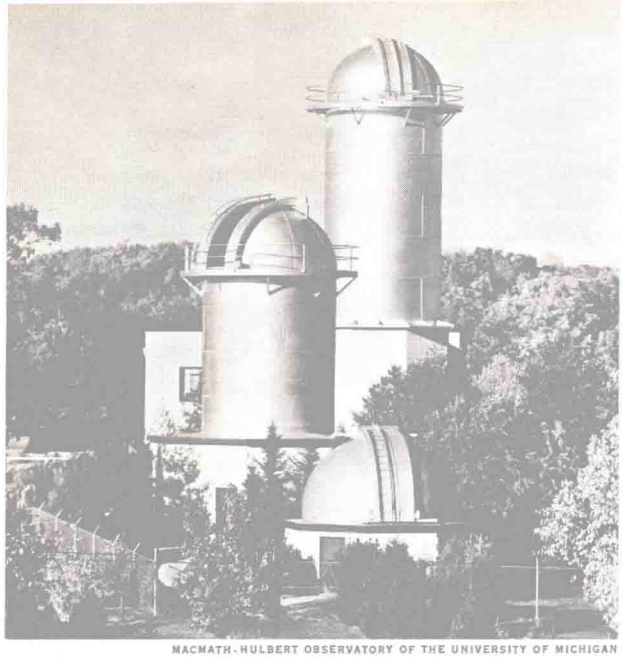
observatory (əb zėr′və tô′ri), a station or institution where astronomical information is collected and analyzed. Large modern observatories have not only telescopes but also photographic darkrooms, computing rooms, laboratories, a library, administrative and research offices, and even residence facilities.

Observatories are generally located on mountaintops to avoid the higher concentrations of fog, smoke, and dust of the lower layers of the atmosphere. Wherever possible, observatories are isolated from large cities, where the reflection of lights in the sky makes it more difficult to view faint celestial objects.

Functions. Most observatories are equipped for a field of specialized study. Some are used mostly for positional astronomy, which is the study of the positions of stars and planets for the purpose of locating related positions on the earth. Other observatories have the primary function of studying the stars, planets, and other celestial objects themselves. By analyzing the light and other radiation received from these objects, many facts about their motion and their physical and chemical nature can be learned.

Equipment. The principal instrument of a modern optical observatory is a large telescope, usually contained in a hemispherical dome that can be rotated on a circular track. The dome has an opening extending from the base to slightly beyond the peak. Roll-back shutters cover the opening when the telescope is not in use. The dome is usually of steel or copper and is often silvered or aluminized on the outside to reflect sunlight that might otherwise produce unwanted heat during the day. The inside is generally painted black to reduce the amount of stray light that could interfere with the work of the astronomers. (*See also* ASTRONOMY; TELESCOPE.)

Modern observatories collect information mostly through the use of photographic plates in conjunction with telescopes. Large telescopes can rotate or pivot to keep track of a moving celestial body.



MACMATH-HULBERT OBSERVATORY OF THE UNIVERSITY OF MICHIGAN

The domes and buildings of the MacMath-Hulbert Observatory of the University of Michigan house two solar tower telescopes.

History

The earliest known observatories were built in Egypt about 2600 B.C., and in Babylonia about 2000 B.C. The observatory at Alexandria, Egypt, was the most famous of antiquity. Ancient observatories were probably as much religious as astronomical in purpose; the stone circles of Stonehenge, for example, may have been built to predict eclipses, or prepare calendars.

During the Middle Ages the Arabs were the dominant force in mathematics and astronomy. The Moslem astronomer Ulugh Beg (1394–1440) had an observatory at Samarkand equipped with large stone instruments. Arab influence and learning spread eastward to Persia, and filtered into Europe through Spain.

From 1576 onward the Danish astronomer Tycho Brahe carried out extensive naked-eye studies of the heavens from his observatory on the island of Ven. The invention by Galileo in 1609 of one of the first telescopes marked the beginning of a new era in astronomy. In the 1670's, national observatories were founded at Paris, and at Greenwich, near London. Today observatories are common throughout the world.

Until the beginning of the 20th century most observatories had refracting telescopes as their principal instruments. A 40-inch (102-cm) refractor, installed at Yerkes Observatory in 1877, is still the world's largest. Large reflecting telescopes are to be found at Mount Wilson Observatory (100 inches, or 254 cm), Palomar Observatory (200 inches, or 508 cm), Zelenchukskaya Observatory in the Soviet Union (236 inches, or 600 cm), and in many other countries.

Space Age Astronomy. The astronomer of today can make use of many parts of the spectrum besides the light "window" to observe the heavens. Radio astronomy, the study of radio waves from space, developed rapidly after World War II. Gamma-ray astronomy and X-ray astronomy began in the 1960's when rockets, orbiting observatories, and space stations carried instruments beyond the obscuring effects of the earth's atmosphere. These, together with the Large Space Telescope (LSP) to be launched in the 1980's and, eventually, observatories on the moon, will add much to man's knowledge of the universe. *See also* RADIO ASTRONOMY.

**Lloyd Motz*

obsidian (ob sid'i ən), a glassy, usually black, igneous rock. It is formed when lava cools too rapidly to allow crystals to grow.

**Patrick M. Hurley*

obstetrics (ob stet'riks), the branch of medicine that deals with pregnancy, labor, and childbirth. An obstetrician cares for patients from the detection of pregnancy until a few weeks after delivery. He examines the patients regularly throughout pregnancy and aids them during labor and delivery. Obstetricians also treat diseases, abnormalities, and complications of pregnancy.

**Louis J. Vorhaus, M.D.*

ocarina (ok'ə rē'nə), a musical wind instrument, popularly called a sweet potato because of its oval shape. It is small and hollow and is made of metal, terra-cotta, or plastic. Its pure, whistle-like tone is controlled by blowing into a mouthpiece and closing or opening the ten finger holes. The modern ocarina, developed in Italy during the 19th century, is a popular amateur instrument.

