The New Caxton Encyclopedia

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KEY TO PRONUNCIATION

Symbol	As in:	Symbol	As in:	Symbol	As in:
a	above	ī	high	oor	gourd
ă	cat	īr	fire	ow	now
ā	date	j	jacket	ow(r)	flour
ār	bare	k	cat	p	put
ah	past	kh	loch	r	rat, beer
ah(r)	car	ks	exclaim	s	sit, city
aw	author	kw	queen	sh	shine
aw(r)	war	l	live, battle	t	time
b	bad	m	man	th	thin
ch	chase	n	nail	th	this
d	dad	ng	singer	u	mud
e	bet	(ng)	French 'bon'	ur	slur
ē	deed	ng g	finger	ū	tune
ēr	dear	ngk	think	ūr	pure
er	better	o	bomb	v	love
f	fog	ō	bone	w	wave
g	game	oi	boy	y	young
h	hear	ŏŏ	book, put	z	haze
i	him	oo	loom	zh	vision

The accent (') follows the stressed syllable or syllables.

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phlebitis

Inflammation of the wall of a vein. Phlebitis is very often associated with thrombosis (clotting) within the lumen of the vein. It is, however, often very difficult to ascertain whether the phlebitis was the cause of the thrombus, or vice versa.

Pathologists attempt to distinguish between thrombophlebitis, which is primarily a phlebitis with secondary thrombus formation, and phlebothrombosis, in which the thrombus is the primary event. This system of nomenclature is widely regarded as unsatisfactory and confusing, and it is likely to be amended.

Thrombophlebitis most commonly occurs in the legs. The chief symptoms are pain, redness of the skin, and swelling of the leg. The risk of complications is not great, but treatment with anticoagulant drugs is given.

In phlebothrombosis the risk is much greater, because pieces of clot may break off into the vein and pass round the circulation until they lodge in the lungs (pulmonary embolism). This is a common cause of death, and the disorder is particularly likely to occur in anyone who has been confined to bed for a few days—especially newly-delivered mothers or people who have just had surgical operations. For this reason, patients are nowadays mobilized as early as possible; if they do have to stay in bed for more than a few days, they should be given intensive physiotherapy to the legs.

phlox

A genus of hardy perennial and half-hardy annual herbs of the Polemoniaceae family. Natives of North America and Siberia, they were introduced into Britain in the early 18th century for their showy flowers. The stems are straight and upright, bearing lanceolate leaves with smooth edges, and the flowers are borne in large terminal cymes. The flower consists of five joined sepals, and five petals joined in their lower parts to form a narrow tube, but separating above as five large lobes turned back to form a flat disc. Five stamens alternate with the petals.

One of the best known species is *Phlox drummondii,* an annual from Texas. It grows about a foot high, and its many varieties produce masses of white, pink, crimson, yellow, blue, and violet flowers. The perennial species include the fragrant *Phlox paniculata,* often marketed as *Phlox decussata,* which grows from three to four feet high and has white and purple flowers. There are also numerous alpine species, such as *Phlox nana* with creamy-rose flowers (nine inches), and the 'moss pink' *(Phlox subulata),* of which there are many varieties and hybrids.

Phoenicians

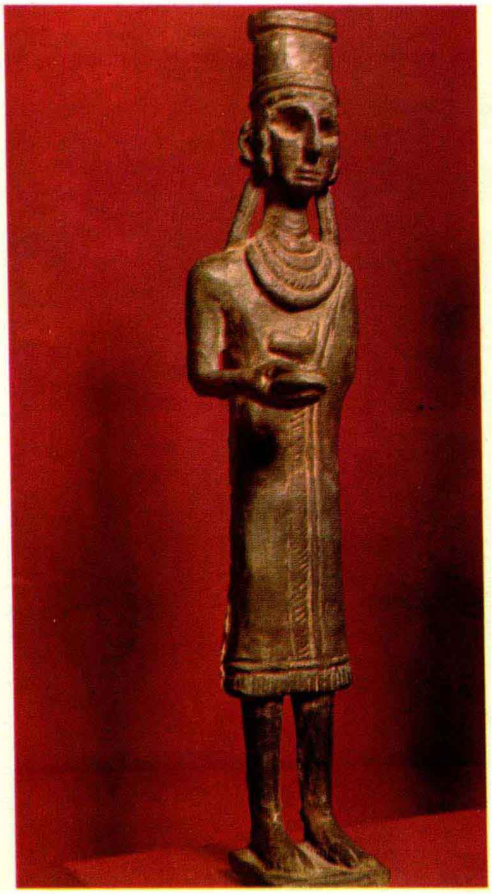
[*fenēsh'anz*] An ancient Semitic people who from the 4th or beginning of the 3rd millennium B.C. inhabited the eastern shores of the Mediterranean to the north of Mount Carmel, between Palestine and Syria. Prehistoric remains show that the region was inhabited from the Stone Age (Palaeolithic) onwards, but it is only from the 3rd millennium B.C. that there is some evidence, though very incomplete, of successive waves of immigration of Semitic peoples, probably originating from Mesopotamia. Until the beginning of the 2nd millennium B.C. there is only indirect information about the Phoenicians. This comes from the archives of the Mesopotamian cities; in particular those recently discovered at Mari testify to close commercial and political relations between the Akkadian kings and the Phoenicians. Throughout the history of the Phoenicians (including that of the western colony of Carthage), there is no literary evidence of Phoenician origin still extant. So our knowledge is derived from either archaeology or the writings of their conquerors or their enemies.

The Egyptian records are particularly informative, especially from the time of the IVth dynasty onwards. They provide a record both of commercial transactions and also of the military expeditions carried out by the pharaohs against the coastal peoples of northern Syria, over whom they managed to establish a lasting ascendancy which was maintained by governors and small garrisons of troops.

Phoenicia from the beginning was divided into small city-states which always retained a measure of local autonomy. Their chief activity, almost forced upon them by the scarcity of cultivable land in the region, was maritime trade, particularly between Byblos and the Egyptian cities of the Nile Delta. But industry must also have been well developed, for the Phoenicians were able to profit by the achievements of both the Egyptian and the Mesopotamian civilizations, between which at first they acted as a bridge, and also by the products of the Aegean civilization.

The chief city-states, apart from Byblos which was the principal religious centre of Phoenicia, were Sidon, Acre, Beirut, and Tyre. Between those cities there arose long and bitter rivalries, more or less dormant or violently explosive according to whether or not a strong central government existed in Egypt. Phoenicia was engulfed by Egypt about 1525 B.C., but towards the end of the 2nd millennium B.C. the irreversible decline of the pharaohs set in and the bonds keeping Phoenicia subject to Egypt were loosened or fell away completely. It seems that Sidon then experienced its

Phlox: a pink variety of this widely grown garden flower. About 60 species of phlox grow wild in North America, and many are cultivated for their showy flowers. *George E. Hyde*



A bronze statuette dating to c. 1500 B.C. of a Syrian god, from the Sidon area, now in the Louvre in Paris.

***Left:* A sarcophagus in the Phoenician necropolis of Byblos. Perhaps due to Egyptian influence, the Phoenicians developed the habit of building deep underground tombs. The sarcophagus was placed in the funeral chamber. *Right:* Phoenician gold cup with artistic decorations, now in the Louvre.**

first great period of hegemony. Subsequently, after 574 B.C., supremacy passed to Tyre, under whose leadership Phoenicia experienced its greatest period of expansion and pushed forwards from the Aegean to the central and western Mediterranean, founding numerous and often highly prosperous colonies in Cyprus, Malta, Sicily, southern Sardinia, and along the south-eastern shores of the Iberian peninsula and the north coast of Africa. Among such colonies were Mogador in Morocco and Cádiz in Spain on the Atlantic Ocean.

The most important of the north African colonies was Carthage, founded according to tradition in 814 B.C. as a result of a civil war that forced part of the population of Phoenicia to flee from Tyre.

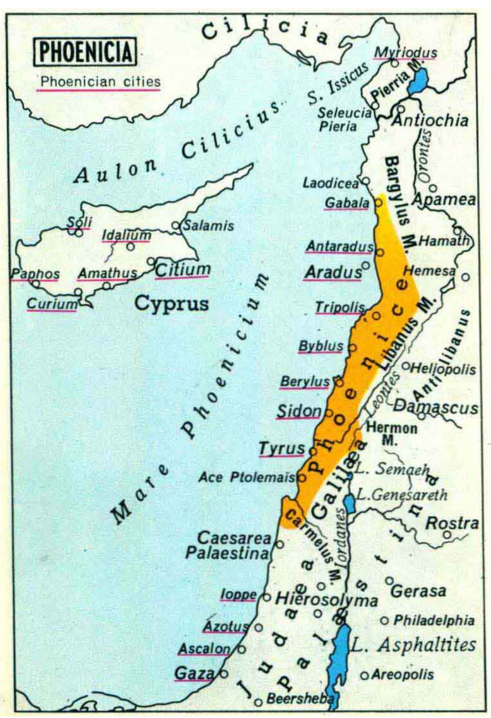
Soon, however, Phoenician power began to totter under the pressure of the expansionist policy of the Assyrian kings. Nebuchadrezzar, who had subjected the Israelites by the capture of Jerusalem, completed the subjection of the Phoenicians in 574 by the capture of Tyre. When Babylon fell to the Persians in 539 Phoenicia passed under Persian rule. Its independence as a nation ended, but its fleets became a mainstay of the Persian attack on Greece. Finally, with Alexander the Great's capture of Tyre in 332 B.C., the Phoenicians ceased to exist as an identifiable people.

Meanwhile, the ties of the Phoenician colonies in the west with their mother country grew steadily weaker. Carthage dominated the western Mediterranean until finally destroyed by the Romans in 146 B.C.

We know little about the distinguishing characteristics of the Phoenician civilization, for few traces remain. The Greeks credited the Phoenicians with the invention of the alphabetic system of writing, and it seems likely that in the North Semitic languages, of which Phoenician and Hebrew were variants, there lay the origin of the alphabets adapted by all Indo-European and Semitic languages. Phoenician literature certainly existed but has all disappeared, like the language itself, which seems to have persisted in some form up to the 3rd century A.D.

Interesting excavations have been carried out at Ugarit and Byblos where remains have been found of temples dating back to 2000 B.C. In the sphere of sculpture a number of noteworthy metal statuettes have been found at Ugarit, where bronzes of the middle of the 2nd millennium B.C. show Egyptian influence. Pottery showed both

An interesting example of Phoenician religious architecture is the so-called Temple of the Obelisks at Byblos. Dedicated to Resheph, the god of lightning and thunder, the building was constructed on the site of an earlier temple that was destroyed by fire at the end of the 3rd millennium B.C.



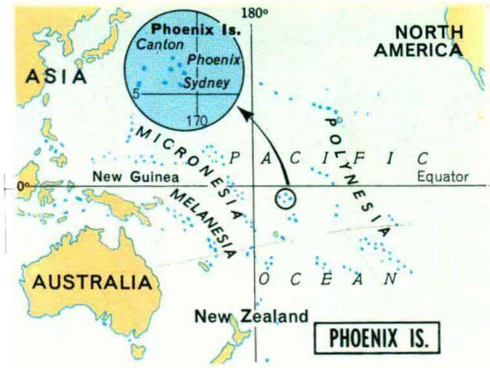
There has been much controversy over the originality of Phoenician art, which many scholars deny. As a whole it tended to display a mixture of skills and styles, perhaps suggesting the attitude of the trader rather than that of the dedicated artist.

Egyptian and Syrian characteristics. After a sudden break at the end of the 2nd millennium due to the invasion of the Sea Peoples, there was an artistic revival of which the most remarkable productions were ivories from Nimrud and metal goblets.

Religion. The supreme deities of the ancient Phoenician pantheon were the two gods El and Baal and the two goddesses Anat and Astarte. El (literally 'god') was the supreme deity, detached from the world. He was associated with underground waters, dwelt in the west 'at the source of the two rivers', and was a god of wisdom, a characteristic he shared with the Mesopotamian god of magic, Enki or Ea, who lived in the depths of the ocean. El's wife was Asherat-of-the-sea and their son was Baal (literally 'lord'), an active god who bestowed fertility on the crops and controlled the weather, 'riding on the clouds' and watering the fields with abundant rainfall. His worship was widely diffused amongst the Semitic peoples of Syria and Palestine and Mesopotamia: the Aramaeans called him Hadad, the Assyrians and Babylonians Adad.

