Merit
Students
Encyclopedia

15

MERIT STUDENTS ENCYCLOPEDIA

WILLIAM D. HALSEY
EDITORIAL DIRECTOR
LOUIS SHORES
SENIOR LIBRARY ADVISOR

MACMILLAN EDUCATIONAL CORPORATION
NEW YORK
P. F. COLLIER, Inc.
LONDON and NEW YORK

Library of Congress catalog number 78-56516

Manufactured in the United States of America.

2

3

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 kā′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
ā	age, face
ã	care, air
ä	father, far
b	bad, rob
ch	child, much
d	did, red
e	let, best
ē	equal, see
ėr	term, learn
f	fat, if
g	go, bag
h	he, how
i	it, pin
ī	ice, five

j	jam, enjoy
k	kind, seek
l	land, coal
m	me, am
n	no, in
ng	long, bring
o	hot, rock
ō	open, go
ô	order, all
oi	oil, voice
ou	house, out
p	paper, cup
r	run, try
s	say, yes
sh	she, rush
t	tell, it
th	thin, both
ᴛʜ	then, smooth

u	cup, butter
u̇	full, put
ü	rule, move
ū	use, music
v	very, save
w	will, woman
y	young, yet
z	zero, breeze
zh	measure, seizure

ə represents:
- a in about
- e in taken
- i in April
- o in lemon
- 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.

ʏ as in French *du*. Pronounce ē with the lips rounded as for English ü in rule.

œ as in French *peu*. Pronounce ā with the lips rounded as for ō.

ɴ as in French *bon*. The ɴ is not pronounced but shows that the vowel before it is nasal.

ʜ as in German *ach*. Pronounce k without closing the breath passage.

PHOENICIA to REVELATION

15

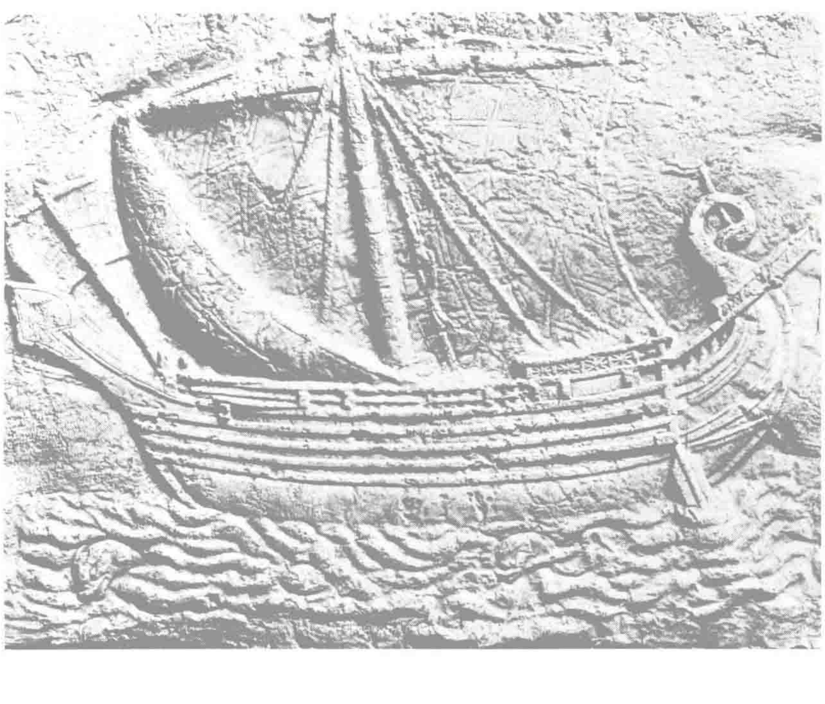
Phoenicia (fə nish′ə), an ancient district on the eastern Mediterranean coast, in the area that is now Lebanon. The Phoenicians were enterprising merchants and sailors who had a great commercial and cultural influence on the Mediterranean world for many centuries until about 300 B.C. Their far-flung trading colonies were spread along the shores of the sea. The Phoenician homeland, occupied for much of its history by a loose federation of city-states, was at times referred to as Lebanon or Canaan. The word "Phoenicia" is based on the Greek word for purple and probably refers to a valuable purple dye that was produced in the area. Later, "Canaan" came to mean the region of Syria and Palestine, and "Phoenicia" meant the narrow strip along the Mediterranean.

Early History

Along the Phoenician coast human settlements have been built one on top of the other since prehistoric times. At Byblos, archaeologists discovered the circular huts of a Neolithic, or New Stone Age, culture that vanished about 3000 B.C. Little is known about the people, but the style of such relics as tools and pots indicates that these Stone Age men already had come into contact with the civilizations of Egypt and Mesopotamia.

Overlying the Neolithic ruins are the remains of city walls, temples, and rectangular houses, indicating a well-developed urban civilization. Invaders from the north and south seem to have entered the area, intermarried with the settled population, and created a new culture. Those who came from Asia Minor introduced bronze, an alloy of copper and tin, ushering Phoenicia into the Bronze Age. Between 3000 B.C. and 2000 B.C., Semitic tribes from farther east infiltrated and gradually came to dominate Mesopotamia, Syria, and Phoenicia. To these countries they brought their Semitic language and their nature-worshiping religion. In addition, they probably brought with them elements of their laws.

Left. A goddess of Phoenicia. The finely executed bronze statuette of the goddess indicates the skill of Phoenician artists. It was unearthed at Ras Shamra, Syria.



Below. A Phoenician merchant ship. This type of heavily built, square-rigged merchantman formed the backbone of the Phoenician commercial fleet.

GIRAUDON

PHOENICIAN SETTLEMENTS
8th — 6th centuries B.C.

Extent of Phoenician influence

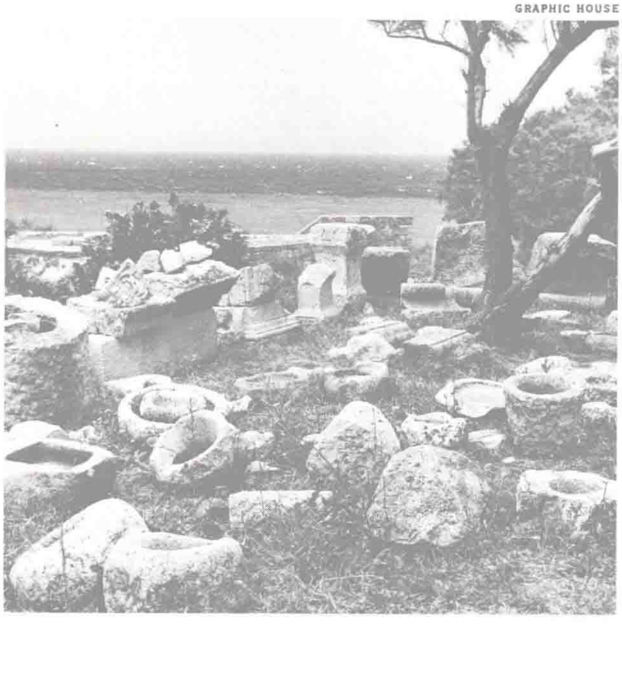
Some of the Phoenician settlements have become modern cities under different names.

Phoenician name	Modern name
Gadir	Cádiz
Malaca	Málaga
Oea	Tripoli
Sidon	Saida

The Phoenicians occupied a narrow fertile plain with many springs and rivers. The Mediterranean Sea in the west and the snowcapped limestone peaks of the Lebanon mountain range in the east protected the area from enemy attack. The winds from the sea dropped their moisture as they rose to cross the mountains, and this rainfall watered crops of wheat, barley, vegetables, figs, dates, olives, and grapes. The sea yielded abundant fish and shellfish. On the mountain slopes were tall, majestic cedars, up to 120 feet (37 meters) in height and 8 feet (2.4 meters) in diameter. Their timber was in great demand as a building material. The cedars came to symbolize grandeur and power, and ancient kings coveted them. As early as 2750 B.C., Egyptian monarchs imported the cedars, and in the 10th century B.C., Solomon procured cedars from Lebanon to use in building the Hebrew Temple. A small grove of cedars in modern Lebanon is all that survives of the great forest.