**Sigmund Spaeth*

O'Casey, Sean (ō kā'si, shôn), *Irish dramatist. Born Dublin, Ireland, Mar. 30, 1880. Died Torquay, England, Sept. 18, 1964.*

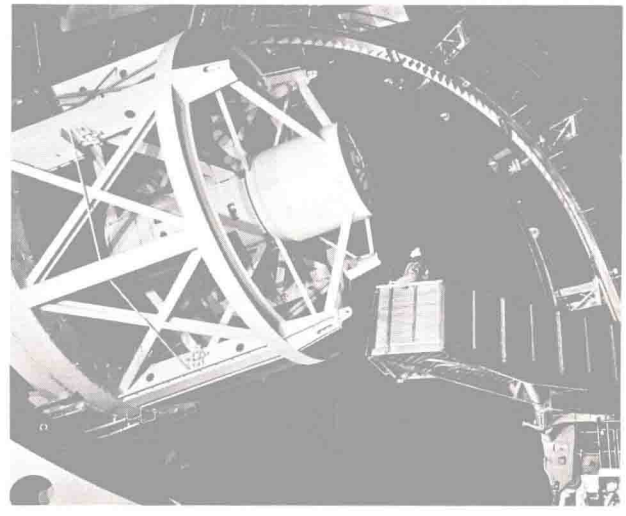
O'Casey is best known for his early tragicomedies, including *The Shadow of a Gunman* (1923), *Juno and the Paycock* (1924), and *The Plough and the Stars* (1926). In these plays he portrayed the Irish working classes during the early-20th-century rebellions against English rule. The plays are noted for their bold comedy and dramatic power.

After working as a laborer for many years, O'Casey began to write professionally at the age of 44. His early plays were first produced at the Abbey Theatre in Dublin. Embittered by the poor reception given *The Plough and the Stars,* he left Ireland in 1926 and settled in England. Many of his later plays, such as *Purple Dust* (1940) and *Cockadoodle Dandy* (1949), are exuberant comedies, marked by a strong use of symbolism and elements of fantasy. His other works include an autobiography, *Mirror in My House* (1956), and *The Green Crow* (1956), a collection of essays on the theater.

**A. M. Nagler*

An observer at the Palomar Observatory rides the elevator to the prime-focus position of the 200-inch (508-cm) Hale reflector.

MOUNT WILSON AND PALOMAR OBSERVATORIES



Occidental College. *See under* SCHOOLS, COLLEGES, AND UNIVERSITIES.

occultation (ok'ul tā'shən), in astronomy, the eclipse, or covering, of one celestial body by another. The term usually refers to the eclipse of a star or planet by the moon. Occultations provide strong evidence that the moon has little or no atmosphere. They also provide accurate information for determining the exact orbit of the moon. **Lloyd Motz*

occultism (o kul'tiz əm), belief in the existence of mysterious or hidden spiritual powers that are beyond man's normal capabilities of understanding. The term also applies to the study of such powers and to the special practices by which man can achieve and use supernatural knowledge. In ancient times, possession of occult powers was commonly believed to bestow such abilities as telepathy, clairvoyance, foreknowledge of future events, and telekinesis, which is mental control of material objects. Astrology, alchemy, necromancy, and fortune-telling were among the forms of occultism believed to involve these abilities. Occultism still exists, although the natural sciences have explained many phenomena formerly understood only in occultistic terms. **Morton H. Fried*

occupational therapy. *See under* REHABILITATION.

ocean (ō'shen), the body of salt water covering the greater part of the earth. Viewed from outer space on a clear day, the earth would appear predominantly blue. This is because the planet is mostly under water. Here and there the surface of the earth rises above the sea to form land. Areas of land range from vast continents to tiny islands a few steps wide and isolated rocks, many too small to be shown on maps.

Most scientists believe that the solar system—the sun and its planets—was formed from swirling clouds of dust and hot gases between 4 and 5 billion years ago. With cooling temperatures, beginning at least 4 billion years ago, the earth's first crust began to appear. This started a process that, over vast periods of time, led to earth's early atmosphere and first surface waters. Somewhere in these shallow seas simple forms of life began to emerge. Fossil impressions of living things already relatively advanced are found in rocks almost 4 billion years old. Life continued thereafter to develop along many lines, some of which led to the higher animals and eventually to the human species.

Man, a product of the ocean, has always felt drawn to the sea. Early man was terrified of its violent motions and rarely ventured out of sight of land. The Phoenicians are said to have been the first seamen who dared to sail at night, guided by the North Star. Gradually man began to harvest the sea for food and ornament, to venture ever further from its shores on voyages of barter and discovery, and to come to a better understanding of its changing moods. Many masterpieces of literature, painting, and music have been inspired by man's fascination with the sea. Today, the history of the ocean is reasonably well known, and the details of its floor are beginning to be mapped in detail. Yet modern man, strolling along a lonely seashore, can still sense something of the mystery and magic that puzzled and challenged his remote ancestors.

The History of the Oceans

No geological record exists of the first billion years or so of the earth's history. The earth was probably a much larger planet originally, with a huge atmosphere of cosmic gases and a rocky, molten core. This early atmosphere was swept away, perhaps during a period of intense solar activity. Vast amounts of gases were given off by the semi-molten surface of the earth and, later, by volcanoes. At the same time, the primitive crust was forming. Over billions of years the exhaled gases—enriched in time with oxygen from plant life—began to show a resemblance to the present environment: an atmosphere of nitrogen and oxygen, with oceans and rainstorms of water. Thus, the earth's present atmosphere, and its surface waters, derived entirely from the planet itself.

Crustal Rock. There is a basic division to earth's crust. About 40 percent of the crust consists of lightweight rocks that make up the continents. The remaining 60 percent is composed of heavier rocks for the most part covered by water; they form the ocean floor and are very similar to the lavas that erupt from the volcanoes of Hawaii.