Anat, sister and wife of Baal's son Aliyan, was the goddess of virginity and love. Her essential characteristic was a passionate temperament, so that she was worshipped also as the goddess of violence, war, and slaughter. Astarte (or Ashtoreth in Hebrew) was the great goddess of fertility, known in the West as Tanit and identified by the Greeks with Aphrodite; both her name and nature recall the Mesopotamian goddess Ishtar.

Alongside these principal deities there were many others, the most important being the patron deities of individual cities. Melqart (literally 'ruler of the city') of Tyre (and of Carthage) was assimilated by the Greeks with Heracles, Eshmun of Sidon was assimilated by the Greeks with Asclepius.



Phoenix Islands

[*fē' niks*] An archipelago in the Pacific Ocean, between 2°30′ and 4°30′S. and 171° and 174°30′W.; area 11 sq. miles, pop. 1,300. This Polynesian group consists of eight small coral islands: Canton (or Mary), Enderbury, Phoenix, Birnie, Gardner (or Nikumaroro), McKean, Hull (or Orona), and Sydney (or Mama). Phoenix, Birnie, and McKean islands are uninhabited, and long droughts led to the abandonment of Sydney, Hull, and Gardner from 1958 to 1964. The islands were annexed to the British colony of the Gilbert and Ellice Islands in 1937, but since 1939 the two northern islands of Canton and Enderbury have been administered as a condominium by the United Kingdom and the United States. Canton was for a time an important airport between Fiji and Honolulu, but is now uninhabited.

When the Phoenix Islands were discovered in 1823 they were uninhabited, though remains of ancient buildings are evidence of a former settlement. Today the population obtains a livelihood from fishing and from the very productive plantations of coconut.

phonetics

The science that investigates the acoustic qualities of the sounds of languages: the manner in which they are produced, their transmission and reception, and their analysis and classification and transcription. Speech sounds are of many kinds. Some are articulated in the mouth – such as *p, t, k*. Others are made in the larynx – by air passing through wide-opened vocal cords, or by vocal cords close together that are made to vibrate, or by the glottal stop. Vowels are special modifications of voiced sounds produced with the lips apart and the tongue separated from the palate.

Articulatory phonetics is concerned with the motive processes and anatomy involved in the production of speech sounds, such as the movements of the larynx, lips, tongue, etc. Acoustic phonetics investigates the receiving end of the sounds in terms of their acoustic properties such as pitch, loudness, and duration.

The simplest division of speech sounds is into the two main categories of consonants and vowels. Consonants are formed by complete or partial closures in the throat or mouth. Complete closure gives rise to *plosive* consonants such as *p* and *k*. Closure in the mouth and lowering of the velum produces *nasal* consonants such as *m* and *n*. A rapid succession of taps gives a *rolled* consonant,

		Bi-labial	Labio-dental	Dental and Alveolar	Retroflex	Palato-alveolar	Alveolo-palatal	Palatal	Velar	Uvular	Pharyngal	Glottal
CONSONANTS	Plosive	p b		t d	ʈ ɖ			c ɟ	k g	q ɢ		ʔ
	Nasal	m	ɱ	n	ɳ			ɲ	ŋ	ɴ		
	Lateral Fricative			ɬ ɮ								
	Lateral Non-fricative			l	ɭ			ʎ				
	Rolled			r						ʀ		
	Flapped			ɾ	ɽ					ʀ		
	Fricative	ɸ β	f v	θ ð | s z | ɹ	ʂ ʐ	ʃ ʒ	ɕ ʑ	ç j	x ɣ	χ ʁ	ħ ʕ	h ɦ
	Frictionless Continuants and Semi-vowels	w ɥ	ʋ	ɹ				j (ɥ)	(w)	ʁ		
VOWELS								Front Central	Back			
	Close	(y ʉ u)						i y ɨ ʉ	ɯ u			
	Half-close	(ø o)						e ø ə	ɤ o			
	Half-open	(œ ɔ)						ɛ œ æ ɐ	ʌ ɔ			
	Open	(ɒ)						a	ɑ ɒ			

(Secondary articulations are shown by symbols in brackets.)

OTHER SOUNDS.—Palatalized consonants: ƫ, ᶑ, etc.; palatalized ʃ, ʒ: ʆ, ʓ. Velarized or pharyngalized consonants: ɫ, ᵭ, ᵶ, etc. Ejective consonants (with simultaneous glottal stop): p', t', etc. Implosive voiced consonants: ɓ, ɗ, etc. ɼ fricative trill. σ, ϱ (labialized θ, ð, or s, z). ƪ, ƺ (labialized ʃ, ʒ). ʇ, ʗ, ʖ (clicks, Zulu *c*, *q*, *x*). ɺ (a sound between r and l). ŋ Japanese syllabic nasal. ɧ (combination of x and ʃ). ʍ (voiceless w). ɩ, ʏ, ɷ (lowered varieties of i, y, u). ɜ (a variety of ə). ɵ (a vowel between ø and o).

Affricates are normally represented by groups of two consonants (ts, tʃ, dʒ, etc.), but, when necessary, ligatures are used (ʦ, ʧ, ʤ, etc.), or the marks ͡ or ‿ (t͡s or t‿s, etc.). ͡ ‿ also denote synchronic articulation (m͡ŋ = simultaneous m and ŋ). c, ɟ may occasionally be used in place of tʃ, dʒ, and ƻ, ƨ for ts, dz. Aspirated plosives: ph, th, etc. r-coloured vowels: eɹ, aɹ, ɔɹ, etc., or eʴ, aʴ, ɔʴ, etc., or ᶒ, ᶏ, ᶗ, etc.; r-coloured ə: əɹ or əʴ or ɹ or ᶕ or ɚ.

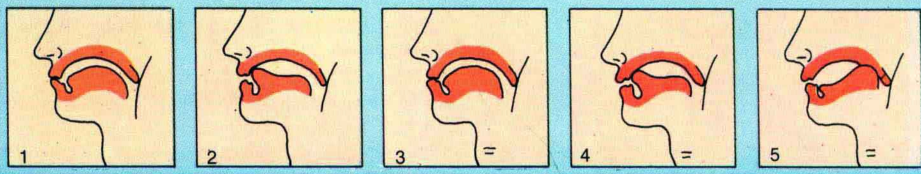
LENGTH, STRESS, PITCH.—ː (full length). ˑ (half length). ˈ (stress, placed at beginning of the stressed syllable). ˌ (secondary stress). ˉ (high level pitch); ˍ (low level); ˊ (high rising); ˏ (low rising); ˋ (high falling); ˎ (low falling); ˆ (rise-fall); ˇ (fall-rise).

MODIFIERS.—˜ nasality. ˳ breath (l̥ = breathed l). ˬ voice (s̬ = z). ʻ slight aspiration following p, t, etc. ̫ labialization (n̫ = labialized n). ̪ dental articulation (t̪ = dental t). ˙ palatalization (ż = ʑ). ̣ specially close vowel (ẹ = a very close e). ̨ specially open vowel (ę = a rather open e). ˔ tongue raised (e˔ or e̝ = ẹ). ˕ tongue lowered (e˕ or e̞ = ę). ˖ tongue advanced (u˖ or u̟ = an advanced u, t̟ = ṭ). ˗ or ̠ tongue retracted (i˗ or i̠ = ɨ˖, t̠ = alveolar t). ˒ lips more rounded. ˓ lips more spread. Central vowels: ï (= ɨ), ü (= ʉ), ë (= ə˔), ö (= ɵ), ɛ̈, ɔ̈. ̩ (e.g. n̩) syllabic consonant. ̯ consonantal vowel. ʃˢ variety of ʃ resembling s, etc.

THE INTERNATIONAL PHONETIC ALPHABET

The same vowel is often pronounced very differently in different parts of Britain and the United States, apart altogether from inconsistencies in spelling inherited from the past; and these differences, as for example between 'southern' English and speech in Scotland and various parts of North America, mean that it is not possible in fact to represent the sound of an English word in such a way as to be acceptable to every reader.

The inadequacies of the ordinary alphabet to transcribe pronunciations have spurred phoneticians for centuries to devise special alphabets that would indicate more clearly the sounds of a particular language. The system now most widely accepted is that of the International Phonetic Association, as reproduced.



Phonetics. Profile of mouth, lips, and tongue in the pronunciation of consonants: 1) *p* as in *pit*, 2) *t* as in *tit*, 3) *b* as in *bit*, 4) *d* as in *did*, 5) *g* as in *get*.

as in the continental European or Scottish *r*. Narrowing of the passage to such an extent as to produce audible friction when the air passes produces *fricative* consonants such as *f*, *s*, and *v*. Consonants produced by both lips, such as *b* and *p*, are *labials*. When formed by the lower lip and upper teeth, as in *f* and *v*, they are called *labio-dentals*, while *dentals* such as *th* are formed by the tongue against the upper teeth, and *alveolars*, as in *t* and *d*, are formed by the tongue against the upper gum. *Palatals* are formed with the tongue against the hard palate, as in *j*; *velars* with the tongue against the soft palate, as in *k* and *g*. *Glottals* are formed by the position of the vocal cords as in English *h*, and *pharyngals*, as in Hebrew *h*, by contraction of the pharynx. Some consonants are made in intermediate positions; thus *sh* is intermediate between palatal and alveolar.

Vowels are classified according to the position of the tongue. Thus *front, central,* and *back* vowels refer to the part of the tongue that is raised, *close* and *open* vowels to the height of the part raised. Each tongue position may be combined with spread, neutral, close-rounded, or open-rounded lips. Gliding sounds that begin at a close vowel position and pass rapidly to a more open position are called *semi-vowels* though categorized as consonants, as the English *w*.

Phonetics is also concerned with the representation of speech and speech sounds in writing. In a 'perfect' or phonetic alphabet there should be a single and constant symbol for each sound or *phoneme*, and no sound should be represented by more than one symbol. But no literary alphabets are perfect. Italian, Spanish, and German are all relatively simple in the graphic representation of their speech sounds, and it is generally supposed that in these languages 'words are pronounced as they are spelt'. But living speech often does not conform to the written word, and all literary

A well-known use of phosphorescence is in the luminous dial and hands of a clock, so that it can be read in the dark. *Fotoarchivi*

alphabets omit symbols for some sounds, and all contain redundant letters. Thus in English the number of the ancient Roman letters was from the beginning insufficient to express with accuracy all the sounds; there are no single letters for the sounds *th, sh, ch,* while several letters (such as *c* and *q* when representing the sound *k*) are redundant. Generally speaking, the Roman alphabet of 23 letters is not adequate for writing languages phonetically. The number of phonemes varies from about 20 as in Japanese to over 60 in Hindustani. In English there are about 43 phonemes, including the 12 diphthongal sounds, while the pronunciation scheme used in this encyclopedia uses 57 symbols.

phosphorescence

Delayed fluorescence, in which a substance called a 'phosphor' continues to emit light after the exciting radiation has been cut off. An example is calcium sulphide, which absorbs blue light during the daytime, but continues to shine with a greenish glow at night. It is used in non-radioactive luminous paints. A substance that glows only while still under the influence of an exciting radiation is called a 'scintillator'. The scintillators used for television screens are commercially, but inaccurately, called 'phosphors'; if true phosphors were used the successive pictures transmitted would persist confusingly on the screen.

The word 'phosphorescence' was originally applied to any substance that glows with a cold light, including both phosphorus and barium sulphide ('Bologna phosphorus'). But the luminescence of white phosphorus is caused by its slow oxidation in the air and is not due to excitation by radiation, whereas barium sulphide is a phosphor, like calcium sulphide. Decaying bones and dead fish are other examples of chemical luminescence, and it has become necessary to use different terms to distinguish these unrelated phenomena. The general term embracing all forms of cold light is 'luminescence' and the light given by certain fish and insects is called bioluminescence.

phosphorus

A non-metallic element of atomic number 15 and atomic weight 31 belonging to the 5th group of the periodic table. Its discovery is usually attributed to Hennig Brandt, who obtained it in 1669 by distilling a mixture of urine and charcoal.