With so many natural resources, the protected position of their land, and the great water highway of the Mediterranean at their doors, it is easy to understand why the Phoenicians became rich merchants rather than warriors and seekers of territory. For about 2,000 years, Phoenicia was the center of Mediterranean trade, and Phoenician merchant sailors carried goods and new ideas to distant lands.

Phoenician stone pots unearthed at the ancient city of Byblos
GRAPHIC HOUSE



The city of Ugarit, which is usually considered Phoenician, rose and fell in this early period. Archaeologists have unearthed at Ugarit a library of clay tablets inscribed with records in a cuneiform, or wedge-shaped, alphabet. The idea of the alphabet seems to have been developed about 2000 B.C. in the Sinai peninsula, brought north into Phoenicia probably by traders, and elaborated there into a purely symbolic alphabet, without the pictographs that were a part of Egyptian writing. The Phoenician alphabet spread to the Hebrews, Etruscans, and Romans and from them to the whole Western world.

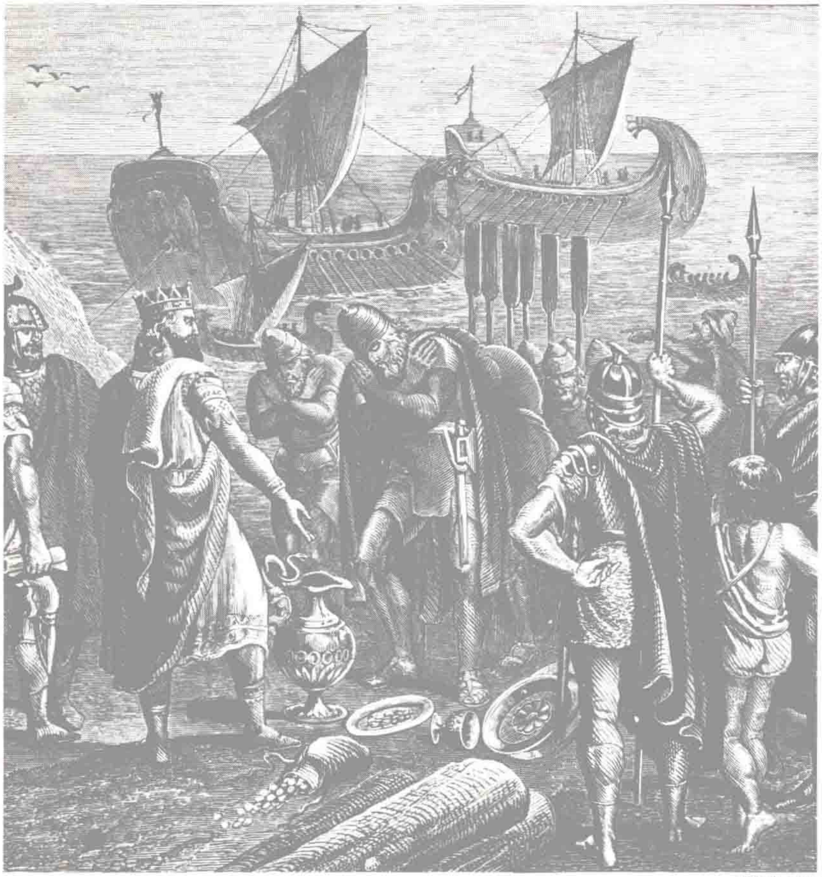
Two large temples resembling descriptions of Solomon's Temple have been unearthed at Ugarit. The chief god of these people was El, but the nature god Baal, who governed rain, fertility, and growing crops, seems to have been more regularly worshiped. Other deities were Baal's bloodthirsty wife Anat and his mortal enemy Mot, the god of death. According to Phoenician belief, Mot subdued Baal each year at the time of harvest and drought, but Anat rescued her husband. Baal remained the most important deity in later Phoenician religion.

Ugarit was devastated by an earthquake in the 14th century B.C., rebuilt, and destroyed in the 12th century B.C. by a group of raiders called the Sea Peoples.

Golden Age

About the time of Ugarit's decline a general unrest and movement of warring peoples shook the ancient world, from Mesopotamia to Egypt. These migrations both weakened Phoenicia's competitors for trade and provided Phoenician traders with new markets and new trade goods. Also, such commercial cities as Troy in Asia Minor and Mycenae on the Greek mainland broke the monopoly of trade long held by the Minoans on the Mediterranean island of Crete. Finally, a great new trade route to the Indian Ocean opened when, with the domestication of the camel as a beast of burden, goods were brought overland from southern Arabia to the eastern Mediterranean coast. The population of Phoenicia may have received valuable new elements as some of the carriers of the Arabian trade settled in its growing commercial centers.

Great cities, marvels of their day, were built with the profits from Phoenicia's booming industry, shipping, and trade. The oldest of these self-governing



BROWN BROS.

BROWN BROS.

Phoenician sailors, shown bringing treasures to King Solomon (left), helped to spread the Phoenician alphabet (right).

cities was Sidon (now Saïda), whose craftsmen were known for their dyes and glassware. Sidon was Phoenicia's first important port. Its peoples built Tyre, on an island just off their coast. By 1400 B.C., Tyre was a flourishing port, said to be richer in fish than in grains of sand. Its most famous industries were the making of textiles and purple dye. The dye was made from the poisonous secretion of the murex snail, a shellfish that abounded in Phoenician waters. Tyrian purple, or the purple dye of Tyre, was sought after as a mark of rank and power.

Two other very ancient city-states were Berytos (now Beirut, Lebanon) and Byblos, about 20 miles to the north. Because Byblos exported quantities of papyrus, from which a paper-like writing material was made, it gave rise to the Greek word *biblion*, meaning book, and from that to the English word "Bible." The Phoenicians also cast beautiful objects in bronze and made pottery and ivory articles.

Much later, the people of Tyre founded another Phoenician port, Tripolis (now Tripoli, Lebanon). Baalbek (now Heliopolis, Lebanon) was a center of the worship of Baal. The most northerly of the Phoenician cities was Aradus (now Ruad, Syria).

Phoenician sailors, famous for their discipline and skills, carried goods to foreign ports and brought back other goods in exchange. Their ships were capable of voyages lasting many months and became known as the fastest and best designed in the ancient world. An upper deck provided space for passengers, and below were two banks, or tiers, of oarsmen. At first there were only 16 to 20 oarsmen to a ship, but later there were as many as 50. The ships had short broad beams and high bows that cut easily through the water and served as rams in sea warfare.

As improved ships made longer voyages possible, the Phoenicians established trading connections and colonies in most of the known world. They traded in Egypt and throughout the Mediterranean, receiving gold in exchange for perfume, spices, and incense that they brought from Arabia. To get oil and wine, the Phoenicians sold timber to the Hebrew king Solomon and supplied him with skilled sailors, pilots, masons, and carpenters. They bartered slaves, bronze weapons, and textiles to the Greeks for wine and cattle. At the height of Phoenicia's seapower, ships voyaged through a canal from the Nile delta to the Red Sea, down the coast and around the tip of Africa, and back to Spain in the western Mediterranean three years later.

By 1000 B.C. the Phoenicians had founded the rich city of Gadir (now Cádiz), on the Spanish peninsula. Tin was brought from the peninsula and even, according to legend, from as far away as Cornwall in England. In northern Africa the Phoenicians founded Utica, by 1000 B.C., and Carthage, which became the greatest of all the colonies, 150 years later. Carthage provided metalwork, ivory, precious stones, and slaves for trade with Italy, Sicily, and Greece.

Decline

The rise of Assyria in the eastern Mediterranean in the 8th century B.C. meant a decline of Phoenician political independence at home. Assyrian kings destroyed Sidon and the palace of the King of Tyre. Assyria later fell to the Babylonians, and King Nebuchadnezzar of Babylonia besieged Tyre for 13 years. Although exhausted in the struggle, the Tyrians managed to exact an honorable settlement from the Babylonians. Then, in the 6th century B.C., Persia rose to supremacy and became the new master of Phoenicia. In exchange for Phoenician ships and sailors, King Cyrus of Persia permitted the ancient cities almost complete independence, even excusing them from paying tribute.