The latter, or oceanic, type of rock is called basaltic. Basaltic rock probably composed the original crust of the earth. The first, or continental, type, known as granitic, may have derived from the basaltic by repeated cracking and remelting of the original crust, or granitic rock may be the result of a much more gradual process involving the remelting of the products of continental weathering. Geologists tend to favor the first view, but there is as yet no general agreement on the origin of crustal rock.

Ocean Basins. Approximately 60 percent of the surface of the earth's crust lies beyond the continental margins. This part of the surface is low-lying and filled with water, forming the ocean basins. Thus, the Pacific Ocean fills a vast depression between North America and South America on the east and the Asian and Australian continents on the west.

Prior to 180 million years ago, the Pacific, Atlantic, Indian, and Arctic oceans did not exist as separate entities. Instead, the continents were then a single mass surrounded completely by what has been termed the Tethyian Sea. As Gondwanaland, as this single continent is called, began to rift apart new oceans were formed. The Atlantic formed with the splitting of North and South America from Europe and Africa. Similarly, Australia split off from Antarctica forming a boundary between the Indian and Pacific oceans. The Arctic has been enclosed by the general northward drift of continents away from Antarctica. Each ocean basin is an area of major rifting, and no sea floor has yet been found with an age greater than about 180 million years.

Marine Sediments. The floor of the ocean is covered, although not uniformly nor everywhere, with sediments of organic and inorganic origin. The two types of sediment may occur separately, but are often found together.

Organic Sediment. This is formed from the shells, skeletons, and other hard parts of mainly microscopic plants and animals. Depending on local conditions, this organic material may settle on the seabed or, if the ocean is deep enough, be largely dissolved on the way down, leaving a residue of fine silt on the bottom.

WESTON/RAPHO GUILLUMETTE

A stretch of rugged California seacoast. The force of wind and ocean waves gradually changes shorelines by wearing away bits of rock.

Inorganic Sediment. All traces of the original surface of the earth has been removed by weathering and erosion. The process continues today: streams and wind sweep the land of loose debris and deposit it on the sea floor as sediment. The heavier material sinks close to the land, but dust and fine particles, as well as volcanic ash, may remain in suspension for a long time. When it finally settles it may cover an entire ocean basin with fine red, gray, and green clays.

Abyssal clays are laid down at a rate of about one meter per million years; organic detritus may be 10 to 15 times thicker for a similar period of time.

The World Ocean

Slightly more than 70 percent of the earth's surface lies under 330 million cubic miles (1,375 million cubic km) of ocean; a volume of water sufficient to cover the globe to a depth of 12,000 feet (3,660 meters) if the surface of the planet were smooth. Salt water covers about 60 percent of the Northern Hemisphere, and about 81 percent of the Southern Hemisphere.

Although the world ocean is global, that is, everywhere continuous, it was discovered piecemeal, and its various parts were called by different names at different times. For example, the Pacific was once known as the Western Ocean, the Atlantic as the Great Ocean, and the North Atlantic as the North Ocean. The names Atlantic, Pacific, Indian, Arctic, and Antarctic were recommended by the Royal Geographical Society of London in 1845.

The Major Oceans. The Pacific Ocean, Atlantic Ocean, and Indian Ocean are the world's largest oceans. The Pacific Ocean, 70 million square miles (181 million sq km) in area, is almost circular in shape and covers more than one-third the earth's surface—almost as much as the Atlantic Ocean and Indian Ocean combined. The Atlantic Ocean, 36.3 million square miles (94 million sq km), forms a broad "S" with the two

Student's Guide

This article is organized under the following major headings.

Individual oceans are the subjects of separate articles. The ways in which scientists study the ocean are discussed in the article OCEANOGRAPHY. Movements of ocean water are discussed in greater detail in the articles OCEAN CURRENT; TIDE; and WAVE. For further study of life in the ocean consult the articles MARINE BIOLOGY; ANIMAL; FISH; and individual articles on marine animals. Fish and other food resources in the sea are discussed in the article FISHING INDUSTRY.