Phosphorus is not found free in nature but occurs as phosphate rock or phosphorite and apatite. The former consists largely of calcium phosphate and there are large deposits in North America and North Africa. Apatite is a natural calcium phosphate often containing fluorine, when it is known as fluorapatite, and sometimes other impurities such as chlorine or carbonate.

World production of phosphate rock totalled 110 million tons in 1974. The United States produced 37% of the total, mostly by opencast mining in Florida in Bone Valley, so-called because the phosphate deposits are the accumulation of the remains of shellfish laid down over many millions of years when Florida was a shallow sea. Reclamation of the land after extraction is a major problem. The port of export is Tampa. The U.S.S.R. in 1974 produced 20% of the world total, two-thirds of which come from the Kola peninsula. As both the U.S.A. and the U.S.S.R. use themselves three-quarters of their production, the major exporting country is Morocco, which in 1974 produced 17$\frac{1}{2}$% of world production. Tunisia ranks fourth in production figures, followed by China, Togo, and Nauru.

Elemental phosphorus is obtained by the reduction of phosphate rock with silica and carbon in an electric furnace. Phosphorus vapour given off is condensed under water, because the phosphorus so obtained is in the white allotropic form which is spontaneously flammable in air at room temperature. In the white form it is a yellowish, translucent solid, easily cut with a knife. It has a specific gravity of 1·8 and melts at the relatively low temperature of 44°C. It is extremely toxic if ingested and causes severe burns.

There are two other allotropic forms of phosphorus, red and black, of which only the former is commercially important. Red or amorphous phosphorus is obtained by heating white phosphorus at 240-250°C. in the presence of iodine or sulphur, which act as catalysts. It is a purple-red solid much less chemically reactive than the white form, having a specific gravity of about 2·2. Its melting point is 590°C. and its ignition temperature in air is 260°C. It is far less toxic than white phosphorus.

Over 80% of phosphate rock is used in the production of phosphatic fertilizers. Apart from this use the most important single industrial use is in the manufacture of detergents, in the form of sodium polyphosphate (SP). In metallic alloys small quantities are added to bronzes either for the purpose of deoxidation or to improve their bearing qualities. Such alloys are known as phosphor bronzes. In cast irons, the presence of phosphorus increases hardness but reduces impact strength. The temperature at which a cast iron starts to solidify is also lowered by the presence of phosphorus and such materials are often used where intricate castings of thin section are required. Another use of phosphorus is in matches (red phosphorus is used for the striking surface of safety matches), incendiaries, fireworks, and smoke bombs.

Phosphatic fertilizers. Phosphorus is essential to all animal and plant life. Organic phosphate compounds exist in the structural units of every cell, while inorganic calcium phosphate makes bone and teeth. Phosphates are vital in protein synthesis, in fat metabolism, and play a main role in the transfer and storage energy in all body tissues. In a stable ecology the phosphate withdrawn from the soil by growing plants is replaced by their decay and by the excreta and corpses of animals. A mixed agricultural economy of cereals and livestock (including horses) could substantially replace the losses of phosphates. But the change to chiefly arable or livestock systems involved the need for the addition of fertilizers to the soil. Experiments at Rothamsted in England in the 1840s of dissolving bone phosphate in sulphuric acid showed how phosphates could be made reavailable to plants and became the foundation of the modern fertilizer industry.

A large amount of phosphate rock is ground and applied directly to the soil but, since the phosphorus is in an extremely insoluble form, better

Left: **The non-poisonous phosphorus sesquisulphide is used in the manufacture of friction or non-safety matches and as a sulphuring agent in many organic processes.** *Centre:* **Red phosphorus, the most stable of phosphorus, is non-poisonous and less reactive chemically than white phosphorus.** *Right:* **Calcium phosphide appears luminescent in the dark and is used in buoys, fireworks, and the manufacture of phosphorated hydrogen.**

results are achieved by applying it in a soluble form so that its uptake by the plant is quicker. The three most common forms of soluble phosphate fertilizer are: superphosphate, obtained by the action of sulphuric acid on phosphate rock, giving a mixture of calcium sulphate and calcium phosphate monobasic; triple superphosphate, which results from the addition of phosphoric acid to phosphate rock, thus avoiding the formation of insoluble calcium sulphate and at the same time giving three times the amount of available phosphorus as the former; and nitrophosphate, which results from the action of nitric acid, nitric/sulphuric acid, or nitric/phosphoric acid on phosphate rock. Nitrophosphate has the advantage that the product also contains nitrogen; potassium salts are usually added to produce complete fertilizers. Phosphorus is also used in the form of diammonium phosphate and the other ammonium phosphates for high analysis solid fertilizers and in liquid fertilizers.

Phosphoric acid. Reference has already been made to the fact that the bulk of the elemental phosphorus produced is converted to phosphoric acid. Another method used for the production phosphoric acid, known as the wet process, is the addition of sulphuric acid to ground phosphate rock. This results in a solution of phosphoric acid and a precipitate of calcium sulphate which is filtered off. For many applications purification and concentration of the wet process acid is required.

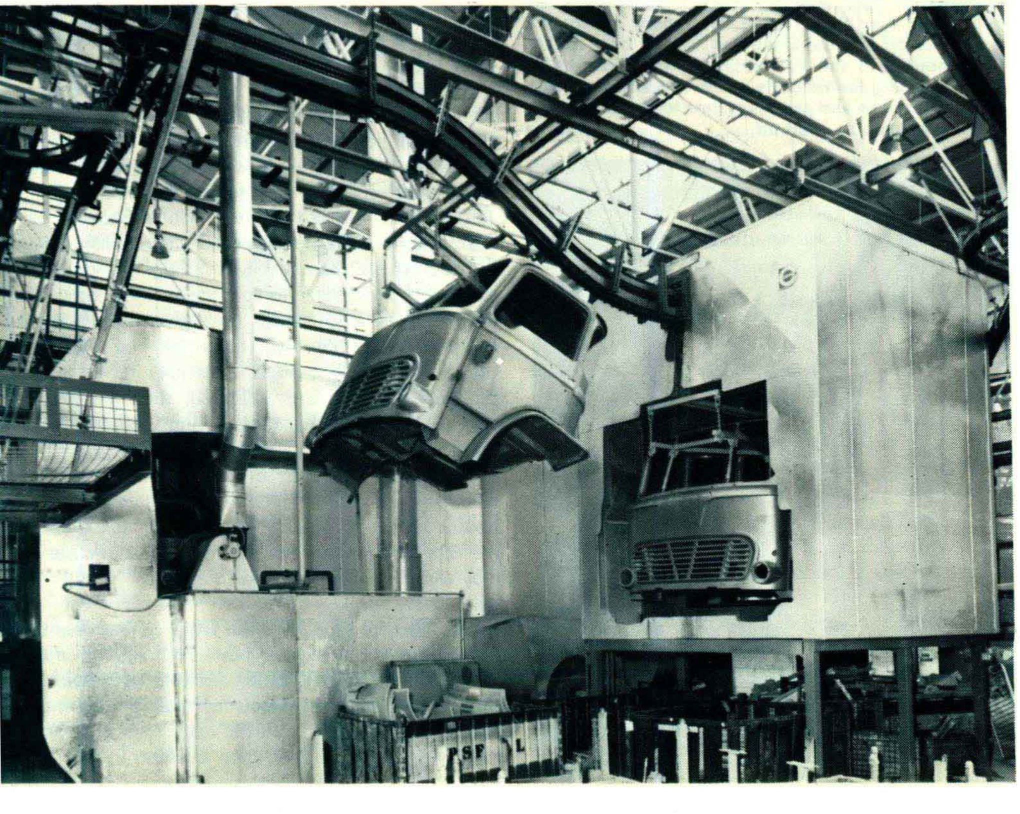
Phosphoric acid, or more properly orthophosphoric acid, has a number of applications of which one of the most important is in metal finishing. It is used, together with zinc and manganese phosphates and accelerators and modifiers in the preparation of phosphating solutions. These solutions, when used in the treatment of steel, form a crystalline phosphate coating which improves paint adhesion and prevents rust spreading beneath the paint film.

Other metal finishing applications include the chemical and electrolytic polishing of aluminium and copper alloys and stainless steels; the production of etch and wash primers where the inclusion of phosphoric acid improves paint adhesion and catalyses the necessary reaction within the paint film; and in the manufacture of de-rusting solutions based on mixtures of phosphoric acid and alcohol.

Phosphoric acid is also used in the manufacture of catalysts for the conversion of propylene to dodecene in the manufacture of doecylbenzene-sulphonate, for the polymerization of C_3 and C_4 fractions to increase the octane number of petrols, and for the co-polymerization of butadiene and styrene to form synthetic rubbers.

The food industry is another large user of phosphoric acid as a cleaner to remove milkstone from dairy equipment and other deposits from brewery and food-processing equipment. It is also a constituent of soft drinks and cordials and in sugar refining it is used as a defecant.

The phosphating of ferrous metals to protect against corrosion is one of the main applications of phosphorus and its derivatives. Trunk cabs are seen here leaving an automatic spray phosphating plant.



Inorganic phosphates. Most phosphoric acid, about 80%, is converted into inorganic phosphates, which are used in a variety of applications. It is, in fact, the ability of phosphorus to form polymeric compounds or condensed phosphates such as the pyro- and poly- phosphates, which gives phosphorus one of its most important commercial applications, the manufacture of sodium tripolyphosphate for the detergent industry.

Sodium tripolyphosphate has the ability to sequester calcium ions to form a soluble complex and it is this property which is used in the modern washing powder to overcome the problems of calcium salts in hard water or from soiled clothes; these calcium salts cause soap scum when soap is used and interfere with the washing process when synthetic detergents are used.

The ability of the polyphosphates and to a lesser extent the pyrophosphates to sequester calcium ions in hard water is used to prevent the formation of calcium scale in boilers. Curiously enough, these compounds are also used in soft-water areas where corrosion of iron or galvanized pipes is sometimes severe enough to cause perforation or blockage but where discoloration of the water is often the most troublesome feature. In such cases a protective film is formed on the iron surface which arrests further corrosion.

Dicalcium and tricalcium phosphate are used in the pharmaceutical industry and as toothpaste abrasives and food additives, while acid sodium pyrophosphate and acid calcium phosphate are used in baking powders and self-raising flours and as bread improvers. The ammonium phosphates also have a number of uses—as a yeast food in fermentation processes, for the flame-proofing of timber and fabric and for the production of crease-resistant finishes.

Other phosphorus chemicals include the oxy-, tri- and penta-chlorides and penta- sulphide which are used in organic chemical synthesis and for the manufacture of dyestuffs, and the organic phosphates and thiophosphates which are used as insecticides, catalysts, antifoam agents, oil additives, plasticizers, and ore flotation agents.

Photius

[fō'shus] Byzantine patriarch (c. 820-893). Photius became patriarch of Constantinople in 858 when his predecessor Ignatius was deposed by the Emperor Michael III. Pope Nicholas I disapproved, and excommunicated Photius in 863. The ensuing quarrel was ultimately to lead to the split between the Western and Eastern Churches. In 867 the Emperor Basil reinstated Ignatius, and banished Photius, but in about 876 he was recalled to Constantinople and entrusted with the education of Basil's children. On the death of Ignatius in 878 Photius became patriarch once more. Photius ignored a second excommunication by Pope John VIII in 879, but was banished after a palace revolution in 886 and died in exile in Armenia.

The history of his stormy patriarchate must not be allowed to obscure the fact that Photius was one of the greatest scholars of the early Middle Ages and a great teacher in the refounded university at the centre of the Byzantine renascence of his time. Posterity owes a debt for two of his works especially. One is a *Lexicon* of rare words and expressions in classical literature, many quoted from works now lost. The full text of this work was only discovered, in a Greek monastery, in 1959. The other work was the *Bibliotheca* or *Myriobiblon,* a summary with criticism of and often quotation from 280 classical works studied in a reading circle he conducted. Though the absence of any works of poetry and philosophy shows the limitation of interest of Photius, the work is of great value as over half the works discussed are no longer extant.

photochemistry

The study of chemical reactions induced by electromagnetic radiation of any wave-length, but particularly by visible light and ultra-violet rays, such as are involved in photography, the fading and bleaching of colours, photosynthesis, and many other chemical reactions. The fading of dyes by sunlight, and the etiolation of green plants deprived of light, must have been observed in very early times, but it was not until the end of the 18th century that the relation between light and chemical reactions began to be studied scientifically. In 1790 Théodore de Saussure invented a simple actinometer to measure the activity of light by an induced chemical reaction: actinometers based on the combination of hydrogen and chlorine to form hydrochloric acid when exposed to light were designed by J. W. Draper (1843), R. W. Bunsen and H. Roscoe (1875), and others.

