A type: velar (guttural) + vowel + u(w)

	Indo-European	Hebrew	Arch. Chinese	Polynesian	Turkish	Greenlandic
(1)	*ĝheu* = to pour (Gr. χέω)	*qw-a* = to spew out	*giw-an* = to flow		*gev-ış* = chewing the cud	*kîv-â* = presses together
(2)	*geu* = to bend (Gr. γυρος, 'round')	*qw-ph* = to go round	*giw-o* = to bend	*kuw-ha* = the thigh	*kav* = cave, vault	*qiv-erpoq* = bends
(3)	*sqeu* = to cover (Lat. ob-scū-rus)	*ehw-m* = to be black (covered)	*g'w-âd* = lid, cover		*ḳav-ram* = embracing	
(4)	*qău* = to cut (Engl. to hew)	*gw-b* = to cut	*kiw-at* = cut off	*haw-a* = chipped	*cav-lak* = peeled off	*kiv-dlorpâ* = cuts off its length

B type: velar (gutt.) + vowel + b (bh, p, ph)

	Indo-European	Hebrew	Arch. Chinese	Polynesian	Turkish	Greenlandic
(1)	*qap* = to grasp (Lat. cap-io)	*gb-a* = to gather together	*g'iap* = to grasp, hold	*hop-u* = to catch, seize	*kap-ış* = seizing, snatching	*qâp-oq* = sticks in something
(2)	*qamp* = to bend (Gr. καμπή, 'bending')	*gb-b* = to be curved	*kap* = cyclical character	*hap-a* = crooked	*kuf-a* = round boat	*qûp-ôq* = keg, jar (the curved form)
(3)	*(s)qep* = to cover (Gr. σκέπας)	*kp-r* = to cover	*g'âp* = to cover	*kap-i* = to be covered	*kab-alak* = head-cover	*qáp-ivoq* = disappears below the water, the sea closes over it
(4)	*ĝeb(h)* = branch (cut-off) (Icel. kaf-li)	*hb-r* = to cut	*xiăp* = to break ?			*qap-erpâ* = cuts it with a pair of scissors

C type: velar (gutt.) + vowel + m

	Indo-European	Hebrew	Arch. Chinese	Polynesian	Turkish	Greenlandic
(1)	*gem* = to press together (Ags. cum-ul, 'swelling of glands')	*ehm-ṣ* = to oppress	*g'iam* = to pinch	*ham-a* = to be consumed	*gem* = bit (of a bridle)	*qim-ɫpâ* = strangles him
(2)	*qam* = to bend (Lat. cam-ur, 'vaulted')	*qm-š* = to be curved	*kiəm* = collar, sash, string	*ham-u* = the back of the skull	*ham-ut* = collar, yoke	*qim-eriaq* = eyelash (the curved)
(3)	*k̂em* = to cover (German hem-d)	*hm-r* = to cover with bitumen	*g'iəm* = black (covered ?)			
(4)		*qm-d* = to cut off				*qum-arpoq* = becomes shorter

velar (guttural) sound + vowel + labial, of the type *geb*, *gem*, *geu* in six 'unrelated' families of languages, namely, Indo-European, Hebrew, Archaic Chinese, Polynesian, Greenlandic and Turkish. The meanings attached to this type of word-forming are very clearly seen in all these languages and it will be clear that differences between the velars (*g*, *gh*, *k*, *kh*, *q*, etc.) or labials (*b*, *bh*, *p*, *ph*, etc.) are of insignificant importance. Instead of the type *geb* we can have *gheb*, *keb*, *qeb*, *ghabh*, *kap*, etc.

It must be remembered that in unconsciously imitating shapes and gestures, the tongue and lips frequently work together, so that, for example, a movement commenced by the tongue may be completed by a lip movement. Thus, in producing the sounds *geb*, *gem*, *geu(w)*, etc., we move the backward portion of the tongue forward towards the lips so that the gesture as a whole represents a curved movement. In producing the sounds *geu(w)*, we finish the movement by rounding the lips; in producing the sounds *gem* we finish the movement by closing the lips; and in producing the sounds *geb* (*gebh*, *gep*, etc.) we finish the movement by only partially closing the lips or by closing them and opening again. It is therefore very natural that words made or derived from these roots designate: (1) to eat, hold in the mouth, to grasp, to contain, to close, to press together, to complete, to finish; (2) curved, vaulted, round, to swell, etc. The comparison of the whole material in the six families shows that the following meanings have developed: (3) to cover, hide, etc.; (4) to cut. Examples are given in the accompanying table.