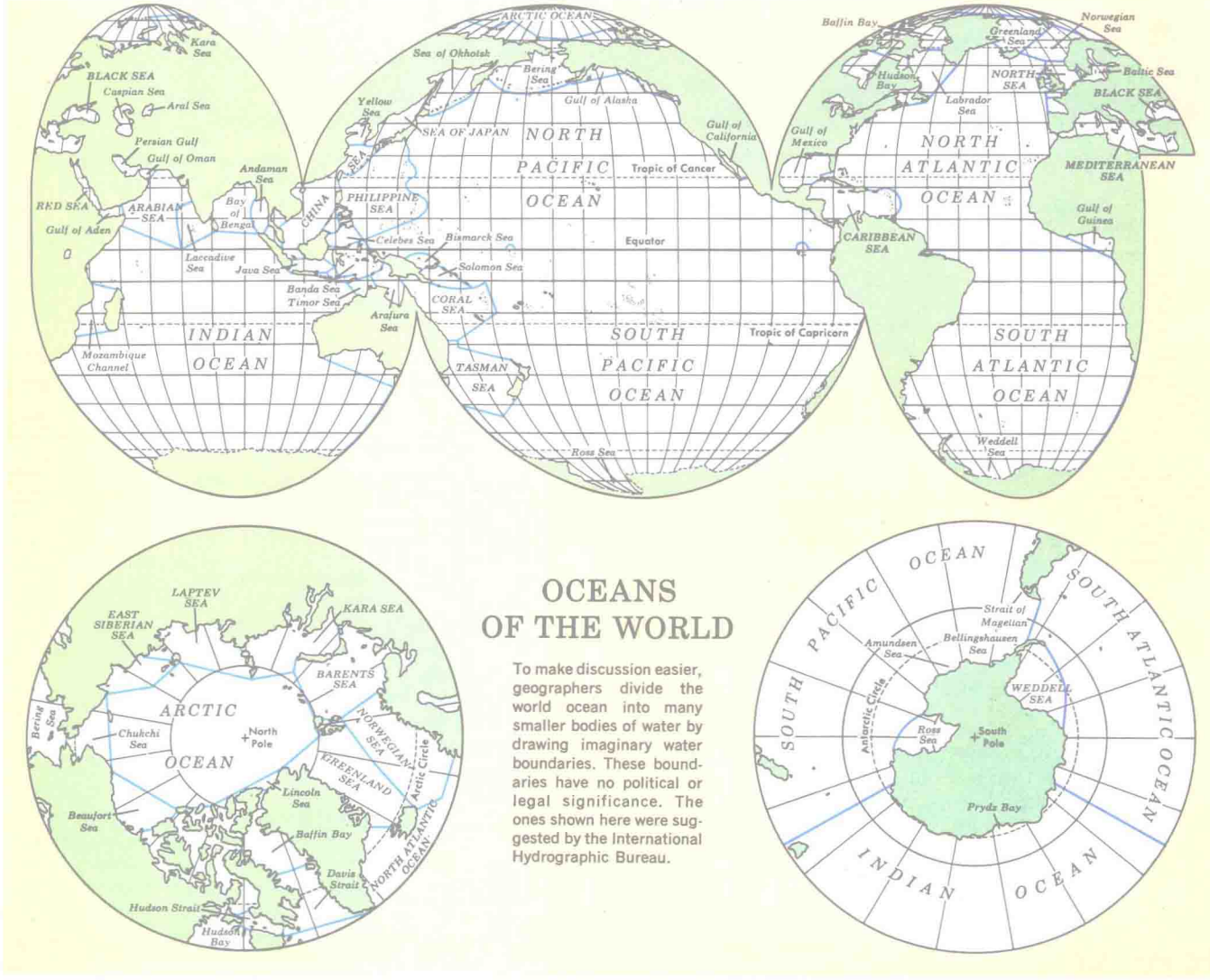
sides almost matching, like the path made by a giant tractor winding its way through a snowfield. The Indian Ocean (28.2 million square miles or 73 million sq km) forms a large triangle with the Indian Peninsula protruding through the upper apex.

The Lesser Oceans. The Arctic Ocean, with its cover of floating ice and area of only 3.7 million square miles (9.5 million sq km), is almost surrounded by land. Like the Pacific, it has a circular shape, as though a hole had been punched into the top of the planet. Some geographers refer to the area around the continent of Antarctica as the Antarctic Ocean. This area, however, has no natural boundaries on the north and consists largely of the southern extremes of the three major oceans. The International Hydrographic Bureau does not accept the Antarctic as a separate ocean.

Seas. These are smaller bodies of water that often link with an ocean. Connected with or merging into the Atlantic Ocean, for example, are such seas as the Mediterranean, the Norwegian, and the Caribbean. There are also seas within seas: the Mediterranean has seven internal seas. Seas are often named for the color imparted to them by their content or surroundings. Thus, the Red Sea is so called for the small reddish algae that grow in it; the Yellow Sea owes its name to the color of its mud; and the color of the White Sea is due to the ice that covers it for most of the year. Some seas are completely landlocked and generally more salty than the ocean. The Dead Sea is such a sea.

The Ocean and Atmosphere. The ocean has an average depth of 2.5 miles (4 km), a thin cover compared to the 8,000-mile (almost 13,000-km) radius of the earth. The atmosphere, which fades into outer space several hundred miles up, is far more of an envelope surrounding the earth.

The ocean and the atmosphere act and react upon each other with the combined effect of a great engine, with the ocean as regulator. Nearly a third of all solar energy reaching the earth's surface goes to evaporate seawater, in a process that both helps to maintain moisture in the atmosphere and supplies it with energy. Atmospheric winds, in turn, help to drive the great ocean circulations and strongly effect the properties of seawater. Thus, ocean and atmosphere are linked together as two fluid streams in which life is sustained and whose nature and motion determine the environment and profoundly influence weather and climate. Winds, the earth's rotation, and land barriers all effect the circulation of the ocean and the atmosphere in ways not yet well understood.



The Ocean and Climate. Climate is the long-term behavior of weather in any area. It is well known that temperature and climate at any given latitude may vary greatly from inland locations to the seashore. Compared with the land, the ocean heats slowly in summer and cools slowly in autumn. The oceans of the world are thus a moderating influence on temperature, and hence on climate.

A substantial portion of the atmosphere's heat and almost all its water vapor comes from the ocean. Only surface waters are involved in this heat transfer; over 95 percent of the ocean is so deep that the temperature of the water there does not change. Atmospheric water vapor is concentrated mainly in the lower troposphere —the lowest layer of the atmosphere, where most of earth's weather is generated. Water vapor rises to form clouds, is blown about by winds, and keeps the planet fertile by watering it with rain or snow.

So far as is known, the earth is the only planet in the solar system with large standing bodies of water, allowing it to support abundant life.

The Nature of Ocean Water

Composition of Seawater. Ocean water is, on average, about as salty as a glass of water containing a teaspoon of salt. The salty taste is due to the 3.5 percent of dissolved mineral matter—largely sodium and chlorine, the principal ingredients of table salt. In general, high salinity needs a closed, or nearly closed basin. It is estimated that the salt in the oceans would cover all the continents to a depth of about 500 feet (150 meters). Magnesium is next in order of abundance, followed by sulfur; all the common metals are included. Most of the chemical elements have already been detected in seawater, and probably all are present. The nonmetallic elements calcium and silicon are of particular importance as they are extracted from seawater by most marine animals to form shells and skeletons. Due to the churning effect of waves and currents the chemical composition of seawater is about the same anywhere in the oceans. Seawater and human body fluids are much alike in composition; evidence, perhaps, that life began in the ooze of the primeval ocean.