The first theoretical explanation of photochemical phenomena was given by Theodor von Grotthuss in 1818, and this was developed by Draper in 1841 into a general law. Known as the Grotthuss-Draper law, this states that 'only those radiations which are absorbed by the substances exposed to them are active in causing chemical changes'. Attempts to establish a quantitative relation between the energy absorbed and the change produced met with no success until Albert Einstein (1905) and Johannes Stark (1908) offered the first plausible interpretations. Einstein continued to study the problem, both from the thermodynamic point of view (1912), and on the basis of Niels Bohr's model of the atom (1913), and finally deduced a general principle which became known as the Stark-Einstein law, or the law of photochemical equivalence. This states that 'every molecule participating in a chemical reaction brought about by light absorbs one quantum of the incident radiation'.

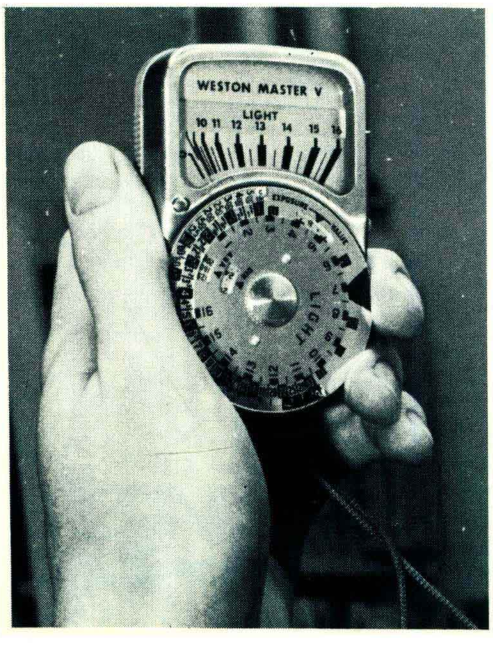
From this law, a mathematical relation between the nature of the reaction and the light absorbed can be simply stated. This is known as the 'quantic yield', and is indicated by ϕ, where:

$$\phi = \frac{\text{No. of molecules in reaction}}{\text{No. of quanta absorbed}}$$

This ratio implies that if the Stark-Einstein law is strictly observed the quantic yield should always be equal to 1. Stark himself, and more explicitly Max Bodenstein (1913), demonstrated that the apparent experimental deviations from the law are due to secondary reactions.

The mechanics of the photochemical effect are as follows. One quantum of light is absorbed by one molecule or atom, which thus acquires a quantum of energy equal to $h\nu$ (in which ν is the frequency of the light and h is Planck's constant). This energy permits the displacement of one electron from its normal orbit to an orbit of higher energy. The molecule or atom thus acquires enhanced chemical activity and is said to be in an excited state. It may then act in various ways, resulting in the association of two atoms, the decomposition of the molecule, the formation of a new compound, and so on, but with a quantic yield obeying the Stark-Einstein law. However, other things may also happen. For example, if the energized molecule does not effect a reaction in a very short time, its displaced electron will return to its normal orbit with the emission of radiation.

Photocells are widely used in the exposure meters by means of which photographers estimate the intensity of light, and therefore the exposure required for their film. In the instrument shown the light falls on the sensitive cell at the back of the instrument, and the light intensity is indicated on the scale. The dial below is set to this scale reading, and the aperture and exposure time for a given speed of film can then be read off. *Keystone*



Even a single energized molecule can give rise to a chain of reactions involving a larger number of molecules than would be compatible with the law of equivalence. But if the secondary reactions are related numerically to the combining proportions of the molecules concerned in the chemical reaction, the quantic yield is expressed by simple whole numbers (1, 2, 3 . . .), thus confirming the basic accuracy of the Stark-Einstein law.

Photolysis. A phenomenon of photochemistry in which a chemical compound is decomposed by light or ultra-violet rays, such as happens in the sensitive emulsions used in photography. Flash photolysis is a technique in analysis which exploits the chemical effects of light to detect the transient intermediate stages of a photochemical reaction. In general, the vapour of a suitable compound at low pressure is subjected to a very brief flash of high-intensity radiation. A second flash, which follows almost immediately, is used to photograph the absorption spectrum of the product, so that the free radicals or unstable molecules produced by the photochemical action of the first flash can be detected and identified before they have combined with other radicals. Other flashes and photographs may follow at measured intervals, to determine how long the various radicals or molecules persist in the free state.

Since the end of the Second World War flash photolysis has been developed to a remarkable degree, chiefly by R. G. W. Norrish and George Porter, who shared the Nobel Prize for chemistry in 1967 in recognition of their work. They used flashes of light lasting for only a few millionths of a second, and later achieved even shorter flashes by the use of lasers. Porter, working at the Royal Institution in London, has used flash photolysis with liquids instead of vapours, and the succession of micro-events in many almost instantaneous chemical reactions has been elucidated.

photoelectric cell

Device based on the effect whereby materials can, under suitable circumstances, emit electrons when electromagnetic radiation falls upon them.

Vacuum photoelectric cells (photocells) consist of a highly evacuated glass tube containing two electrodes. One electrode acts as anode, the other as cathode (photocathode). The surface of the photocathode may be coated with a substance of low work function, such as caesium oxide, so that photoelectrons can be ejected by visible light. If the electrodes are connected to an external circuit, and a suitable potential difference set up between them, then any light falling on the photocathode gives rise to photoelectrons that are collected by the anode and give a detectable current in the circuit. If the applied potential difference is high enough to ensure that all of the emitted electrons are collected, then the photocell is said to be at 'saturation'. Under these conditions the current, which is then directly proportional to the rate of production of photoelectrons, gives an accurate measure of the luminous flux to which the instrument is exposed: for this flux determines the rate of production of electrons in a definite, and in any case a more or less linear, way.

Gas-filled photocells differ from vacuum photocells in that the glass bulb contains an inert gas, such as argon, under suitable pressure. In this case the photoelectrons cause additional ionization in the gas, and the extra ions generated greatly increase the electric current in the circuit. It follows that gas-filled photocells are a good

A London bus passes a photoelectric scanner. This directs a beam of light on to individually coded light-reflection equipment on the side of the bus, so that its progress through London's crowded streets can be traced by a central control room and, if necessary, some action taken. *Keystone*

deal more sensitive than the vacuum type. There is not, however, a saturation state, and this increases the problem of calibration. There is also a certain time-delay compared with a vacuum tube; this gives a slower response to the gas-filled type of tube, which is a disadvantage in some applications.

The term 'photocell' is also applied to devices that work not by the photoelectric effect in the form described above but by the photoconductive or photovoltaic effects. These are typical semiconductor effects, whereby suitable substances show a marked change in electrical conductivity under the influence of light (photoconductive effect); a suitable geometrical arrangement can cause an actual flow of current in an electrical circuit even in the absence of any other electromotive force (photovoltaic effect).

Photocells of various types have an enormous range of applications, both in research and in technical affairs. They are used for the detection and measurement of electromagnetic radiation in many branches of science, from the monitoring of ionizing radiation to the detection of light from distant stars. They are used in cinema and television to translate light variations into variations in the currents in electrical circuits. They are used in devices to turn on street lamps, to detect fog, to monitor smoke emission, to detect the passage of objects along production lines, and in many other circumstances in which variation in light can usefully be made to give a variation in an electric circuit.

photoelectricity

Emission of electrons from a material as a result of electromagnetic radiation falling on the material. The phenomenon was first studied for ultra-violet light falling on metal surfaces. The photoelectric effect, which is the basis of the photoelectric meter and of the solar cell used in space research, is explained in terms of the transfer of energy from the electromagnetic radiation to electrons within the material irradiated. Part of this energy is needed to release the electrons from the forces binding them to the material, and the remainder takes the form of kinetic energy of the emitted electrons.

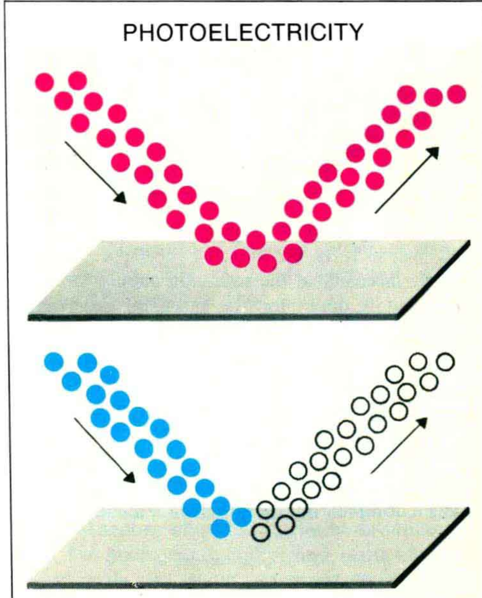
The minimum energy needed to release an electron from the surface of a metal is known as the 'work function' of the particular metal. This energy is commonly expressed in electron-volts (eV), one electron-volt being the energy needed to move an electron against a potential difference of one volt. Work functions are typically several electron-volts. According to classical physics, which held that electromagnetic radiation could be fully explained in terms of its wave properties, it might well be expected that photoelectric emission would occur for light of any wavelength, on condition that the intensity was high enough. In practice, there exists for each metal a minimum frequency ν_0, known as the 'photoelectric threshold', such that no photoelectrons are produced at all, however high the intensity, if the frequency of the light or other electromagnetic radiation is below this threshold. If the radiation is above the threshold, then the kinetic energy of the emitted electrons increases with the *frequency* of the radiation, and it is the *number* of photoelectrons that depends on the intensity of the radiation.

An explanation of the photoelectric effect, and of its disagreement with classical ideas, was provided by Albert Einstein in 1905. This explanation was based on an extension of the quantum hypothesis, introduced by Max Planck in 1900 in his interpretation of 'black-body' radiation. According to the final form of this theory, electromagnetic radiation of frequency ν behaves, in many ways, as though it was made up of particles (photons), the energy E of each particle being given by $E=h\nu$, where h is the universal constant known as Planck's constant. The value of h is about 7×10^{-34} joule-seconds. For electromagnetic radiation in the near ultra-violet (e.g. of wavelength 3×10^{-7} metres), the photon energy is about 4 electron-volts, which is of the same order as the work functions of most metals.

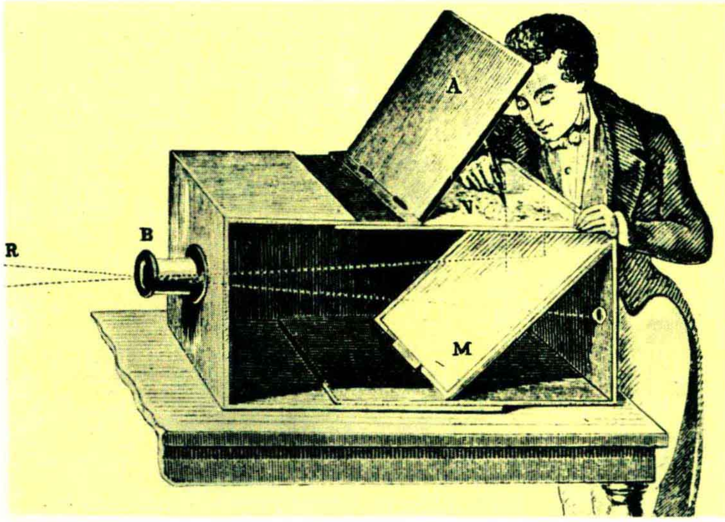
The process of photoelectric emission is believed to consist in the emission of one electron as a result of the bombardment of the metal by one photon. If this photon is in the visible region of the spectrum, its energy will be less than that of the work function for most metals, and photoemission will not be possible. (Visible light causes photoemission only in the alkali metals, or in other surfaces with an unusually low work function.) An ultra-violet photon, on the other hand, will have sufficient energy to exceed the work function of a more typical metal such as zinc. In this case, the kinetic energy of the emitted electron will equal the difference between the energy of the incident photon and the work needed to release the electron. That is,

$$E=h(\nu-\nu_0),$$

where E is the kinetic energy of the electron, and where ν is the frequency of the incident radiation. According to this equation, there should be a linear variation of the kinetic energy of the electron with the frequency of the incident radiation. Such a variation is indeed found experimentally; and the value of h derived from the



The photoelectric effect is dependent on the frequency of the light falling on a surface. Red light (low frequency radiation) is composed of photons whose energy is much lower than that necessary to produce a photoelectric effect at a metal surface, so it is merely reflected. Photons of blue light (radiation of high frequency) have much higher energy and so are able to cause the emission of electrons from a metal surface.