Under such generous terms the Phoenician cities formed a new federation. Once a year they held a meeting with the Persian governor and his aides at Tripolis, which became for a time the capital of Phoenicia. Then Persian power began to wane, and in 358 B.C. the Phoenicians attempted to revolt. However, Sidon's king betrayed his city to the Persians. The Persian king Artaxerxes entered without difficulty and destroyed the city in 351 B.C.

During this long period, Phoenicians centered their hopes of prosperity in Carthage in northern Africa. For several centuries, Carthage dominated Mediterranean trade. It controlled Sardinia, much of Sicily, and a large part of the northern African coast. However, in the 3d century B.C., Rome began to contest Phoenician claims in the Mediterranean in a series of conflicts known as the Punic Wars.

As their cities declined at home and abroad, the Phoenicians neared collapse. When Alexander the Great came in 333 B.C. to add the Phoenician homeland to his conquests, only Tyre refused to submit to him. Alexander built a breakwater from the mainland to the island city and brought his war machines over it. It took him seven months, even with help from the other Phoenician cities, to reduce Tyre to submission.

With the change in trade routes that followed Alexander's founding of Alexandria in Egypt, Phoenicia's commercial importance ended. Under the Hellenistic dynasties that followed Alexander, Phoenician cities somewhat revived, but they were assimilated into Greek culture. Sidon and Tyre became centers of Greek philosophy. Finally, Rome defeated the Phoenicians of Carthage and burned the city in 146 B.C. With Roman hegemony in the Mediterranean, Phoenicia forever lost its independence. However, it enjoyed some prosperity under Rome. **John H. Marks*

Phoenix (fē′niks), *a city in south-central Arizona; the seat of Maricopa County; on the Salt River. Pop. (1970) city 581,562; metropolitan area 967,522.*

Phoenix, the state capital of Arizona, is the largest city in the state and one of the largest in the western United States. In addition to serving as an administrative center, Phoenix is the principal industrial and commercial center of Arizona. It lies in the Salt river valley, the state's largest and most productive cropland area. The Phoenix metropolitan area, coextensive with Maricopa County, accounted for 55 percent of Arizona's total population in 1970.

With its warm winter temperatures, low relative humidity, and generally cloudless skies, the Phoenix area is one of the country's leading winter tourist resorts and health centers. In addition to tourism, the city's major economic activities include the manufacture of electrical equipment, machinery, and transportation equipment and the processing and shipping of fruits and vegetables and other local produce.

Phoenix lies on National Interstate highways 10 and 17 and on U.S. highways 60, 80, and 89. The city is a scheduled railroad and airline stop. The educational institutions in Phoenix include Grand Canyon

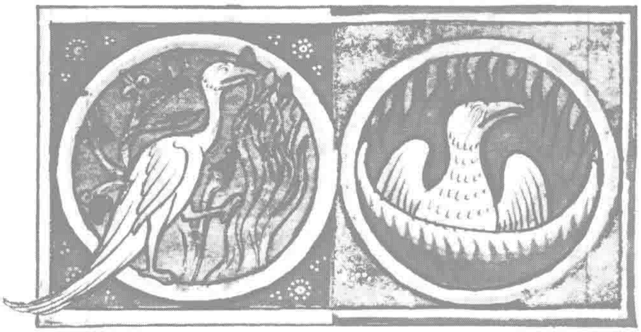
The Arizona State Capitol in Phoenix was first built in 1900. Legislative wings were added in 1960 and a state office tower in 1974.

SUE LEVY/ ARIZONA REPUBLIC

College and Phoenix College, which is a junior college. In the vicinity of Phoenix are Arizona State University and the American Graduate School of International Management.

History and Government. The site of Phoenix was settled in about 1867. The city was incorporated in 1881. Designated as the territorial capital in 1889, Phoenix became the state capital when Arizona was admitted to the Union in 1912. Since the 1940's, Phoenix has been one of the fastest-growing cities in the United States. Between 1940 and 1970 it annexed many nearby communities and increased nearly ninefold in population. The city has the council and city manager form of municipal government.

**Thomas K. Sanford, Jr.*



PIERPONT MORGAN LIBRARY

The phoenix builds its own funeral pyre from fragrant wood (left), and a new phoenix then rises from the ashes (right).

phoenix, in Egyptian and Greek mythology, a miraculous bird that supposedly lived in Arabia. It had a life-span of 500 years, at the end of which time it built a new nest from fragrant wood, set fire to it, and died in the flames. According to legend, a new phoenix then arose from the ashes. The phoenix was described by the Greek historian Herodotus as a red-and-gold bird similar to the eagle in appearance. In the symbolism of ancient Egypt the phoenix represented the rising sun, which is reborn every morning after dying, or disappearing, at night. The phoenix is the Egyptian hieroglyph for the sun. In the symbolism of the Christian religion the phoenix stands for resurrection and immortality. **Pearl Cleveland Wilson*

Phoenix Islands, *a group of islands in the southern Pacific Ocean. Area about 11 square miles (28 sq km). Pop. (1966 est.) 1,100.*

The Phoenix Islands are a group of eight coral islands. They include the islands of Birnie, Hull, Gardner, McKean, Phoenix, and Sydney, which are part of the British colony of the Gilbert Islands, and Canton Island and Enderbury Island, which are under the joint control of Great Britain and the United States.

**Charles M. Davis*

phon (fon), a unit on a scale for measuring the loudness of sounds. The faintest audible sound has a value of zero. The phon is related to the decibel, which is used for comparing the intensities of sounds. The intensity of a sound is an absolute measurement of its energy, whereas the loudness is simply how intense the sound appears to the listener. Two sounds of different intensity can be equally loud if their frequencies are different. For comparisons a standard frequency of 1,000 cycles per second is used. A one-phon sound is as loud as a standard tone that has an intensity of one decibel. *See also* SOUND.

**Lyman Mower*

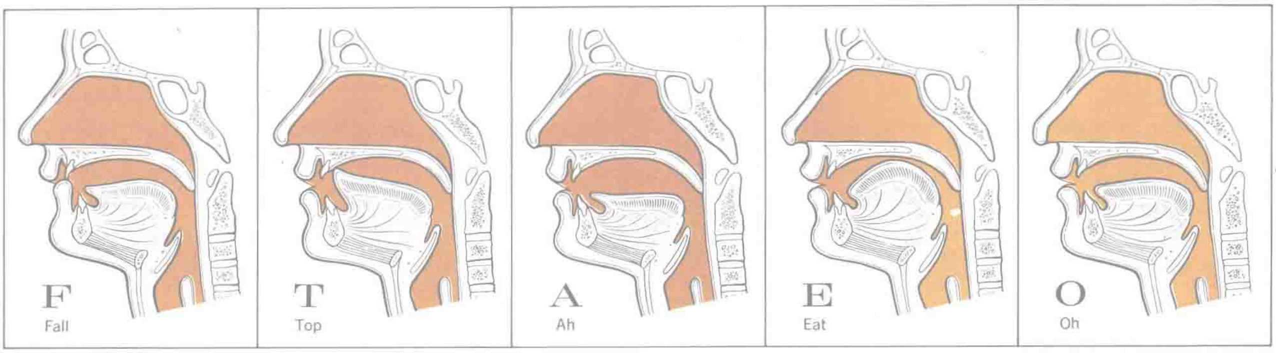
phonetics (fə net′iks), the study of sounds used in vocal communication. The science of phonetics is especially concerned with the production, transmission, and perception of speech. Phonetics includes the investigation of the way in which different sounds are produced by the human vocal organs. It takes account of the various characteristics of spoken sounds as they pass from speaker to hearer. It also analyzes how the human ear hears and reacts to these sounds.