Of 85 Indo-European roots belonging to the three types (*geu*, *gem*, *geb*, etc.), 63 show one or the other of the postulated meanings. Of 144 words in Hebrew, 92 (or 63 per cent) give the same result. In Archaic Chinese 90 roots of 107 in one way or another show similar meanings (or about 84 per cent). In Polynesian I have collected fifty examples, which are all in accordance with the postulated meanings. In Turkish I have collected (assisted by a Turkish linguist, Cemal Enisoğlu, in Trabzon) 72 roots (the overwhelming majority of the Turkish roots of this type). The total number of these roots in Greenlandic is 101; of these 68 (or 67 per cent) are in accordance with the results obtained in the other languages. The dispersion of the four variations of meanings in the six languages is very unequal, as will be seen in the following summary:

Indo-European	Hebrew	Arch. Chinese	Polynesian	Turkish	Greenlandic
(1) 15 roots	31	27	13	13	21
(2) 30	42	63	32	49	25
(3) 5	10	11	3	9	5
(4) 8	12	13	2	1	17

This shows very clearly that the two most natural meanings of these sounds, produced by moving the jaws from behind forwards to the lips, are contained in the first two groups. Besides the meaning to eat, hold in the mouth, grasp, contain, close, etc., the meaning curved, vaulted, round, etc., has developed and, probably later, to cover, hide and cut. In the roots of every language we see more or less the 'fossils' of human speech, and it will be possible, by comparing the various sound-groups of the languages of the world, to reconstruct the main characteristics of human speech in its genesis.

[1] *Nature*, **153**, 171 (1944); **154**, 466 (1944); **157**, 847 (1946); **162**, 902 (1948).

SPECTROSCOPIC BINARIES

GEORGE DARWIN LECTURE

PROF. OTTO STRUVE, chairman of the Department of Astronomy, University of Chicago, and director of the Yerkes and McDonald Observatories, was awarded the Gold Medal of the Royal Astronomical Society in 1944; but owing to war conditions he was unable at the time to be present to receive it and to deliver the George Darwin Lecture. On October 14, 1949, Prof. Struve gave the Lecture to the Royal Astronomical Society at Burlington House, taking for his subject "Spectroscopic Binaries". His address has already been published in full (*Mon. Not. Roy. Astro. Soc.*, 109, 5; 1949) and also in a slightly abbreviated form in *The Observatory* (69, 853; Dec. 1949).

Special attention is given by Prof. Struve to the well-known eclipsing variable *U* Cephei, which has been investigated by some of the best-known photometric workers. The light curve supplies an accurate determination only of $e \cos \omega$, where e is the eccentricity of the orbit and ω the longitude of periastron, and each of these can be determined separately only when $e \sin \omega$ is also known. In 1930 E. F. Carpenter at the Lick Observatory, California, found by means of a spectrographic study an unsymmetrical velocity-curve from which he deduced that e is 0·47 and ω 25°, which implies that $e \cos \omega$ is 0·43. This would mean that the secondary eclipse could not be half-way between two primary eclipses, but should occur about twelve hours later than had been observed with the photometer. As an error of only a few minutes can occur in the secondary eclipse, it was impossible to explain the discrepancy on the assumption of ordinary Keplerian motion.