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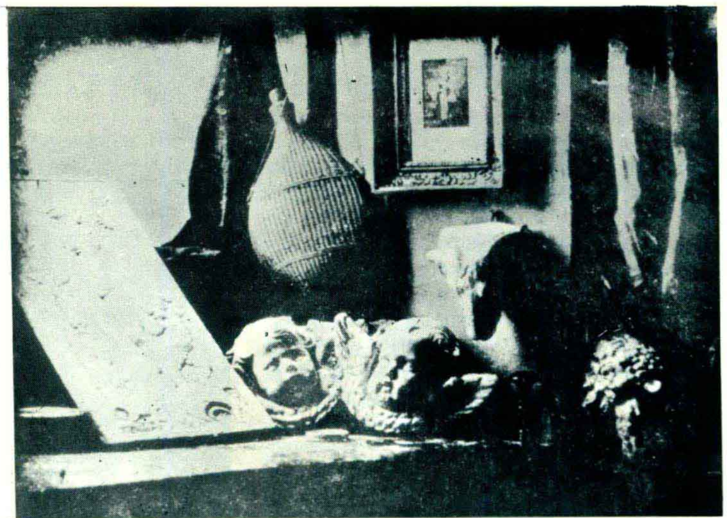

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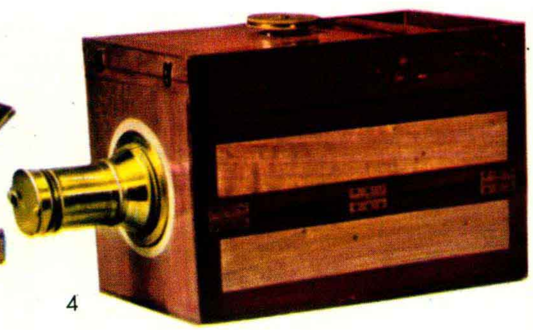


4

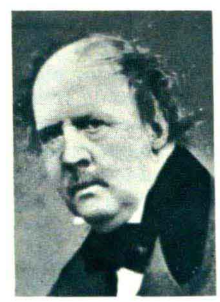
J. H. Schulze

J. N. Niepce

5

The birth of photography. 1) A camera obscura as used by William Fox Talbot for drawing landscapes in Italy. 2) The earliest existing daguerreotype, 1837. 3) L. J. M. Daguerre's apparatus, designed by his brother-in-law Alphonse Giroux and signed by the holders of the patent. 4) Charles Chevalier's adaptable camera, which could also be used for making negatives on paper. 5) The Bourguin camera of 1844, with a Petzval lens.

L. J. M. Daguerre



W. H. Fox Talbot

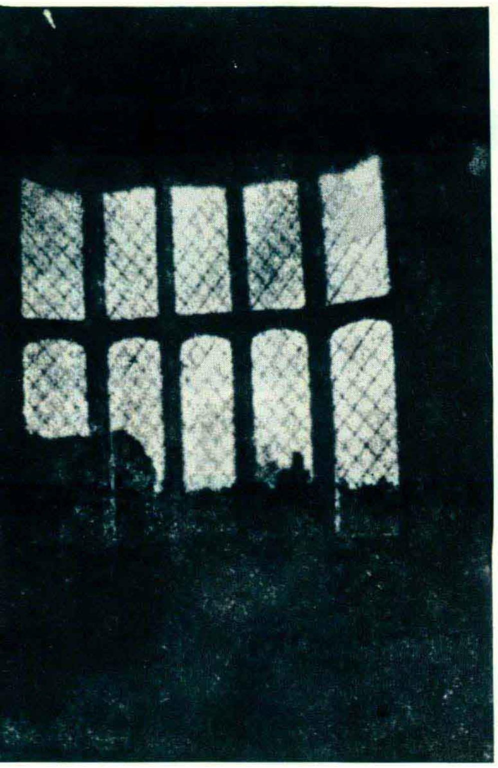
measurements agrees with that determined in other ways. It is obvious, in terms of photons, why the intensity of the radiation should have the effect that it does: for the intensity determines the number of photons of given frequency, and therefore the number of emitted electrons.

Although the photoelectric effect is most easily observed in the case of metals, the theoretical interpretation is simpler in the case of gases: for the atoms can then be treated as behaving effectively independently of one another, instead of having a complex interaction as in a metal or other solid.

photography

The art of fixing an optical image by photochemical means. The image is usually produced by a convex lens, as in the camera obscura, but the lens may be replaced by a 'pin-hole' in a screen, or – as in X-ray and contact photography – by a beam of diverging rays. The common requirement of all photography is a surface which is sensitive to light in a manner that produces visible photochemical changes. Some such surfaces appear to have been used in China some 2,000 years ago for decorative purposes, but the method probably exploited the properties of dyes which fade rapidly in sunlight, the patterns produced being comparable with the dark rectangles seen on old wallpaper after long-hung pictures have been removed. The effects of light on some substances were studied by the Arabs in the Middle Ages, but did not arouse interest in Europe until after the camera obscura had been fitted with a lens by Giambattista della Porta and others about 1550. The brilliant images thus thrown on the screen aroused the desire to 'fix' them, and this became theoretically possible when J. H. Schulze observed the blackening of silver salts by sunlight in 1727, though nobody realized it at that time.

However, K. W. Scheele and William Lewis made further researches into the light-sensitivity of silver salts in the second half of the 18th century, Scheele making the important discovery that the blue and violet rays of sunlight are more active than the red. When Lewis died in 1781, his notebooks were bought by Josiah Wedgwood, the potter, and so came to the notice of Thomas Wedgwood (1771-1805), his fourth son. In 1802 Thomas Wedgwood made contact prints of leaves by laying them on paper soaked in silver chloride and exposing them to sunlight. They were 'negatives', the dark leaves showing white on a background of blackened paper, but as he had no method of 'fixing' them the prints of the leaves also blackened over in a short time. He then conceived the idea of using silver chloride to capture the picture produced by the lens in a camera obscura, and with this object he made several experiments with Humphry Davy. To obtain an intense enough light they used a very small image, and so produced the first microphotographs, but very long exposures were still required. There was as yet no method of either positivizing or fixing the pictures, but in 1835 William H. Fox Talbot discovered that the blackening could be more or less stopped by washing them in brine, and he already had a method of making positive prints. However, Fox Talbot did not announce his discoveries to the Royal Society until 1839, immediately after the publication of a rival system of photography by L. J. M. Daguerre.



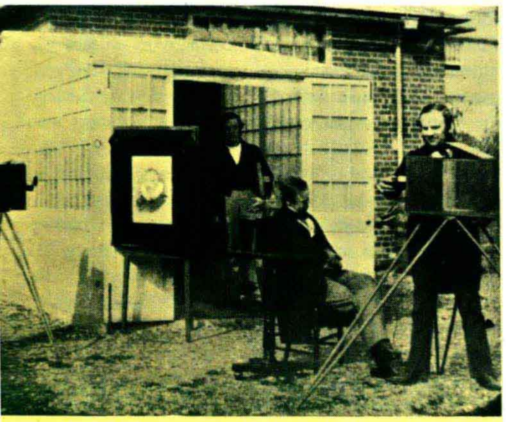
The earliest paper photograph in existence. A window in Lacock Abbey, taken by Fox Talbot in 1835 by the process later called 'calotype'. The original is a negative about one inch square, and is in the Science Museum in London. *Crown copyright*

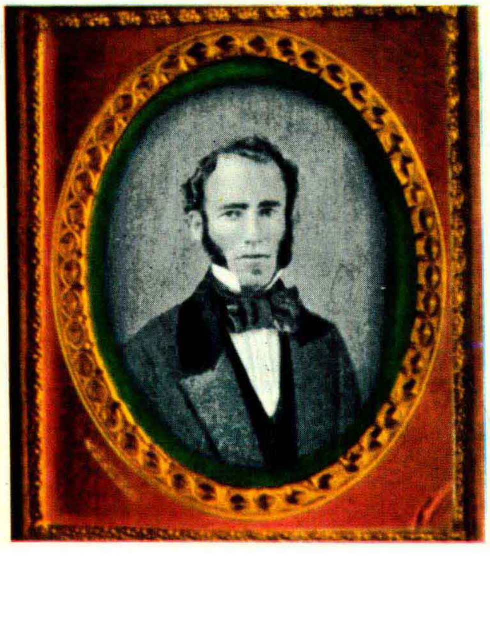
Meanwhile, J. Nicéphore Niepce, a French officer who studied lithography in his spare time, happened to run short of lithographic stone one day in 1816, and tried drawing on metal plates coated with a layer of bitumen of Judea dissolved in oil of lavender. This was unsatisfactory, but he then thought of exposing a plate to the image in a camera obscura. After about eight hours the bitumen became hard where the light was strongest, and he was able to wash the rest off without disturbing it. He then etched the plate with acid and so produced a crude picture which he called a 'heliograph'. Two of these plates still exist in the museum at Chalon-sur-Saône, his native town, where a large memorial announces that *'Dans ce village Nicéphore Niepce inventa la Photographie en 1822'*. What he really pioneered was photo-engraving, but he seems also to have produced photographic negatives on paper treated with silver chloride, and to have had a method of fixing them.

In 1826 Niepce discovered that Daguerre had been experimenting on somewhat similar lines, and they decided to collaborate, becoming partners in a company to develop photography in 1829. It is not known how much Niepce contributed to Daguerre's system, for he died in 1833 and the product of the company was announced under Daguerre's name in 1835. Daguerre used silver (or silvered metal) plates, which he treated with silver iodide and then exposed to iodine vapour. He found he could develop a latent image in an under-exposed plate by subjecting it to the action of mercury vapour, thus cutting down the time of exposure from an hour or more to about twenty minutes. Furthermore, his prints were positive, showing the light parts as light on the plate, and in 1837 he succeeded in fixing them with brine. This was the first really satisfactory photographic process, and the 'daguerreotype', as it was called, was the first to achieve commercial production. But since the plates were positive only one picture was available for each photo taken.

The sitter for a daguerreotype portrait had to remain perfectly still for anything up to half an hour (later, six minutes), and photographers' chairs were devised in which the subject was prevented from moving his head by a set of three adjustable points, one at each side behind the ears, and one behind the head. The first daguerreotype portrait was exhibited in Paris in 1839, and in 1840 daguerreotypes appeared in Berlin and New York. There was a sudden 'epidemic' of what the press called 'Daguerreotypomania' on both sides of the Atlantic, and in 1841 one studio in Berlin was taking a hundred portraits per week.

While Daguerre was still developing his system, John Herschel in England was experimenting with a completely different method of photography, not involving photochemical reactions. An image was projected on to a horizontal plate, which was then flooded with a suspension in spirit of fine particles of carbon. The light and heat rays evaporated the spirit where they fell, and at the right moment the dried particles of carbon could be blown off, leaving the picture in the particles which were still wet. These could then be fixed by spraying with gum or varnish. But the method was tricky and uncertain, and Herschel's name is associated with photography chiefly for his discovery that sodium hyposulphite is a much more efficient fixing agent than brine for silver photographs. Though it was later replaced by sodium thiosulphate, the name 'hypo' continued to be used and is still frequently heard.