Properties of Seawater. Seawater has a density of about 1.03, slightly greater than that of fresh water (1.0). This makes it more buoyant, hence easier to swim in, than fresh water. The density of seawater increases with depth (pressure) and also varies with temperature and salt content. The deeper parts of the ocean are also the coldest and most saline parts. The densest water in the ocean may remain cold and deep for more than a thousand years.

Because seawater has low viscosity and high surface tension it yields to a ship's bow or a swimmer and runs off surfaces easily. The predominant blue of the sea—like that of the sky—is due to the scattering of sunlight by molecules. The presence of pigments, minute plants and animals, and suspended or dissolved materials may result locally in various other hues, such as yellow, green, and shades of red.

Seawater is much less transparent to visible light than air, but is more transparent than most other substances. Sunlight has been observed to depths as great as 2,300 feet (700 meters), but 1,800 feet (300 meters) is about average. Seawater can be penetrated for short distances only by electromagnetic waves, making a submerged submarine difficult to detect by radar.

There is a surprising amount of noise in the sea—from marine animals, waves, undersea tremors and volcanoes, submerged and surface vessels, etc. The velocity of sound in seawater varies around 5,000 feet (1,500 meters) per second. Sound waves may travel through the ocean for thousands of miles.

Seawater conducts electricity about 4,000 times better than fresh water. The sea is slightly alkaline; its pH (degree of alkalinity or acidity) is constant at about 8.1. Because of its high salt content (average salinity: 35 parts per thousand) it cannot be used for drinking or irrigation.

Oceanic Life

The ocean teems with over 200,000 species of living organism of a diversity almost impossible to imagine. New species, and specimens of known but rare species, are continually being discovered. Some, like the coelacanth, are living fossils whose ancestors flourished more than 300 million years ago; others have evolved in more recent times.

Most sea life occurs in shallow waters where light penetrates and allows photosynthesis to take place. In 1960, however, a fish and a shrimp were seen through the porthole when the manned bathyscaph Trieste I descended to the bottom of the Challenger Deep, 36,198 feet (11,033 meters) down. More recently, abundant life (clams, mussels, sea anemones, limpets, chitons, and dandelion-like organisms) have been found clustering around active hot springs at depths of 9,000 feet (2,700 meters) in the Galapagos Rift zone. Fish have been photographed under the 1,375-foot (420-meter) ice shelf in Antarctica. Zones relatively rich in oxygen and in nutrients such as nitrates are also favorable to life. The process known as *upwelling* brings nutrient-rich water to the surface and accounts for the abundant marine life found along some coasts.

Life in the ocean varies from microscopic one-celled plants and animals to 50-feet (15-meter) fish such as the whale shark and to mammals such as the blue whale that may be more than 100 feet (30 meters) in length —larger than the largest dinosaurs that once roamed the earth. For a detailed account of oceanic life see the article MARINE BIOLOGY.

Waves, Tides, and Currents

The ocean, like the universe itself, is never still. The forces of nature, including catastrophic events such as erupting volcanoes and undersea earthquakes, produce a great variety of motions in ocean waters.

Waves. Waves are beautiful to look at from the

SAMPLE OF SEAWATER ELEMENTS

Element	Tons per Cubic Mile
Chlorine	89,500,000
Sodium	49,500,000
Magnesium	6,400,000
Sulfur	4,200,000
Potassium	1,800,000
Bromine	306,000
Iron	47
Tin	14
Silver	1
Lead	0.1
Gold	0.02

shore, but are sometimes unpleasant in their effect on ships' passengers. Ordinary waves are the result of wind blowing unevenly on the surface of the sea. This action sets particles of water in motion. Ripples are first formed, followed by a rhythmic rise and fall of the surface. Patterns develop, somewhat like those set up in a rope jerked at one end. The surface of the ocean moves up and down, but individual particles of water move almost in a vertical circle, with little or no forward motion. As the wind increases, the waves grow higher. In the open sea the distance between the crest and trough of a wave may reach 100 feet (30 meters). Distances between crests may be as much as 1,000 feet (300 meters).

Waves may break by either *plunging* or *spilling*. Plunging breakers, coming from distant storms, have a hollow front; their crests curl over, descending like a waterfall. The famous surfing waves at Waikiki beach, Honolulu, are plunging breakers. Spilling breakers, developed in wind waves, lack the hollow front; a spilling breaker descends like a cascade. In both types of wave, the water is carried up the beach as an *uprush* and returns as *backwash*.

Catastrophic Waves. These may be due to a sudden change in depth—a fault movement—of the sea floor (*tsunamis*); to a hurricane or other great storm (*storm surges*); or to a landslide from coastal cliffs (*landslide surges*).

Tsunamis may advance over the deep ocean at speeds of 450 to 500 miles (700–800 km) per hour. They come ashore as huge breakers, flooding the land to as much as 100 feet (30 meters) above normal sea level. Tsunamis can be very destructive. At Hilo, Hawaii, waves coming from Alaska in 1946 and from Chile in 1960 caused much loss of life and property. Tsunamis are also caused by volcanic eruptions or collapsing island craters, as at Krakatoa (Krakatau) Island in Indonesia in 1883.