Speech Production. The process of speech production begins with minute interruptions of the flow of air into and out of the lungs. In most languages, including English, only the air exhaled from the lungs is used to produce speech sounds. This flow of air is controlled and modified by coordinated movements of the organs involved in speech, which include the lungs, rib cage, diaphragm, vocal cords, and various parts of the throat, nose, and mouth.

The stream of air from the lungs passes through the windpipe between the vocal cords, two folds of tissue located at the larynx. When the vocal cords are drawn toward each other and vibrate in the stream of air, sounds known as voiced sounds result. When the vocal cords are kept apart and the air passes freely between them without vibration, the sounds produced are known as voiceless sounds. Voiced sounds in English include the vowels and such consonant sounds as *b, d, g, v,* and *z*. Voiceless sounds in English are represented by the letters *p, t, k, f,* and *s*.

BASIC SYMBOLS OF THE INTERNATIONAL PHONETIC ALPHABET

Consonants			Vowels		
p	pop	pɑp	i	beet	bit
b	bob	bɑb	ɪ	bit	bɪt
t	tat	tæt		pity	pɪtɪ
d	dad	dæd	e	bait	bet
k	kick	kɪk	ɛ	bet	bɛt
g	gig	gɪg	æ	bat	bæt
f	fluff	flʌf	ɑ	dot	dɑt
v	verve	vɝv	ɔ	bought	bɔt
θ	thin	θɪn		bore	bɔɚ
	breath	brɛθ	o	dough	do
ð	then	ðɛn	ʊ	foot	fʊt
	breathe	brið	u	do	du
s	sauce	sɔs	ɝ	further	fɝðɚ
z	zoos	zuz	ɚ	further	fɝðɚ
ʃ	mesh	mɛʃ	ə	among	əmʌŋ
ʒ	measure	mɛʒɚ		melody	mɛlədɪ
m	mum	mʌm		sofa	sofə
n	none	nʌn	ʌ	but	bʌt
tʃ	church	tʃɝtʃ			
dʒ	judge	dʒʌdʒ	**Diphthongs**		
ŋ	lung	lʌŋ			
l	lull	lʌl	aɪ	my	maɪ
w	woo	wu	aʊ	how	haʊ
j	you	ju	ɔɪ	toy	tɔɪ
r	rue	ru	ju	amuse	əmjuz



The science of phonetics includes the study of the organs involved in producing human speech. The position of the tongue, teeth, and lips is important in the production of sounds. The consonant *f* is created by the friction of breath against the lips and teeth. In producing the consonant *t*, the breath is stopped by the pressure of the tongue against the upper gum ridge and then suddenly released. Vowels are classified according to the position of the tongue. In producing *a* as in "ah," the tongue is in a low central position; in e as in "eat," it is in a high front position; and in o as in "oh," it is in a middle back position.

Speech sounds produced by friction or stoppage in the voice channel are called consonants. Consonants are grouped into stops, or plosives, and spirants, or fricatives. Stops, or plosives, involve a complete stoppage of the breath stream followed by a sudden release. In English, this happens with *p, b, k, g, t,* and *d*. In the case of spirants, or fricatives, there is no complete stoppage of the breath stream, but there is constriction by reason of partial closure of the speech organs, accompanied by audible friction. In English, this occurs with *f, v, s, z,* and other sounds.

A speech sound produced without friction or stoppage in the voice channel is called a vowel. Vowel sounds in English are classified as high or low according to the relative height of the tongue in relation to the lower jaw. Vowels are also called front, central, or back according to the position of the tongue in the mouth from front to back.

In English there are also certain sounds that are intermediate between vowels and consonants. They are often called semivowels or sonorants and include *l, m, n, w,* and *y* and also any *r* that begins a syllable.

Speech Transmission and Perception. The sound heard when someone speaks is actually a pattern of distinctive vibrations imposed by the vocal organs on the air coming from the lungs. Traveling through the air, these vibrations reach the ears of the listener and cause his eardrums to vibrate. The stimulus of the vibrations is transmitted along the nerves of the ear and is interpreted as sound by the brain.

In most languages there are differences in sound that are not noticed by the listener. A person normally notices differences only when they affect the meaning of a word. For example, the sounds of *t* in the words "tip" and "pit" are acoustically different from each other. In English, however, this difference is really meaningless, and most listeners are never aware of it. In another language, on the other hand, as in Chinese, the difference between the two sounds of *t* may be vitally important in distinguishing different words, and native listeners are always aware of it.

The name "phoneme" is given to any group of sounds in a language that seem to be the same sound to the hearer since the substitution of one for another of them does not change the basic meaning of the word. For example, in the words "pit," "spit," and "sip," the written symbol *p* represents three objectively different sounds. However, the American speaker is normally unaware of this and uses each sound automatically in its proper position, with a strongly aspirated *p* for "pit," an unaspirated *p* for "spit," and an imploded *p* (pronounced with final lip closure) for "sip." If one of these sounds is accidentally substituted for another, there is no change in the basic meaning of the word so far as the hearer is concerned. But if *k* is substituted for *p* in any one of the words, the meaning undergoes a drastic change. Therefore, the three variant sounds of *p* constitute a single phoneme in American English, but *p* and *k* constitute two separate phonemes.

Phonetic Notation. In most languages, conventional alphabets do not represent accurately all the phonemes in use. For example, in English there are 12 vowel phonemes, which must be represented by only 5 vowel letters of the Roman alphabet. Certain consonantal letters of the alphabet also have more than one sound, as in the case of *c* in "cat" and "certain" or *th* in "think" and "those." Furthermore, there are not enough letters in the alphabet used for English to assign one to each phoneme.

Phoneticians have therefore attempted to develop systems of notation that give a more accurate picture of how words are pronounced. Such a system can be especially valuable in recording languages that have not developed a system of writing. The most widespread system of phonetic notation is the International Phonetic Alphabet, or IPA. Its symbols are derived in part from the standard Roman alphabet, and a separate symbol is used for each phoneme. Examples of phonetic notation as aids to pronunciation are provided throughout this encyclopedia.

History. The study of phonetics is generally thought to have originated with the Sanskrit grammarian Panini in the 4th century B.C. From then until the 18th century many important discoveries were made concerning human speech, but there was no real attempt at a systematic analysis. During the 19th century, however, phonetics began to take form as a modern science. Ernst Brücke and Hermann von Helmholtz were pioneers in the field of phonetic analysis, along with A. M. Bell. The Abbé Jean Pierre Rousselot and Henry Sweet were among other important contributors to the development of phonetics. With the 20th century came a notable improvement in laboratory techniques and equipment, which has facilitated more detailed and accurate phonetic studies.

Importance. The material provided by research in phonetics is a valuable aid in correcting poor speech habits. It can also be used to assist the teaching of the pronunciation of foreign languages, especially unwritten or unusual languages. The understanding of speech sounds has been very useful in the development of communications engineering, especially in connection with the telephone, radio, recordings, and television. A study of phonetics is necessary for the full comprehension of the aspects of sound in language.

**Mario A. Pei*

phonics (fon′iks), any of various methods of teaching people to read by helping them to associate letters and letter combinations with the sounds of speech. Phonics differs from phonetics, which is the scientific study of human speech. The letter and sound relationships, called phonograms by some phonics teachers, include single letter sounds, such as *t* in *toy* or *d* in *had;* letter-group sounds, such as *str* in *string* or *ng* in *long;* and syllables, such as *bat* in *battery* or *ing* in *driving*. In one of the widely used phonic systems the beginning reader develops a simple reading vocabulary by associating such common words as *cat*, *dog*, and *tree* with appropriate pictures. Once he has established this sight vocabulary, he is taught to recognize the phonograms of these familiar words. Then he is presented with new words composed of phonograms he has learned. By sounding out the already familiar phonograms, he is able to read and pronounce the new words.