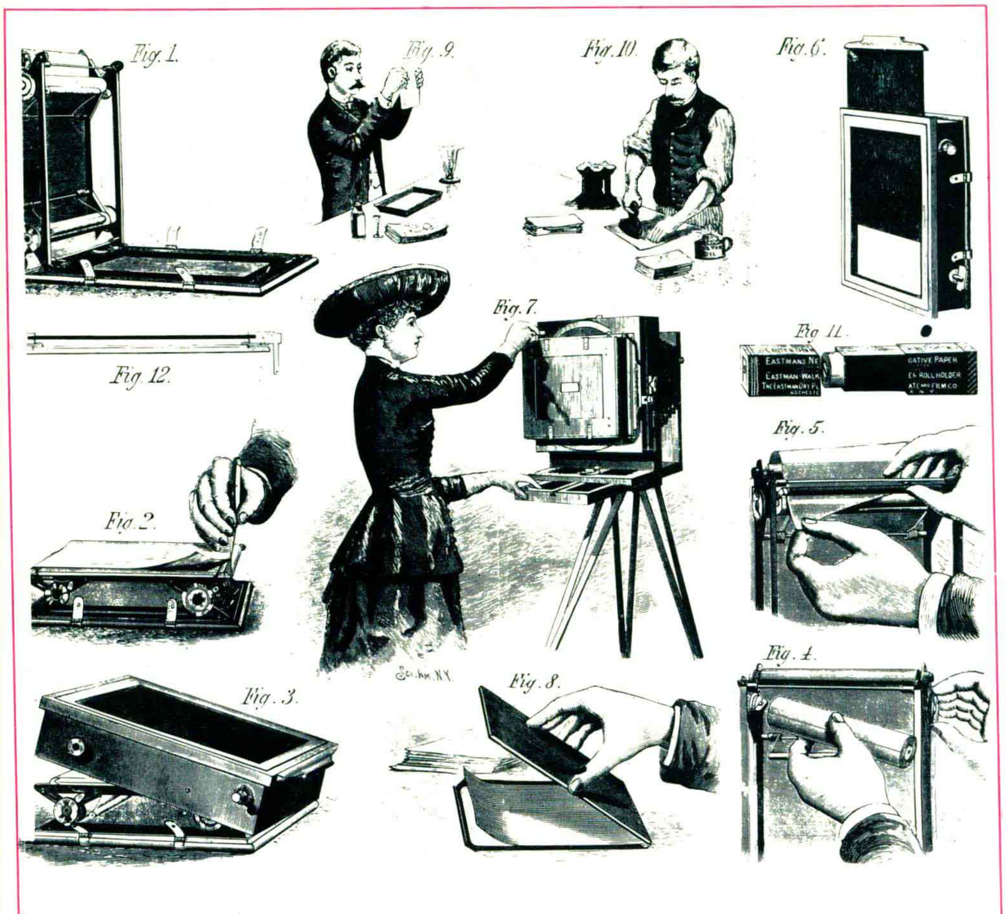
Fox Talbot's studio at Reading, England, c. 1843. The photographer on the left is reproducing a painting, while on the right Fox Talbot is taking a portrait from life. *Right:* A daguerreotype made in Boston, Massachusetts in 1850.

In spite of the popularity of the daguerreotype, modern photographic methods come from William Fox Talbot's inventions; he began his experiments in 1834 and announced the results in 1839. In *On Photogenic Drawing* in 1843 he described how he had first treated paper with silver nitrate, and on it made contact prints of opaque objects. He then put his sensitive paper in a camera obscura and secured a negative print of a building in sunlight after an exposure of 'an hour or two'. In 1835 he took several pictures of his own house, and discovered how to fix them with salt water. He then rapidly improved his method, which he called 'the photogenic art', abandoning silver nitrate for the chloride, iodide, and finally the bromide, which is still the chief salt of silver used. He took his negative pictures on transparent paper, then making positive prints from them, and obtained enlarged pictures of outdoor objects in 1836, three years before Daguerre. He discovered that a short exposure would produce a latent image which could be developed with a reducing agent, and adopted Herschel's 'hypo' as a fixing salt. The basic principles of photography as we know it were thus already established by Fox Talbot by 1842, when he was awarded the Rumford medal of the Royal Society for his work. He called his pictures 'Talbotypes' and later 'calotypes', and went on to take pictures through a microscope with a magnification of 17 diameters, and so became the pioneer of photomicrography.

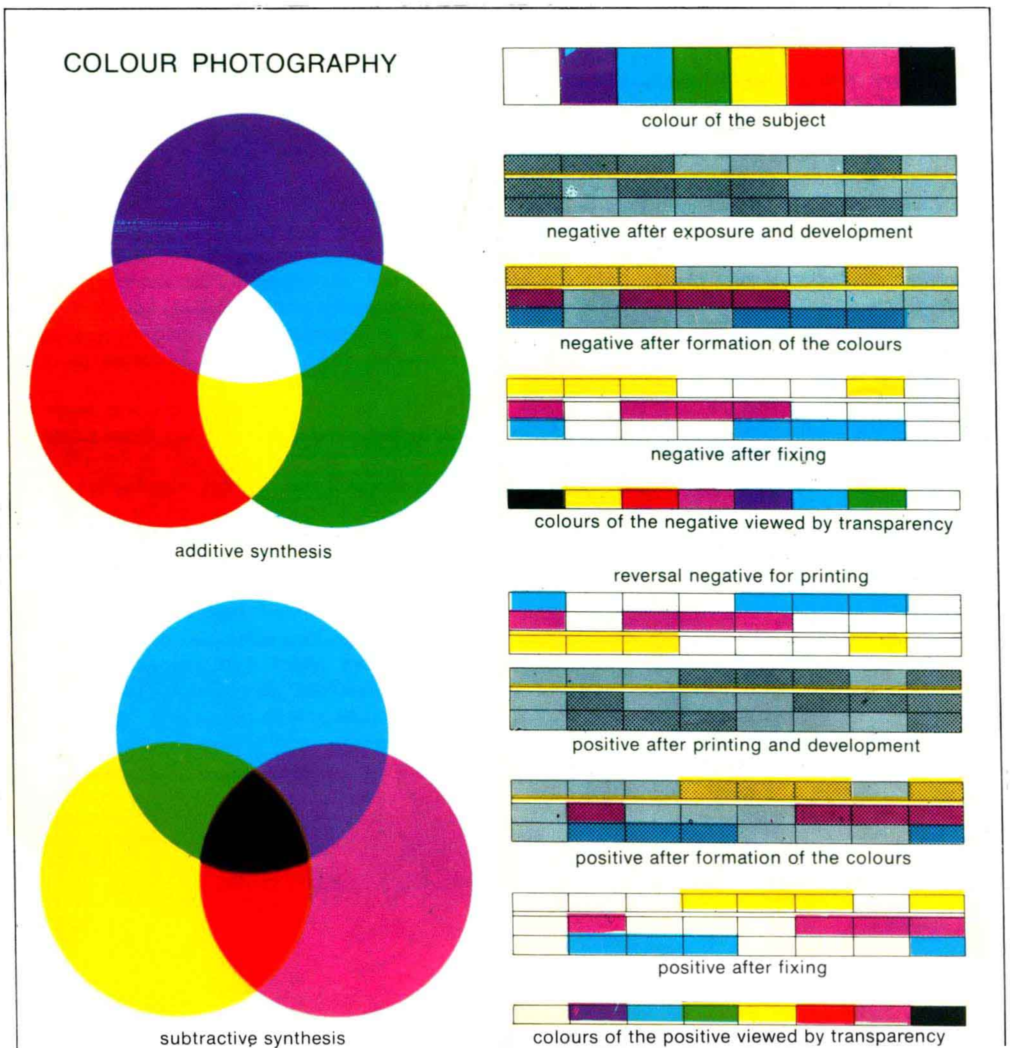
Fox Talbot's transparent paper negatives were the weakest part of his system, but the use of glass instead of paper was invented by C. F. A. Niepce de St Victor, a nephew of J. Nicéphore Niepce. He used glass plates coated with iodized albumen. They were not very satisfactory, but collodion was discovered in 1846, and was proposed as a base for photographic emulsions in 1850. In 1851 Frederick Scott Archer made photographic plates coated with a wet collodion solution containing silver nitrate, with excellent results. Any number of perfectly clear, sharp photographic prints could then be made from the negative, but the photograph itself had to be taken on a wet plate and developed in a solution of pyrogallol containing acetic acid before it was dry, and this was especially inconvenient for outdoor photography. Dry collodion plates were tried by G. R. Muirhead in England and M. A. Gaudin in France in 1854, by J. M. Taupenot in 1855, and by C. Russell in 1862.

In 1864 an important discovery was made by W. B. Bolton and B. J. Sayce. They found a method of forming the sensitive silver salts in the collodion while it was still wet, so that manufacture in the dark by a single process replaced the preliminary coating of the plate and its subsequent sensitization. Bolton and Sayce used wet plates, but a satisfactory dry plate was invented in 1871 by R. L. Maddox, who used a gelatine-bromide emulsion for microphotography, and soon afterwards ready-made dry plates were put on the market, though Maddox died in poverty. The sensitivity of the gelatine-bromide plates was enhanced by

Fox Talbot contested Daguerre's priority as the inventor of photography; there is no doubt that he was the real inventor of photography as we know it today, for Daguerre's methods rose to fame and fell like a rocket, and have been obsolete for almost a century.



The first photographic roll film shown in a contemporary engraving. This film required an adaptor which could be fitted to the standard plate camera of the time. 1) The film carrier seen from the back; 2) cutting the film for single pictures; 3), 4), and 5) inserting the film in the adaptor; 6) and 7) the adaptor seen from the emulsion side and fitted in the camera; 8) frame for single pictures; 9) developing; 10) straightening the film; 11) the roll film in its original pack; 12) cross-section through the plane of movement of the film.



a heating process in 1878, and in 1880 Joseph M. Eder further increased it by treatment with ammonia. The first dry plates were sensitive chiefly to blue light, but increased sensitivity to the green and yellow was achieved by the uses of dyes in the orthochromatic plate, perfected by H. W. Vogel in 1884. The chief landmarks in the improvement of developers were the introduction of hydroquinone ('quinol') in 1880, and of metol in 1891. They were often used together as 'M.Q.'.

These advances were accompanied by a spectacular shortening of the times of exposure, those for subjects with average lighting being:

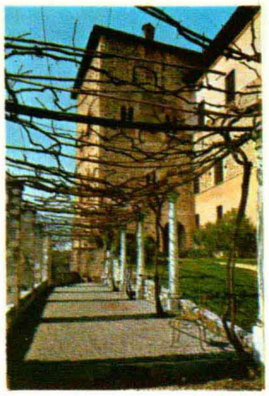
Early daguerreotype	30 to 60 minutes
Late daguerreotype	6 to 20 minutes
Calotype	2 to 3 minutes
Collodion plates	10 seconds
Gelatine emulsion	1/15th second

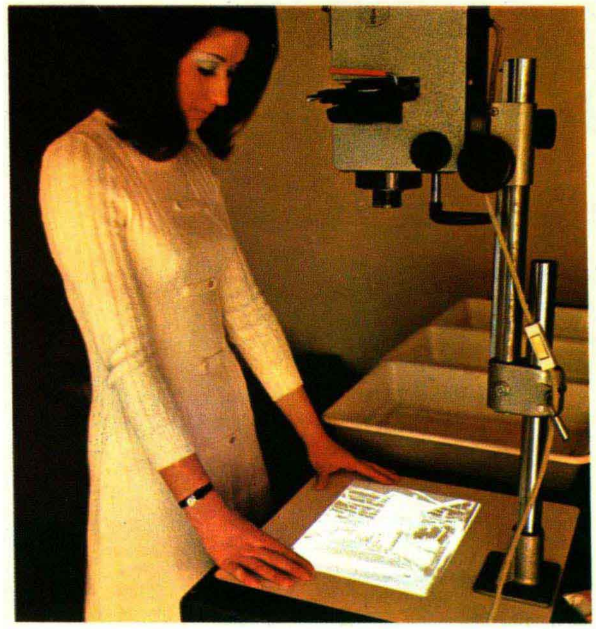
However, paper negatives came back in 1864 in the form of a roll, like roll film, and in 1888 a small box 'Kodak' with a roll to take 100 exposures was produced by George Eastman. In 1887 H. W. Goodwin proposed replacing the paper by celluloid film, and the first roll films appeared in 1889. The cameras, too, were rapidly developed. The first special photographic lens was designed by Joseph Petzval in 1840, and was put on the market by the firm of Voigtländer in 1841. The anastigmat lens was introduced by Carl Zeiss in 1890, and the double-anastigmat by C. P. Goerz in 1892. The focal-plane shutter appeared in England in 1861, and a blade-type shutter acting also as an iris diaphragm was invented in Germany in 1887.