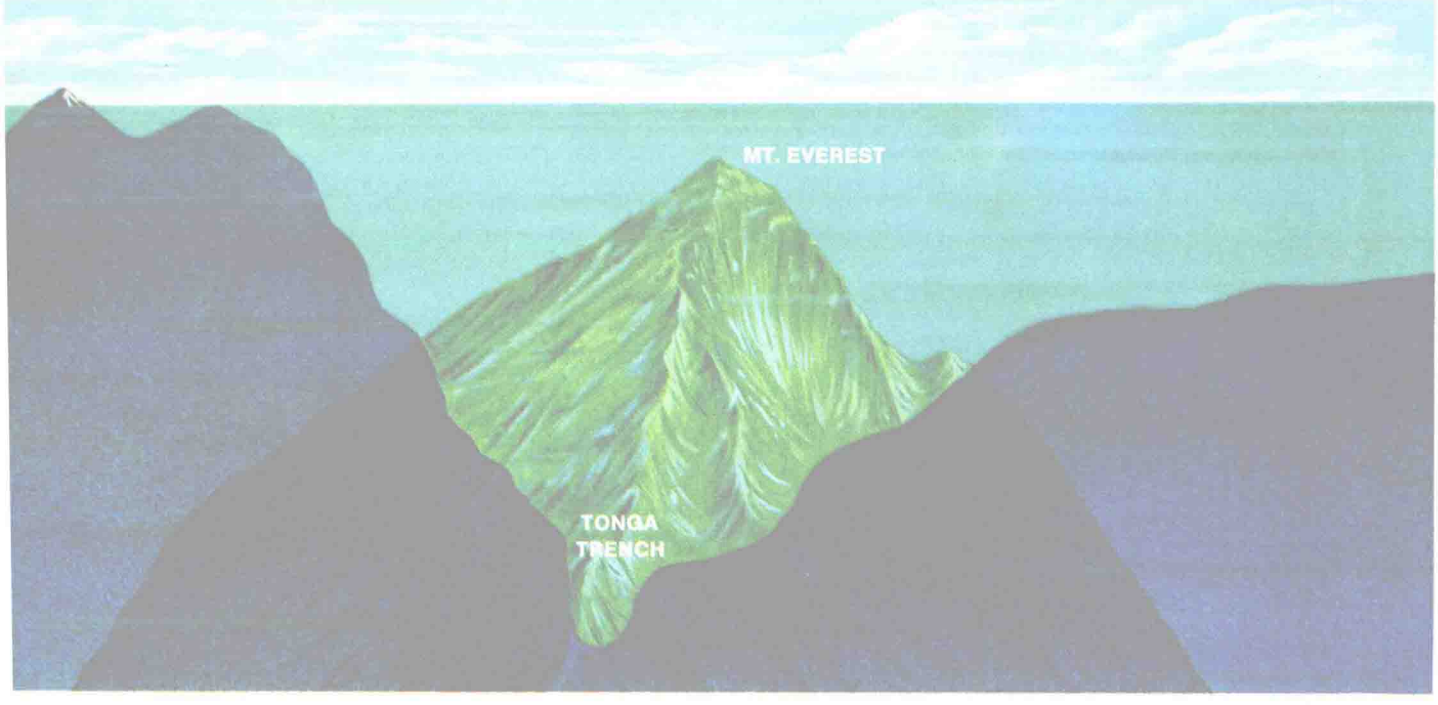
Hurricane storm surges can be even more destructive. The sea, pushed ahead of an advancing hurricane or other great storm, rises as a surge that may carry water over a coastal plain for many miles. In Bangladesh, at the Bay of Bengal, a storm surge drowned as many as 300,000 people in 1737. In 1900 Galveston, Texas, a hurricane destroyed a 10-foot (3-meter) wall and drowned most of the inhabitants.

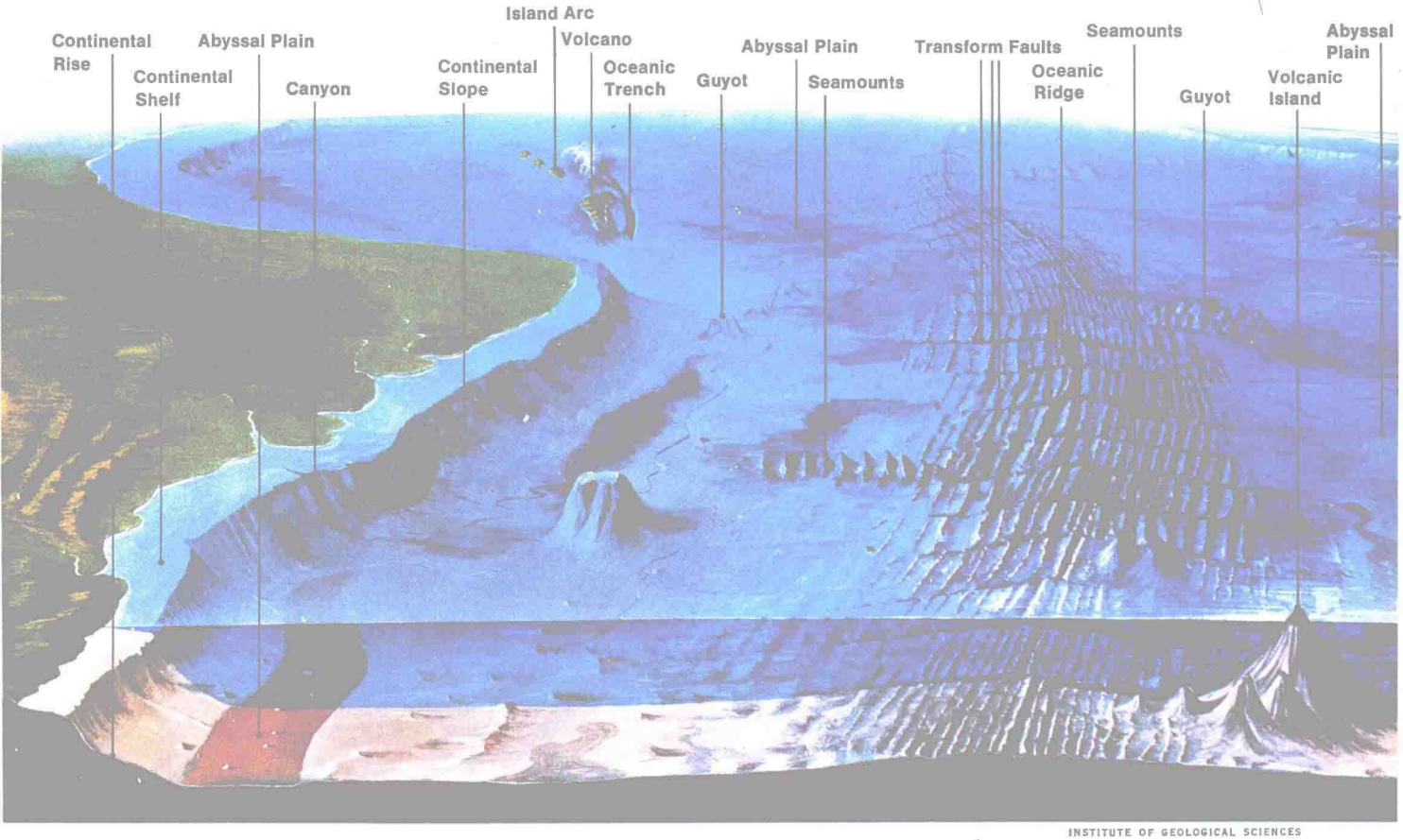
Landslide surges are so rare that they have been given little attention. If a large block falls from a sea cliff into a relatively deep inlet, it may displace an enormous volume of water. In 1796, a landslide on Kyushu Island, Japan, drowned some 15,000 people in a series of three large waves. In Lituya Bay, Alaska, a landslide in 1958 forced water up a mountainside, uprooting trees to a height of 500 meters (1,700 feet). Although this was the largest wave on record, few lives were lost in a sparsely inhabited area.