When the phonic system is used exclusively, it is possible that the beginning reader may simply learn to pronounce words without understanding their meaning. In addition, peculiarities of the English alphabet make a strictly phonic approach ineffective. For example, letters can have more than one sound, as with *a*, which is pronounced differently in *ball*, *gate*, *hat*, and *father*. Moreover, the same sound can be represented by different phonograms. An example is the long *o* sound in *so*, *dough*, *sew*, *coat*, and *folk*. In addition, word endings are often silent, as in *tone*, *have*, and *through*. To solve these problems in reading instruction, attempts have been made to combine phonics with other procedures. One such method that has been both popular and successful emphasizes the meaning of each word within the context of a sentence and relates the phonetic elements to the whole word.

Early reading programs were basically phonic in scheme, but they stressed rigorous drill, excessive memory work, and meaningless recitation of the alphabet. By the middle of the 19th century there was a sharp reaction against the rigid formality of these techniques. Such plans as the so-called look-and-say method of associating the meaning of a word with its complete visual pattern became very popular with modern educators. Recently, however, there has been controversy over reading instruction. Phonics has been criticized by phoneticians and linguists for its failure to treat the speech sounds as primary and the letters as attempts to represent the sounds.

**Harold B. Allen*

phonograph (fō′ nə graf), a device that reproduces music and other sounds recorded on discs of plastic or other material. The discs are called phonograph records, and the sounds are recorded in a continuous groove that spirals inward from the outer edge of the record. Phonographs are widely used for home entertainment and for such other purposes as playing records of books for the blind. They also provide most of the music heard over the radio. High-fidelity systems are phonographs that try to reproduce sound exactly. (*See also* HIGH FIDELITY.)

Parts of a Phonograph

A phonograph consists of four main parts: a turntable, which is rotated by an electric motor; a tone arm, which carries a pickup; an electronic amplifier with controls; and a loudspeaker. (See Fig. 1.)

The turntable is usually made of metal, and its upper surface is covered with velvet, rubber, or a similar material. The motor is mounted underneath the turntable and turns it by a system of rubber-edged wheels, a belt, or some other means.

The tone arm also is usually made of metal and is mounted on a pivot behind and to the right of the turntable. The pivot permits the tone arm to swing across the record. At the end of the tone arm is the pickup, which consists of a stylus, or needle, mounted in a device called a cartridge. When a record is played, the stylus follows the record groove. The cartridge transforms the tiny movements of the stylus in the record groove into a very weak electric current. This current is amplified, or made stronger, by the

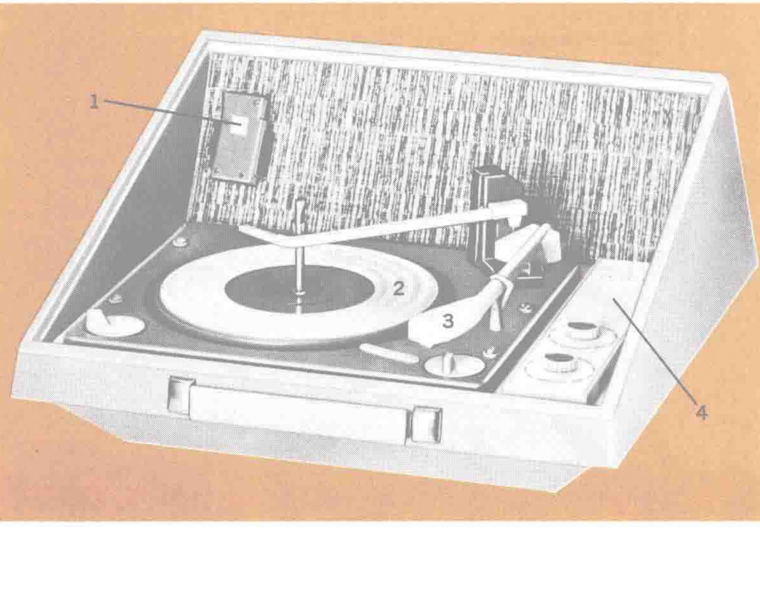


Fig. 1. A modern portable phonograph. The principal parts of a phonograph are the loudspeaker (1), turntable (2), tone arm (3), and amplifier (4).

amplifier. The loudspeaker of the phonograph transforms the electric current from the amplifier into sound. (*See also* AMPLIFIER; LOUDSPEAKER.)

How Records Are Made

The Nature of Sound. Sound consists of waves, or vibrations, in some medium, such as air. The number of vibrations per second is known as the frequency of the sound. The higher the frequency, the higher the pitch of the sound, and the lower the frequency, the lower the pitch. In other words, treble notes consist of high-frequency vibrations and bass notes consist of low-frequency vibrations. The amplitude, or strength, of the waves determines the loudness of the sound.

How Sound Is Recorded. When sound enters a microphone, the microphone produces an electric current that has the same wave shape as that of the sound. For example, a loud bass note produces a strong low-frequency current and a soft treble sound produces a weak high-frequency current.

The devices used to make a recording are shown in Fig. 2. Sound waves originating from a singer, orchestra, or other source enter the microphone, which produces a corresponding electric current. The current is amplified and fed to the recording machine.

The recording machine employs a cutter head, a device that uses the amplified electric current to produce mechanical motion. On the cutter head is a stylus, which presses on the lacquer coating of a metal disc. As the disc rotates, the point of the stylus cuts a continuous spiral groove in the lacquer. The varying current from the amplifier causes the stylus to vibrate slightly from one side to the other, thus making the groove wavy. The waves in the groove correspond to the waves in the amplifier current and, therefore, to the waves of the original sound. The wavy groove is said to be modulated.

How Commercial Records Are Made. The original lacquer record made by the recording machine is too soft to be played many times. For this reason, copies of the original record must be made on some harder material.

The first step in the manufacture of commercial phonograph records from the original recording is the production of a metallic negative, called the master. (See Fig. 3.) The master is made by electroplating the original and is a record in reverse. Where the original had grooves, the master has ridges. From the master a positive metallic record, called the mother, is made. The mother corresponds exactly to the original lacquer recording. From the mother another metallic negative, called the stamper, is made.

The stamper is used to manufacture the records that are sold commercially. It is mounted in a hydraulic press, heated, and pressed onto blank discs of Vinylite or a similar material. The heat softens the Vinylite, and the ridges of the stamper press grooves into each blank disc. These grooves are exact duplicates of those on the original lacquer recording. An-

FIG. 2A. SOUND CAN BE TRANSLATED INTO ELECTRIC CURRENT.

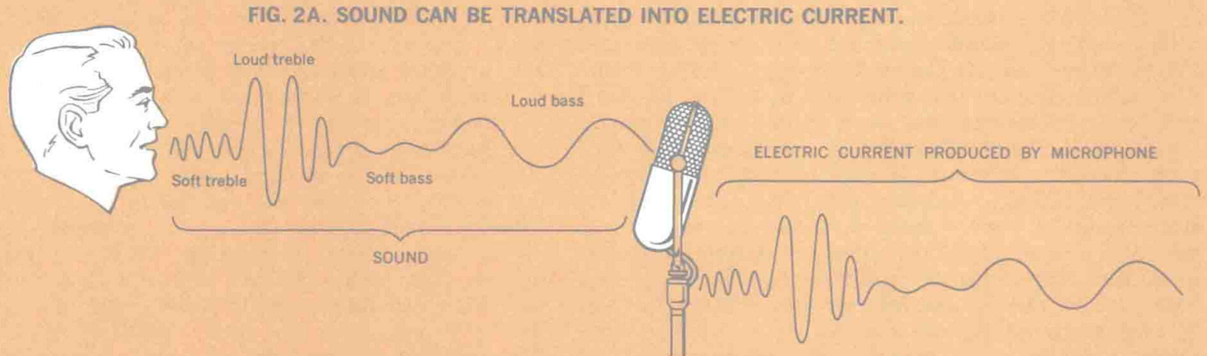


FIG. 2B. HOW SOUND IS RECORDED ON DISCS.