The apparatus required for taking photographs away from the studio was also enormously reduced. When the first commercial photographs were becoming popular, whether by daguerreotype or the wet plate process, several porters were required to carry the necessary equipment. This was soon reduced to a load which one man could push in a hand-cart. Next came a pack weighing about 40 lbs to be carried on the back, with a tripod which could be used as a walking-stick. This arrangement was still in common use in the 1870s, but the coming of the dry plate enabled photographers to do the processing at home, and reduced their picture-taking outfit to a pack the size of a suitcase.

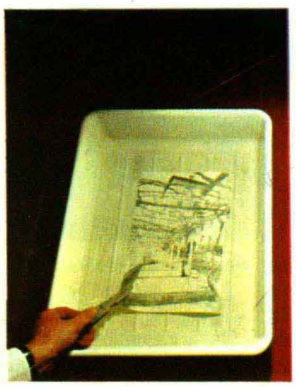
The first experiments in colour photography were made as early as 1861 by James Clerk Maxwell, who took three black-and-white negatives of the same subject through red, green, and blue filters, respectively. Black-and-white positives of these were projected simultaneously on to a screen by three magic lanterns with differently coloured lights, so as to superimpose the red, green, and blue images. The first satisfactory development of this 'additive colour' system was the 'Lumière Autochrome' of 1907, and this was followed by the 'Dufaycolor' process, which employed a microscopic mosaic of the three primary colours on a single screen. The next great advance was the discovery of 'colour development' by R. Fischer in 1912, in which colour formers or 'couplers' were used to react with the oxidation product of development and form dye images. This 'subtractive colour' system came to fruition in the 'Kodachrome' and 'Agfacolor' processes of 1935 and 1936 respectively. These employed multi-

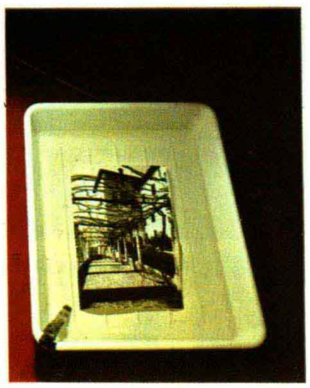
Left above: **Colours produced by blending light;** ***below:*** **colours produced by blending pigments.** ***Right:*** **The successive stages in negative-positive processing of colour photographs.**

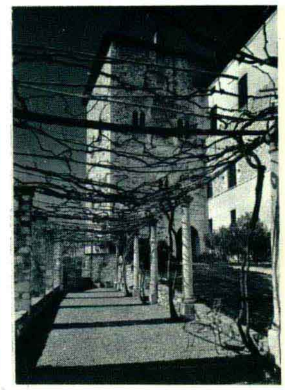




The various processing stages in black and white photography. ***Above:*** **The original subject.** ***Right:*** **Developing and fixing the negative.** ***Far right:*** **Making an enlarged print in a darkroom.** ***Below from left to right:*** **Developing and fixing the positive print; drying under heat; the finished print.**







layer films in which each emulsion layer was sensitive to a different primary colour, the Kodachrome system using the couplers in the developer, and the Agfacolor system incorporating them in the emulsion layers. Coloured prints followed the discovery of a colour-negative material used in the Kodacolor system of 1942, and other processes have since been patented. Kodacolor was also the name given to short-lived lenticular colour film produced for amateurs in the early 1930s.

Basic principles. The light-sensitive material in the emulsion of a photographic plate is almost invariably a silver halide, usually the bromide, these salts having the property of absorbing photons. When a photographic exposure is made, the photons of light confer energy on electrons in the crystals of the silver salt. Each of these moves through its crystal until it finds a flaw in the structure or an impurity such as a molecule of silver sulphide. There it lodges as a captured negative charge, which at once attracts a positive silver ion and converts it into an atom of metallic silver. After a normal exposure the silver atoms are scattered through the emulsion according to the intensity of the light in the various parts of the picture, and constitute the 'latent' image. A mild reducing agent, called a 'developer', is now applied, and under the catalytic action of the free silver atoms this supplies sufficient new electrons to convert the other atoms in each 'seeded' crystal into black metallic silver, which now becomes visible. The photo is thus made up of grains of black silver. The fixing process is simply the removal by chemical solution of all the unaffected silver halide salts.

A photograph so made is a negative, and a positive print may be made from it by placing it in contact with sensitive paper and exposing it to light. This is tantamount to making a photographic copy by Wedgwood's method of making prints of leaves, and the relations between black and white are reversed. No lens is required, and negative and positive are the same size. To make an enlargement the negative is placed in an 'enlarger', which throws an image of the negative on to a baseboard, to which light-sensitive paper has been attached. The silver 'grain' of the negative is too fine to be perceived by the naked eye, but a considerable enlargement will show up the constituent grains on the print. To avoid this, special fine-grain plates and films and developers are made, but unfortunately they are not as sensitive or 'fast' as the coarser-grained plates, though they are still very much faster than the early dry plates. The time of exposure comparable with those cited above is 1/100th or even 1/1,000th of a second by the use of modern lenses with suitable illumination. Modern research has very considerably reduced grain size as well as increasing the possibilities of available light photography.

High-speed photography. Special techniques are used for the photography of rapidly moving objects, such as a bullet as it leaves the muzzle of a gun, or a window in the act of breaking. Extremely sensitive photographic emulsions, intense lighting, and new ways of controlling the exposure are necessary. No camera shutter can be devised to give an exposure, of, say, 1/100,000th of a second, but one way of getting over this difficulty is to set up the camera in the dark, open the shutter, and then illuminate the object with an almost instantaneous flash. Electronic flashes approaching one-millionth of a second have been produced, and are used, for example, in photolysis. Comparatively cheap amateur units work at about 1/2,000th of a second and later models have sensors and quenching units to give automatic exposure control.

The camera. Basically, any camera contains three main parts: the lens, to 'gather' the picture or image; the body or box through which the picture is transmitted; and the film compartment. Various controls are provided to ensure that the correct amount of light reaches the film in the back of the camera, for the correct amount of time, to give a satisfactory image on the film. Control of the amount of light is made by a diaphragm or iris. The brightness of the image depends on the diameter of the light beam entering the lens, and the distance between lens and image. The amount of light is controlled by an aperture or stop, which is a circular hole, usually adjustable in diameter, and positioned between lens components at about the centre of the compound lens. The adjustments are in a numerical sequence, known as 'f' numbers, and image brightness is reduced to one quarter as effective aperture is halved. Control over the time that the light is allowed

Examples of the consequences of incorrect exposure. *Left:* Over-exposure; there is insufficient contrast and the tones are generally flat. *Centre:* Correct exposure. *Right:* Under-exposure; insufficient detail in the dark areas.

Four photographs of the same subject, all taken from the same position. *Left to right:* With a lens of normal focal length (55 mm); with lenses of focal lengths of 100 mm and 250 mm respectively; with a telephoto lens (350 mm). *Gilardi*

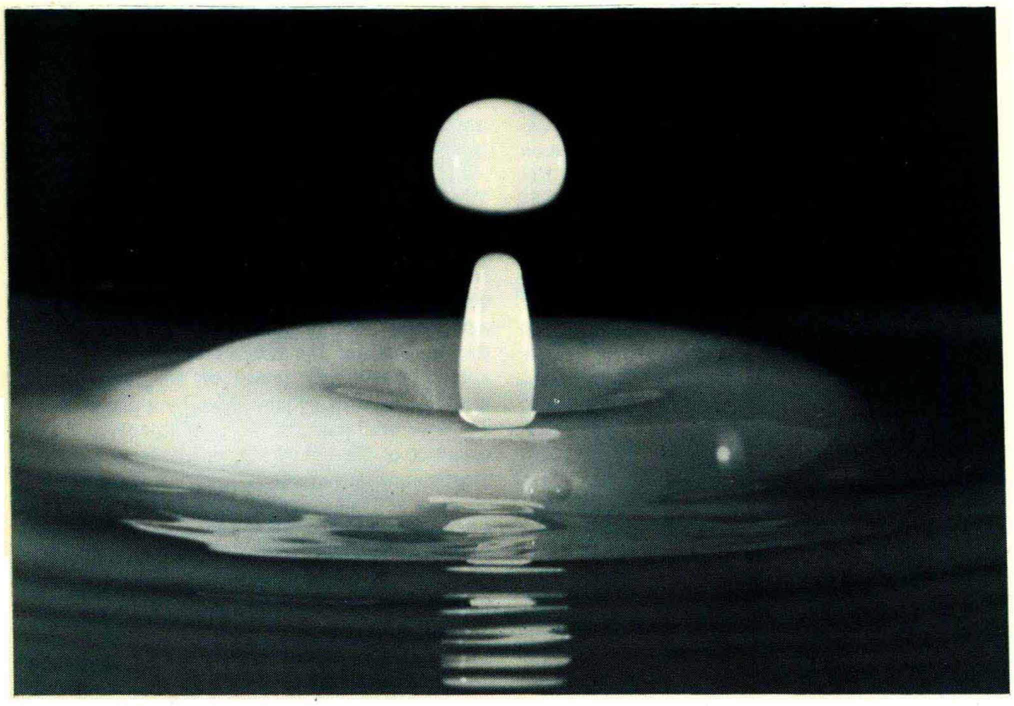
to act on the film is by means of a shutter. This is simply a 'blind' which opens and closes when the camera exposure button is pressed. The shutter can be in the form of a moving blind (focal plane type) or central blade shutter (see diagram). By the use of these two main controls in various relationships, the image is recorded in its correct intensity. The focal plane shutter is fitted close to the film, at the rear of the camera, while the metal blade type is usually built into or just behind the lens. Modern developments are leading to greater use of electronic shutters.

The film compartment has a pressure plate to keep the film flat and at right angles to the light source. Various sizes of film are available, depending on the type of camera. In large, usually technical cameras single sheets of film are used to give a larger negative. For almost all other purposes smaller cameras are increasingly used. The great majority of fashion photography and commercial work is now done with 2¼ inch square cameras and since the Korean war nearly every photojournalist has worked with 35 mm. Improved emulsion technology has meant that at last advantage could be taken of their comparatively light weight and easy interchangeability of lenses.

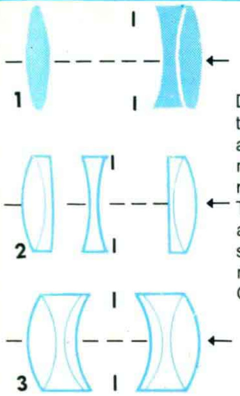
The development of rare earth glasses particularly in Japan in the early 1950s has produced a whole new generation of optical designs. These have provided not only lenses of greater maximum aperture (faster) but also greater definition and negligible distortion except for extreme wide-angle lenses. The very widest angles (90-120°) are produced by fish-eye lenses, but distortion-free lenses of 35 mm focal length, as compared to the normal of 50-55 mm, are widely in use with 35 mm (film size) cameras particularly in photo-reportage because the photographer wants to feel more closely involved with the subject.

At the other end of the scale, extreme telephoto lenses have been largely replaced by *cadiotropic* (mirror) lenses that are considerably lighter (as well as cheaper) and have a greater light transmitting power. The medium- to long-focus lens is often replaced by a variable-focus (zoom) lens, which since the mid-1960s has been capable of producing the necessary definition at all parts of the zoom. Many of these zoom lens designs were developed from cine film and television camera designs where they are very much more common.