Tides. Oceans differ from lakes in more than one important respect. On ocean shores, tides may raise the water level by as much as 50 feet (15 meters). In lakes, tides are almost always negligible. Tides are caused by the gravitational pull of the moon and sun on the earth, and modified by the rotation of the earth —the Coriolis effect. Tides are generally diurnal, that is, there is a high tide and a low tide each day. Tides, although most obvious along or off the seashore, also exist in the open ocean. Tides cause most of the strongest coastal currents, so that navigators need to consult tide and current tables in order to proceed safely. At the entrance to the inland seas of Japan tidal currents have velocities of up to 11 knots and in the Seymour Narrows, British Columbia, as much as 16 knots.

Currents. Ocean currents are due to differences in temperature and salt content (density) between one water body and another, and also due to wind. Surface currents tend to be wind driven; for deeper currents, density differences are more important.

The Tonga Trench, in the south Pacific Ocean near New Zealand, is deeper than Mt. Everest is high by about 6,300 feet (1,900 meters).





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The main features of the ocean floor include ridges, transform faults, seamounts (drowned peaks), and guyots (flat-topped seamounts).

Waves tend to build up along the shore, causing water to move rather slowly in a *longshore current*. At certain points a seaward return current (*rip tide*) occurs which can be dangerous to swimmers. The rotation of the earth causes great ocean currents to move clockwise in the Northern Hemisphere and counterclockwise in the Southern Hemisphere. Some of the best fishing areas are to be found in specific currents, such as the Labrador Current off the east coast of North America, and the anchovy-rich Humboldt Current off the western coast of South America.

Turbidity Currents. Where ocean sediment is not stable, particularly in steep sloping areas, an earthquake or similar force may cause it to flow. These turbid sediment and water flows are known as turbidity currents. They may transport sedimentary material over vast distances of the sea floor. Velocities of from 1 to 6 miles (1.5–10 km) an hour have been measured for turbidity currents. After the Grand Banks earthquake of 1929 most of the cables between the United States and northern Europe were broken, and turbidity currents probably contributed to these dislocations.

Coasts and Coastlines

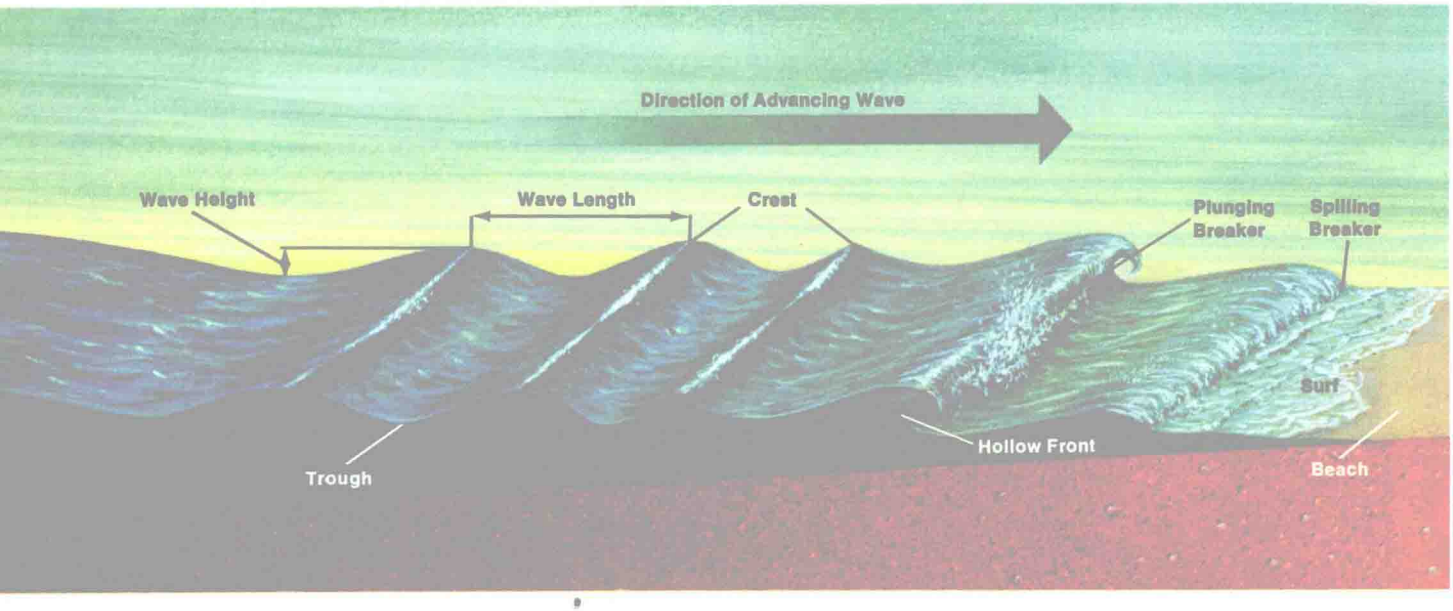
Maps reveal surprising differences in coastal configuration. The coasts of Maine, northern Washington, southern Alaska, and Norway have innumerable bays, islands, and passageways. The coast of Texas is bordered by long, straight sand islands. The coasts of North Carolina, Virginia, and Maryland are notable for deeply penetrating and branching inlets, such as Chesapeake Bay. Examples of similar types of coastline occur in many parts of the earth.