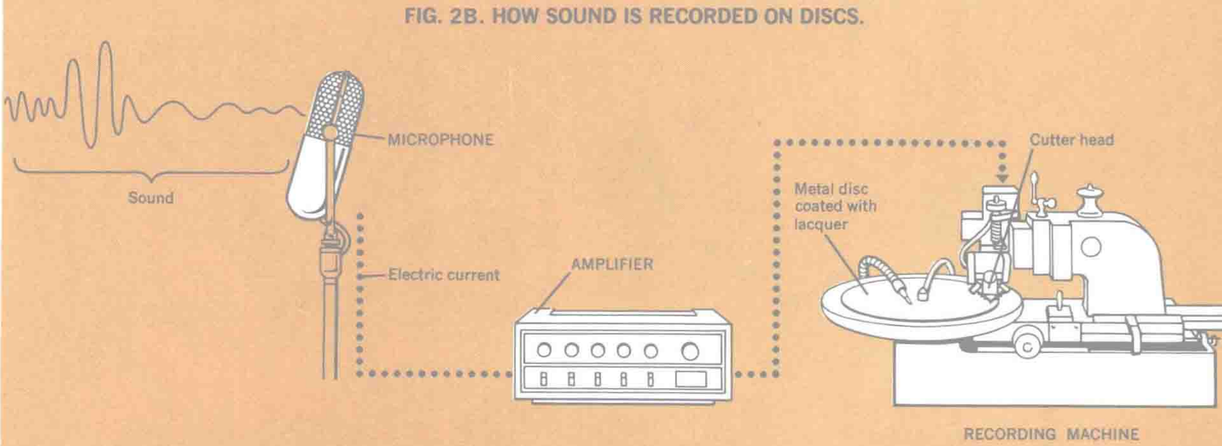
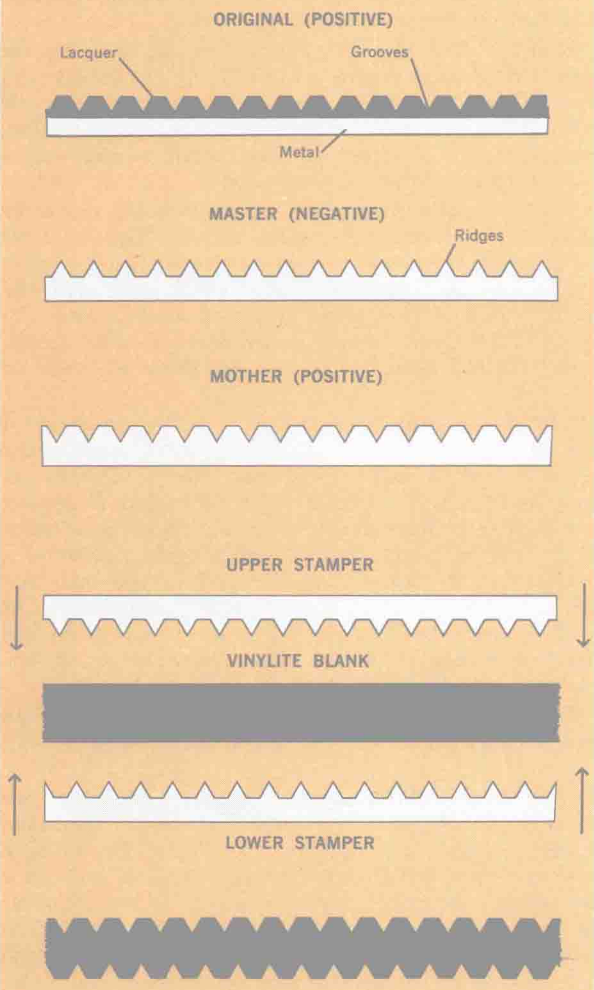


FIG. 3. HOW A RECORD IS MADE.



other stamper, made from a different recording, presses the other side of the Vinylite blank at the same time. Thus, a two-sided record is made in one operation.

How Records Are Played Back

The process of reproducing sound is the reverse of the process of recording sound. As the record rotates on the phonograph turntable, the stylus follows the groove impressed on its surface. In following the wavy groove, the stylus vibrates from side to side. These vibrations correspond to those of the stylus on the cutter head when the original recording was made. The vibrations of the phonograph stylus cause the cartridge to produce an electric current that has a wave shape corresponding to the wave shape of the original sound. This current is strengthened by the amplifier and fed into a loudspeaker, which transforms it into sound.

Thus, the two processes of recording and reproduction may be outlined as follows. In sound recording, sound waves produce a corresponding electric current, the electric current is changed into mechanical motion, and the motion is recorded. In sound reproduction; the recorded mechanical motion produces a corresponding electric current and the electric current is changed into sound waves.

How a Pickup Works. The pickup, which consists of the stylus and the cartridge, is the most important part of the phonograph. Cartridges are of two main kinds: crystal or ceramic, and magnetic. Crystal or ceramic cartridges are used in most phonographs, while magnetic cartridges are usually used in high-fidelity equipment.

Crystal cartridges are based on the ability of certain substances to produce an electric current when they are subjected to mechanical forces. When the stylus in a crystal cartridge follows the groove on a record and moves from side to side, these movements are transmitted to the crystal, which produces an electric current. (*See also* PIEZOELECTRIC EFFECT.)

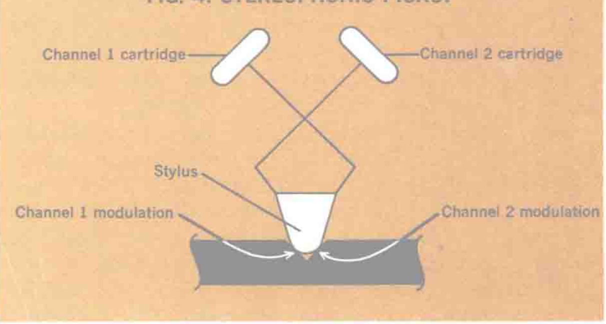
Magnetic cartridges, of which there are several types, are considerably more complicated than the crystal kind. One type of magnetic cartridge, called the dynamic pickup, has a small coil of fine wire and a small magnet attached to the stylus. The coil is located between the poles of the magnet. When the stylus moves as it follows the groove in the record, the coil moves with it, producing a very small electric current by electromagnetic induction.

Stereophonic Phonographs

Phonographs and records may be either monophonic or stereophonic. Monophonic phonographs reproduce sounds as though they were coming from a single source. Stereophonic phonographs, on the other hand, reproduce sound as though it were coming from a broad, deep area in front of the listener. For example, when a recording of an orchestra is played stereophonically, the sounds of the different instruments appear to be coming from different points—left, center, and right—just as they do in the concert hall. (*See also* STEREOPHONIC SOUND.)

Stereophonic Records. A stereophonic record is made from two channels of sound, with at least two microphones being used. The electric current produced by each microphone is fed to a separate amplifier. Both sound sources are then combined in a single groove on the record. This is done by modulating both sides of the V-shaped groove. In monophonic recording, the groove is modulated laterally; that is, the stylus vibrates from side to side but not vertically. In stereophonic recording, however, each channel is modulated vertically with respect to the side of the groove, or at an angle of 45° with respect to the record surface. One channel is recorded by modulation of one side of the groove, and the other channel is recorded by modulation of the other side of the groove. To play back such a record, a special stereophonic pickup is necessary. (See Fig. 4.)

FIG. 4. STEREOPHONIC PICKUP



A stereophonic pickup consists of a single needle with two cartridges. The motions that are made by the stylus when it tracks one side of the groove are transmitted to one of the cartridges, and the motions of the same stylus as it tracks the other side of the groove are transmitted to the other cartridge. A separate current is produced in each cartridge, and each current is separately amplified and fed to a separate loudspeaker.

From Fig. 4 it can be seen that a stereophonic stylus must be able to vibrate not only laterally but also in any other direction. A monophonic stylus, on the other hand, vibrates only laterally and, for this reason, should never be used to play a stereophonic record. Since it cannot undergo other vibrations, a monophonic stylus cannot fully follow the modulation of the stereophonic groove and can therefore cause considerable damage to the groove.