High-speed photography gives an unfamiliar picture of ordinary events. This photograph, taken at 1,000th of a second, shows a drop of milk at the moment of impact. *Picturepoint*

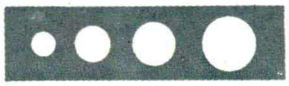


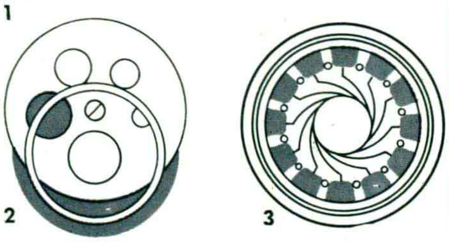
LENS



Diagrams showing the three conventional lens assemblies from which modern lenses are derived. 1 and 2) 'Cooke Triplet', made by Taylor and Hobson, and 'Tessar', by Zeiss (asymmetrical); 3) 'Dagor', by Goerz (symmetrical).

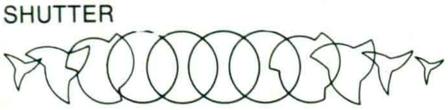
DIAPHRAGM

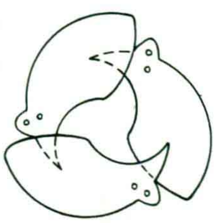




Types of diaphragm. 1) A series of fixed diaphragms on a sliding strip; 2) the same apertures arranged on a rotating disc; 3) the standard type of variable iris diaphragm, now universally used.

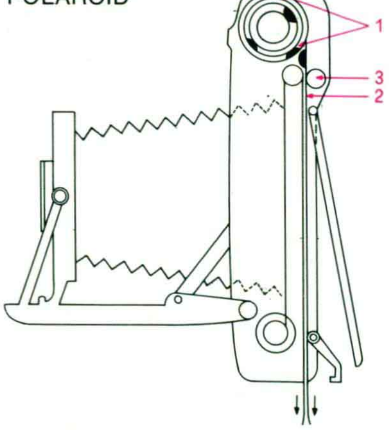
SHUTTER



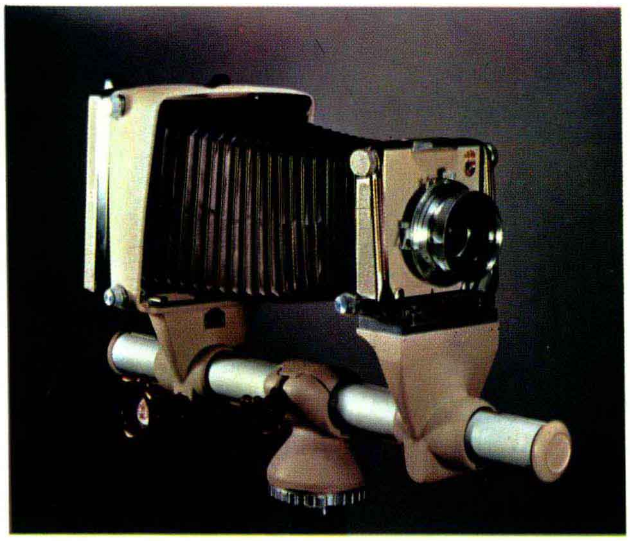


Above and left: Diagram showing the opening and closing of the elements of a central 'blade' shutter.

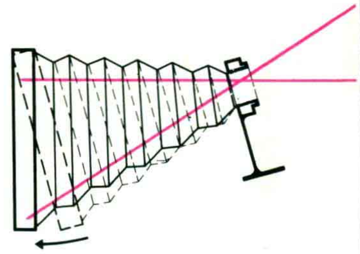
POLAROID

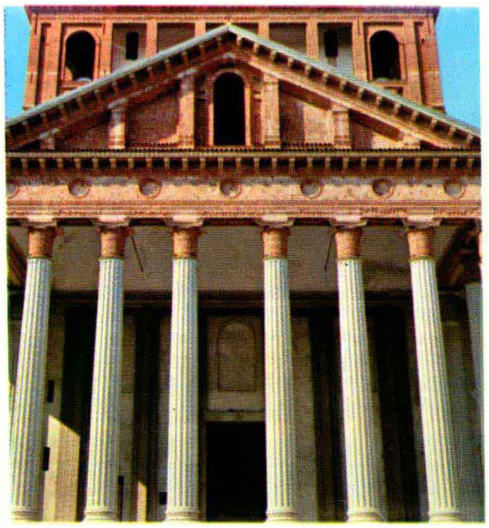


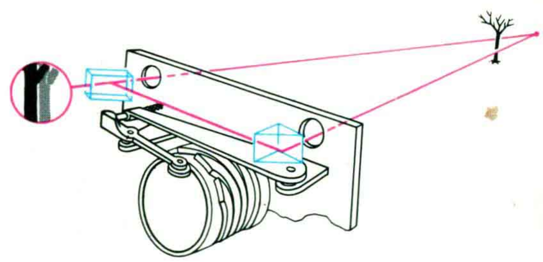
The 'Polaroid-Land' process, which produces positive pictures in a few seconds, incorporates a self-developing gelatine pellet (1), which is spread over the film by the rollers (3), and makes the positive print (2) by contact with the negative image. In this way the conventional developing and printing processes are eliminated.



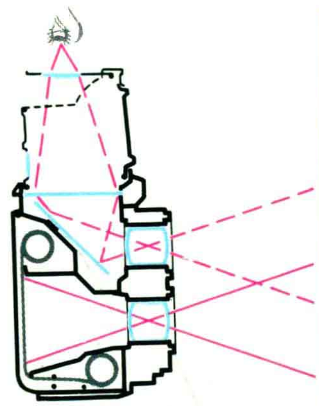
Left: A monorail camera (Linhaf) which can correct for distorted perspective. By means of swings and tilts about the lens and film planes, effects such as the converging of verticals when looking at a building from above or below can be controlled or eliminated. *Below left:* Photograph taken without corrections to alter 'false' perspective. *Right:* Correction by altering the lens axis. The diagram shows the tilt used for such a photograph.

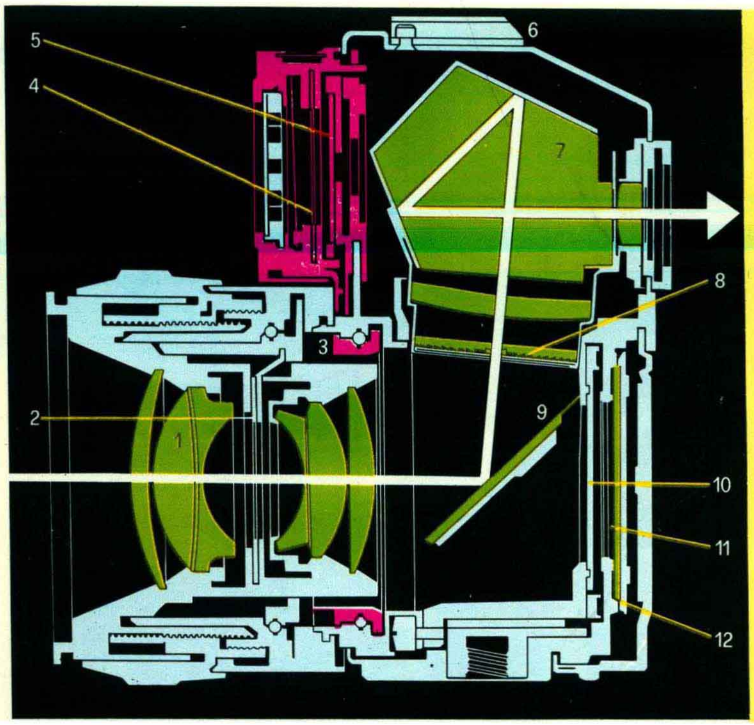






Above: The most famous of the miniature cameras (the 'Leica'), which uses film with an image area of 24×36 mm on film 35 mm wide. The camera has a focal-plane shutter with speeds up to 1,000th of a second. The diagram shows the rangefinder, which is coupled with the lens. The camera is focused by rotation of the lens barrel. *Right:* A twin-lens reflex camera ('Rolleiflex'). The lower lens projects the image on the film, while the upper lens projects the same image on a ground-glass screen (view-finder). The image is correctly focused by an adjustment of a front panel, which moves both lenses backwards or forwards simultaneously.





SECTION THROUGH A REFLEX CAMERA

The diagram shows a single-lens reflex camera with automatic exposure control, where the subject is viewed directly through the lens.

1) lens (Planar)
2) diaphragm
3) control ring
4) automatic exposure device
5) light-sensitive cell
6) accessory for flash lamp attachment
7) double prism for correct viewing
8) Fresnel screen
9) hinged instant return mirror
10) focal-plane shutter
11) film
12) pressure pad to keep film flat

Confusion sometimes arises between photomicrography and microphotography. These are in fact completely different. Photomicrography is a specialized technique used extensively in scientific work; it is the photography of very small objects combining a camera and a microscope, and with special lighting and focusing. Microphotography is the making of very small prints from normal negatives, using emulsions of very high resolving power.

The cost of lenses has been one factor in the increasing dominance of the 35 mm camera, but because of the respect in which photo-journalists are held their example has also been widely followed. The photo-journalist today works almost exclusively with colour film, much slower than black and white. He will be working often in poor light conditions so needs all the lens speed he can get, only readily available with 35 mm cameras. He may also have problems of focusing accurately at times of rapid activity so the extra depth of field provided by a wide-angle lens is especially welcome. The depth of field on the normal lens (50-55 mm) of a 35 mm camera is greater than a wide angle (65 mm) on a $2\frac{1}{4}$ inch square one. It is for these reasons that the last 20 years have seen a fundamental reappraisal of camera technique and a new aesthetic in photography.

The demand for colour film for the amateur market, using as it does many thousand times the amount used by professionals, has caused a tremendous improvement in colour film and a reduction in price. A colour transparency costs less today than a black and white print, and since the colour image is provided by stained gelatine rather than silver grains, grain is not really a problem. Professional users of 35 mm film frequently make black and white prints when required from colour transparencies sometimes direct on to panchromatic reversal paper but usually via an internegative.

Filters. The influence of the photo-journalist can also be seen in the decreasing use of corrective filters. Old text books are full of details of how yellow or green filters can be used to 'correct' the tonal rendering of black and white film. Today the tendency is to ignore filters partly because of improved emulsions, but largely because the 'distorted' photographic tones are more realistic in the photo-journalist's eyes. The scientific and portrait photographer will still use them as required, but in general there is a move to a more specifically photographic vision. The same applies in colour with colour correction filters used mostly in advertising and technical photography.

***The Redwood Trunk* by American west coast photographer Wynn Bullock. The photographer has used the clarity and detail available with modern film and equipment to gain the striking effect of this picture.**

photometry

The branch of optics that deals with the measurement of the amount of light emitted by a source or received on a surface. The quantity of interest is normally the amount of light *as judged by the eye,* rather than the quantity of energy, or the magnitude of the effect detected by some instrument. It follows that all photometric measurements must depend, directly or indirectly, upon a visual comparison. In this respect photometry differs from most other branches of physics, in which the greatest quantitative judgement normally called for by the eye is the judgement of the coincidence of the pointer of an instrument with a particular mark on a scale, or of something equivalent to this (e.g. coincidence of mercury meniscus, or of optical interference fringe, with a mark on a scale).

The fundamental difficulty in designing instruments to measure quantities of light is the fact that the eye has very different sensitivities to different colours. This means that two sources of different colour but of the same power have different effects on the eye as regards their illuminating property, quite apart from their colour. It is impossible to carry out measurements with anything but monochromatic sources until some means of dealing with this difficulty has been found. Fortunately, if two lights, or two illuminated surfaces, are exposed to the eye alternately at a gradually increasing frequency, the flicker due to any colour difference disappears at a substantially lower frequency than does the flicker due to any difference in brightness. By arranging the 'flicker frequency' to lie between these two values, it is therefore possible by direct visual comparison to adjust the sources to be of equal brightness, as judged by the eye, irrespective of any colour difference that may exist between the sources. It is therefore possible to build up a table of 'relative luminous efficiencies' for the different wave-lengths of the visible spectrum. These give the relative effects on the eye for a given intrinsic power, the values being taken relative to that for which the luminous efficiency is greatest, to which is assigned the value unity. Once a table of this sort has been agreed upon, it is possible to calibrate any photometric instruments to give readings of the light radiation as it would appear to the eye, on condition that the spectral composition of the particular source is known (and this can also be determined directly by an instrument).

A number of units are employed in photometry.