History. Up to about 18,000 years ago great glaciers covered most high latitude lands. As the glaciers melted water flowed into the ocean, eventually raising sea level some hundreds of feet. The ocean penetrated the land valleys, forming estuaries. Where the glaciers had cut valleys well below sea level, as off Alaska and Norway, deep embayments with many rocky islands were left. Where the sea rose over lowlands, it drowned the river valleys. Currents also produce long sand islands (*barriers*), some with projecting points, *cuspate forelands*, as at Cape Hatteras.

Where large rivers carrying abundant sediments existed, deltas were built; Louisiana is largely a postglacial delta. Where faulting was raising blocks of land as fast as sea level rose, straight-cliffed coasts could be preserved. In the island of Hawaii, volcanoes were continuing to erupt, and lavas were flowing into the sea, building lava deltas. In many places, as in Chesapeake Bay and the coasts of the northwest Iberian Peninsula, inlets caused by drowning of the river valleys were preserved. Where the waves had been actively cutting back the coasts, sea cliffs developed. Since the rise in sea level has virtually stopped in the past 2,000 years, many of these cliffs (e.g. as in California), remain.

In areas where warm, clear water allowed corals to grow, the rise in sea level allowed the reefs that fringed the coasts to grow upward more actively on the seaward side of the reefs. This resulted in lagoons inside the reefs. Storms broke off coral from the outer reef and threw it up as rubble above sea level. Hence islands developed among the barrier reefs. Rings of coral growing around sinking volcanoes became atolls when the islands finally disappeared beneath the waves.

Beaches. Beaches are one of man's prized possessions. Beaches are composed mainly of sand, although some beaches consist of gravel, and some even of cobbles. Some of the sand is made of waterworn shells.



The profiles of beaches usually show both inclined and near horizontal portions. The steepness of the sloping foreshore depends on the coarseness of the sand. Fine-sand beaches have gentle slopes, those with coarse sand are relatively steeper, while beaches of gravel and cobbles are steepest of all. Although the upper beach (backshore) is usually above water level, it may be inundated by large waves during storm conditions.

There are several types of beach. The long, relatively straight beaches that border barrier islands are the most common along United States coasts. Channels along the shore, called troughs, often occur in this type of beach and may contain dangerous currents. Seaward of the troughs are elongate *sand bars* where the waves usually break. Rip currents are very common during large wave conditions.

Relatively long beaches may border sea cliffs, as in many of the beaches of southern California. Irregular rocky coasts have many caves containing small secluded beaches, often protected seaward by exposed rocks or submerged reefs.

Beaches usually have features such as *cusps, ripple marks, backwash marks,* trails made by starfish and other organisms, and *rill marks* due to water running out of the sand at low tide.

Topography of the Sea Floor

Fifty years ago geologists were convinced that in general the sea floor is monotonously flat. It is now known to contain a maze of great mountain ranges, huge canyons with precipitous walls, long ridges, and deep rift valleys. In fact the seabed is almost as irregular as the surface of the land.

Continental Shelves, Slopes, and Rises. The continental shelf is the extension of a continent out to sea. These shallow platforms are not nearly as flat as had been supposed. It was formerly believed that the shelves were a combination of wave-cut benches along the coast bordered by wave-cut terraces. Actually, the shelves and their adjacent continental slopes are far more complicated. Rock banks are common on the outer shelves and rocks are even found in many places on the slopes.

Off glaciated areas most shelves contain troughs and basins, so that deep water often extends in close to the shore, as in the fiords of Norway, Alaska, southern Chile, and the deep troughs of Maine and the Gulf of St. Lawrence. Glacial troughs often extend across the entire shelf and are locally bordered by shallow banks where fishing is particularly good, such as Georges Bank and the Grand Banks off Newfoundland, Nova Scotia. Shelves are less irregular off unglaciated coasts, but many of them have elongate sand ridges and even rock ridges that rise above the general level.

The average depth at which the continental shelf begins to slope to the ocean floor is about 430 feet (130 meters). This is probably the approximate depth to which the sea level was lowered by the buildup of ice on the continents during the ice age. At such a level deltas were formed in some places. Elsewhere the waves cut platforms into the continental margin close to the lowered sea level. However, there have been sufficient earth movements and postglacial sedimentation to greatly modify this worldwide effect.

Amazingly, sediments have been found on the outer continental shelves that were deposited when the sea level was hundreds of feet below its present level, and which contain bones of mammoths from the glacial period, and occasionally even tools of ancient man.

The continental slopes are notable for two features: their boundaries with the shelves are invariably sharp and well defined, and they are almost always cut by deep canyons. The average slope is about 4° but may be much steeper, even vertical, in places. Around the Atlantic and Indian oceans the continental slope, at its lower limit, becomes a much more gently inclined surface called the continental rise. Around the Pacific Ocean the rise is usually missing; instead, a deep trough is often found, where earthquakes due to fault movements are common and most tsunamis have their origin.

Submarine Canyons. These canyons—similar in many ways to canyons on land—are commonly cut 1,000 feet (300 meters) or more below their surroundings. The Great Bahama Canyon, the deepest known, has walls almost 3 miles (5 km) high. In 1977 two