History

The invention of the first practical sound-recording device is usually attributed to the American inventor Thomas Alva Edison. In 1877, Edison developed a talking machine that consisted of a tinfoil-coated cylinder rotated by a hand crank. Pressing against the tinfoil was a needle that was attached to a rubber diaphragm in a mouthpiece. When Edison spoke into the mouthpiece, the diaphragm vibrated, causing the needle to move up and down. This produced a vertically modulated, or hill-and-dale, groove in the tinfoil. When the recording was played back, the needle was allowed to follow the groove it had made. Its vertical movements caused the diaphragm to vibrate and reproduce the sound of Edison's voice. Edison later improved his machine by substituting a wax cylinder for the tinfoil one and adding an electric motor to rotate it.

The flat-disc record was patented by the German-American inventor Emile Berliner in 1887. Berliner's record was made of shellac and used lateral, or sideways, modulation, rather than the vertical modulation used by Edison. Berliner called his phonograph a gramophone. This term was universally used for many years and is still used for phonographs in Great Britain and the rest of Europe. Present-day phonographs are descended from Berliner's gramophone.

The first electrically recorded discs, made with a microphone, were issued in 1925. Phonographs gradually underwent improvement in both techniques and construction. A major development came in the late 1930's with the introduction of automatic record changers, which became increasingly widespread in the early 1940's.

The growth of interest in high fidelity after World War II led to many improvements in recording and reproduction techniques. This development was given added impetus by the introduction of long-playing records in 1948. Stereophonic discs were introduced in 1958 and have become very popular.

Record Speed. Up to 1948 all records for home use were played at 78 revolutions per minute (r.p.m.), and only about 5 minutes of music could be recorded on each side of a 12-inch disc. In June 1948, however, Columbia Records issued the first long-playing record, which was played at 33⅓ r.p.m. A new process, called microgroove, made it possible to make a much smaller and closer-spaced groove on the disc. With the slow speed and narrow groove up to 35 minutes of music, speech, or other sounds could be recorded on one side of a 12-inch disc.

Shortly after the introduction of long-playing records, RCA Victor issued a record 7 inches in diameter that was played at 45 r.p.m. and contained up to 3½ minutes of recorded sound on each side. A later version, called an extended-play record, contains up to 8 minutes of sound on each side.

Most classical music and much popular music are now recorded on 33⅓-r.p.m. discs. The small 45-r.p.m. records are used almost exclusively for popular music, and 78-r.p.m. discs are used only for children's records and a few other applications. A very slow speed of 16 r.p.m. is used to produce so-called talking books for the blind. **William E. Anderson*

phoronid (fə rō′nid), any of a small group of wormlike marine animals that live in mud or sand or that are attached to rocks. Phoronids inhabit shallow waters, and each lives in a hard tube that it secretes around itself. Most phoronids range from one-fortieth of an inch to nearly 8 inches in length, and they are usually red or orange. At one end of the body is a small mouth surrounded by short tentacles, which are used to sweep food particles into the mouth. Generally they reproduce sexually. Most phoronids have both male and female sex organs.

Phoronids make up the phylum Phoronida of the animal kingdom. **Lorus and Margery Milne*

phosphate (fos′fāt), any of a group of chemical compounds that are salts of phosphoric acid, H_3PO_4. Phosphates are used principally as fertilizers. For this purpose the most widely used phosphate is a mixture of dicalcium orthophosphate, monocalcium orthophosphate, and calcium sulfate. This mixture, which is referred to commercially as superphosphate, is obtained from a type of rock called phosphate rock. Phosphates are also widely used in many different industries.

Sodium hexametaphosphate, $(NaPO_3)_6$, is used to treat water and to prevent the formation of scale inside pipes. Sodium dihydrogen orthophosphate, NaH_2PO_4, is used to clean out pipes and is an ingredient of some baking powders and cattle feeds. It is also used in the dyeing and electroplating industries. Sodium monohydrogen orthophosphate, Na_2HPO_4, is used in the dyeing, textile, ceramics, and chemical industries and is an ingredient of cattle feeds and baking powders. It is also used for water treatment and fireproofing. Sodium orthophosphate, Na_3PO_4, is used as a detergent, water softener, and paint remover and is also used in the tanning, dyeing, paper, and textile industries. Sodium pyrophosphate, $Na_4P_2O_7$, is used as an emulsifying agent and water softener and in the printing, textile, and rubber industries. Dicalcium orthophosphate, $CaHPO_4$, is used as a fertilizer, as an ingredient of tooth powders and animal feeds, and in the glass and plastics industries. Monocalcium orthophosphate, $CaH_4(PO_4)_2$, is used as a fertilizer, in baking powders, and in the glass and plastics industries. Other important phosphates include such ammonium phosphates as dibasic ammonium phosphate, $(NH_4)_2HPO_4$, which is used as a fertilizer and for many industrial purposes. **Alfred B. Garrett*

phosphorescence. *See under* LUMINESCENCE.

phosphorus (fos′fə rəs), *a chemical element. Symbol P. First isolated about 1669 by Hennig Brand (German). Melting point (yellow allotrope) 41.1° C. (111.4° F.). Boiling point (yellow allotrope) 280° C. (536° F.). Oxidation numbers −3, +3, and (the most stable) +5. Atomic weight 30.974. Atomic number 15.*

Phosphorus is a nonmetallic element that exists in three different forms called allotropes. The three allotropes are called yellow or white phosphorus, red phosphorus, and black phosphorus. The three forms exhibit markedly different properties. Yellow phosphorus is a white or yellow waxy solid that ignites spontaneously in air at 35° C. For this reason it is stored under water. It is insoluble in water, but dissolves in carbon disulfide. Yellow phosphorus glows faintly in the dark and is very poisonous. When heated to about 250° C. out of contact with air, it is changed into red phosphorus. Red phosphorus is a dull-reddish-brown crystalline powder that is much less reactive than the yellow allotrope. It does not ignite unless heated above 200° C., does not glow in the dark, and is insoluble in carbon disulfide or most other solvents. In contrast to the yellow variety, red phosphorus is nonpoisonous. Black phosphorus is prepared by heating the yellow form at 200° C. under a very high pressure of about 12,000 atmospheres. Black phosphorus is incombustible and is insoluble in carbon disulfide. The densities of the three allotropes are yellow phosphorus, 1.83; red phosphorus, 2.2; black phosphorus, 2.7.

Uses

The best-known use of phosphorus is in the manufacture of matches. The heads of strike-anywhere matches contain a phosphorus compound, phosphorus sesquisulfide, and the surface on which safety matches are struck contains red phosphorus. Early matches contained yellow phosphorus, but the fire hazard and the widespread cases of phosphorus poisoning that resulted led to the use of red phosphorus instead, because it does not have harmful side effects.

Yellow phosphorus is used to make incendiary bombs and flares. Since it produces dense clouds of white smoke when burned in air, it is also used to make smoke screens in time of war.

Products in whose manufacture phosphorus and its compounds find use include poison gases, rodenticides, water-softeners, detergents, fertilizers, and pharmaceuticals, among many others. Phosphorus is also used as a constituent of certain alloys, such as phosphor bronze, an alloy of copper, tin, zinc, and phosphorus.

Preparation of Yellow Phosphorus

Yellow phosphorus is prepared by heating, in an electric furnace, a mixture of phosphate rock (such as apatite, a calcium-phosphate rock), sand, and coke. The reactions are as follows:

$$\underset{\text{calcium phosphate (rock)}}{2Ca_3(PO_4)_2} + \underset{\text{silicon dioxide (sand)}}{6SiO_2} \rightarrow \underset{\text{calcium metasilicate}}{6CaSiO_3} + \underset{\text{phosphorus oxide}}{P_4O_{10}}$$

$$\underset{\text{phosphorus oxide}}{P_4O_{10}} + \underset{\text{carbon (coke)}}{10C} \rightarrow \underset{\text{carbon monoxide}}{10CO} + \underset{\text{phosphorus}}{P_4}$$

The phosphorus, in the form of vapor, passes out at the top of the furnace and is condensed into solid yellow phosphorus. Molecules of yellow phosphorus each contain four phosphorus atoms, as indicated by the symbol P_4 in the above equation.

Compounds

The most important phosphorus compounds are the phosphates. Large quantities of phosphates, particularly calcium phosphate, are used as fertilizers. Sodium monohydrogen phosphate, Na_2HPO_4, is used as a chemical reagent, and trisodium phosphate, Na_3PO_4, as a cleansing agent. Orthophosphoric acid, H_3PO_4, is a colorless, syrupy liquid that finds use in analytical chemistry. Trivalent phosphorus oxide, P_4O_6, commonly called phosphorus trioxide, is a colorless crystalline compound that is used in chemical processes as a reducing agent. Pentavalent phosphorus oxide, P_4O_{10}, commonly called phosphorus pentoxide, is a white powder employed both as a chemical reagent and as a drying agent. In the form of smoke produced by burning phosphorus, it is also used for military purposes. Phosphorus trichloride, PCl_3, a colorless fuming liquid, and phosphorus pentachloride, PCl_5, a white crystalline solid, are both used in the synthesis of various organic compounds. **Alfred B. Garrett*

Photius (fō′shəs), *Patriarch of Constantinople (now İstanbul, Turkey). Born about 820 A.D. Died about 892 A.D.*

A saintly and learned man, Photius was made Patriach of Constantinople in 858 A.D. He replaced St. Ignatius, who had been deposed because he condemned the evil life of the Byzantine ruler Bardas. However, Pope Nicholas I in Rome upheld Ignatius and excommunicated Photius. In response, Photius wrote attacks on the Latin Church, denying the Pope's authority and accusing Rome of making innovations in doctrine. He was the first to state clearly the theological differences between the Eastern and Western churches, and his arguments became one of the chief sources on which the Orthodox Eastern Church relied in later disputes with Rome. Photius himself was deposed in 867 A.D., when Basil I became Byzantine emperor and restored Ignatius as patriarch. After a brief period, Photius was reconciled with Ignatius, upon whose death in 877 A.D. he again became patriarch. His appointment was accepted by Pope John VIII. However, Photius was deposed once more in 886 A.D. after disagreements with the new emperor, Leo VI. Photius died in exile, although in communion with Rome. He is honored as a saint in the Orthodox Eastern Church.

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

photochemistry (fō′tō kem′is tri), the branch of chemistry that deals with the chemical changes brought about by the action of some forms of electromagnetic radiation on matter. Photochemistry is particularly concerned with the changes that are produced by visible light and ultraviolet radiation. Near-infrared radiation, which has somewhat longer wavelengths than visible light, is sometimes included. Radiation having shorter wavelengths than those of visible light and ultraviolet radiation does cause chemical changes, but the study of such effects is generally referred to as radiation chemistry. (*See also* RADIATION CHEMISTRY.)

Several common processes are photochemical in nature. The conversion of carbon dioxide and water into oxygen and glucose by green plants that have been exposed to light is a photochemical reaction, which is called photosynthesis. Another common photochemical process is the formation of a latent photographic image when light strikes a photographic film. Tiny grains of silver bromide or a similar compound in the film emulsion are so energized by the action of light that they are more easily reduced to metallic silver than those that are not exposed to light. During development of the film the silver ions so activated are reduced to silver atoms, thus forming an image of the object photographed. The process by which this takes place is not yet fully understood. Another photochemical process is responsible for vision. When light strikes the retina of the eye, it causes certain compounds to undergo chemical changes that result in the transmission of electrical impulses to the brain. The formation of ozone from oxygen is another photochemical reaction. *See also* EYE; PHOTOGRAPHY; PHOTOSYNTHESIS. **Alfred B. Garrett*

photocopying (fō′tō kop′i ing), the use of photographic techniques to make copies of handwritten or printed matter and illustrations. Photocopying machines employ light to produce an image of the material to be copied on paper or film that is coated with a photosensitive material. Photocopying processes include the whiteprint, blueprint, transfer, photostat, and microfilm methods. Xerography and thermography are related photocopying processes. (*See also* THERMOGRAPHY; XEROGRAPHY.)

The whiteprint, or diazo, process produces a positive copy of an original without requiring a negative as an intermediate step. The material to be copied must be on translucent material, such as thin paper. The original is placed face down on a sheet coated with diazo compound. The photocopying machine contains an ultraviolet source that destroys the diazo compound, except where it is protected by writing or other dark portions of the original. The sheet is then exposed to ammonia, in liquid or gaseous form, and the remaining compound becomes darkened, producing a positive image of the original.

Blueprints are negative copies made on paper coated with iron compounds that are sensitive to light. Like whiteprints, they require translucent originals. (*See also* BLUEPRINT.)

Translucent copies suitable for reproduction by whiteprint or blueprint machines are called intermediates. Two kinds of intermediates are vandykes and sepias, both of which are brown and white. Vandykes are made on a blueprint machine, and sepias on a whiteprint machine.

In the transfer process an intermediate negative copy is first produced by exposing treated translucent paper placed against the original. The negative is developed for a few seconds in a liquid bath and then pressed together with another sheet to form a positive image by transfer.

Photostats are simply photographs of an original, made with a special camera and high-contrast film. Both positives and negatives can be made. Microfilming is also a common photographic process that uses a camera. The film is extremely small, and the copies made are thus much reduced from the original. *See also* MICROFILM. **Clyde H. Throckmorton*

photoelectric cell (fō′tō i lek′trik), or photocell, an electric device that is sensitive to light or other electromagnetic radiation. It is used in electric eyes, television cameras, light meters, and many other devices. According to the type of photoelectric effect they utilize, photoelectric cells are divided into three groups: photoemissive, photoconductive, and photovoltaic.

Photoemissive cells are those in which light or other radiation liberates electrons from the surface of a material. A photoemissive cell is an evacuated glass bulb containing two electrodes with external connections. One of the electrodes, called the anode, is kept at a positive potential with respect to the other electrode, called the cathode, by a battery or other power source. The cathode is coated with a photosensitive material that emits electrons when light shines on it. The electrons are attracted to the anode by its positive potential, and thus, current flows. Variations in the intensity of the radiation cause fluctuations in the current. An ammeter in the circuit can be calibrated to indicate the intensity of the radiation instead of the strength of the current.

A gas-filled photoemissive cell is essentially the same, but the glass bulb contains a small amount of an inert gas. When atoms of the gas are struck by electrons emitted by the cathode, many electrons are knocked free from the atoms. Because this reaction releases a large number of electrons, the gas-filled cell is used where a large current output is required.

Photoconductive cells consist of two electrodes separated by a thin layer of semiconductive material that is sensitive to light or other electromagnetic radiation. When radiation strikes the material, it releases electrons and decreases the resistance of the cell. Thus, if the cell is connected to a source of current, the magnitude of the current flowing through the cell varies with the intensity of the radiation.

Photovoltaic cells differ from the other two types of cell because they require no current or voltage to operate them. The principal part of a photovoltaic cell is the junction between the two dissimilar materials from which it is made. When radiation strikes the junction, a voltage is set up between the materials. The magnitude of the voltage depends on the intensity of the radiation. **Lyman Mower*

photoelectric effect, or photoemission, the emission of electrons from the surface of a substance by the action of light on the surface. This effect is the basis of the operation of the photoemissive cell, or phototube, which is a type of photoelectric cell.

Early studies of the photoelectric effect were made by the German physicist Philipp Lenard. He demonstrated that when light falls on a light-sensitive surface, the number of electrons emitted from the surface per second is proportional to the intensity of the light, but the energy of the electrons emitted depends on the frequency of the light.

Albert Einstein explained the photoelectric effect in terms of a fundamental extension of the quantum theory, which was postulated earlier by the German physicist Max Planck. Planck had found it necessary to postulate that light was emitted and absorbed in packets, or bundles, which he called quanta. In 1905, Einstein extended this concept by postulating that the light radiation itself consisted of quanta, or photons, as they were later called. On the basis of this postulate he was able to explain the experimental observations of Lenard. Einstein suggested that the maximum energy that an emitted electron can have is given by the equation $E_{max} = h\nu - W$, in which E is the energy,