In 1943 Struve obtained a new velocity-curve of the binary at the McDonald Observatory; the star, the light of which was observed, except for a few hours, at total eclipse, was of spectral type *B*8 or *B*9, and an unsymmetrical curve resembled that obtained by Carpenter, but some aspects of the curve proved puzzling. Among these may be noticed the tendency of the measures to fall systematically above the computed curve between phases 0·8 day and 1·6 days, but between 1·6 days and 1·9 days many points fell below the computed curve. During the past few years there has been confirmation of the view that many close binaries are enveloped in streams of gas which revolve like whirlpools around and inside the system, so that the components do not obey the laws of the two-body motion. When the amount of gas projected in front of the photosphere of the bright binary component is large, the great streams of gas produce absorption lines. Emission lines are produced when large masses of gas, excited by the *B*-type component to emit the Balmer lines of hydrogen, are projected upon the black background of the sky. Certain important conclusions follow from these new ideas.

It may be assumed that the velocity-curve of *U* Cephei is symmetrical, and by a few adjustments the maximum of the true-velocity curve falls approximately at phase 1·83 days, corresponding to a radial velocity of about −80 km./sec. A sketch of this curve in Fig. 2 of the Lecture shows, however, that it is much better represented at phase 0·2–1·8 days; but that after this the observed points are mostly positive—facts which seem to contradict the proposed hypothesis. The objection is not, however, valid, because the hydrogen lines are known to have strong and fairly sharp violet-displaced cores in absorption just before and after first contact, and it is suspected that, near the observed maximum of the velocity-curve, cores were displaced towards the red side of the broad wings of the *H*-line. These displaced cores almost certainly distort the velocity-curve in the sense of raising the measured velocities between phases 1·8 and 2·2 days and depressing them after 2·2 days, a view which is supported by other evidence. The case of *U* Cephei is not unique, and in a number of other systems the same phenomena are in evidence. It seems that in all, or nearly all, eclipsing variables the periods of which are approximately 2–5 days, and also in a number of other systems of longer period, gaseous streams produce blended absorption lines which distort the velocity curve primarily at phases 0·8–1·0, and to a smaller extent at 1·0–0·2, of the period. In addition, the evidence suggests that the motion of the stream is not entirely due to a single mass of gas.

There is no certainty that gravitational forces alone are active, for electric and magnetic forces may also play an important part; and a model which meets the observations is proposed; but no attempt is made to justify it theoretically. On the assumption that the flow occurs mostly between two successive equipotential curves in the XY-plane, then

$$(1 - \mu)/r_1 + \mu/r_2 + \tfrac{1}{2}(x^2 + y^2) = \tfrac{1}{2} C,$$

where $\mu = m_2/(m_1 + m_2)$, $1 - \mu$ and μ are the forces producing the equipotential curves, and r_1 and r_2 are the distances of the centres of force from the point under consideration. On the assumption that the motion is uniform, or nearly so, between the two inner curves shown in Fig. 12 of the Lecture, then at all phases between $0{\cdot}15\,P$ and $0{\cdot}85\,P$ the line of sight would project upon the disk of the small *B*-star different sections of a formation which is nearly circular in the XY-plane, and hence shows no radial component of velocity between the stream and the centre of the *B*-star. If the gases were excited to emit *H*-lines, double bright lines could be observed, as actually happens in *RW* Tauri, *SX* Cassiopeiæ, *RX* Cassiopeiæ, *RZ* Ophiuchi, etc. Although the proposed model is consistent with a number of observational data which are referred to in the Lecture, a theoretical explanation of the model is very difficult, and it will suffice to sum up some of the conclusions to which Struve has been led.

All close binaries possess the common gaseous envelope referred to, and, as they cannot be dynamically stable, they probably play an important part in the evolution of binaries. The envelopes are ring-like and flow round the system with velocities of several hundred km./sec.; but from the dilution effect it is estimated that their extent is not larger than two or three times the diameter of the brighter star. The thickness of the ring is greater in the direction of motion of each star, and a range in the velocity of expansion of the ring appears to lie between 0 and 100 km./sec., though accurate measurement is difficult. In the system *UX* Monocerotis and also in several Wolf-Rayet binaries, violent motions away from the *G*-type subgiant component are considered to afford evidence of prominence activity. In the former system they seem to be concentrated in one hemisphere, and produce a gradual diminution of the star and probably in its angular momentum as well.

In the case of β Lyræ, where the *G*-component is small in size, the absorption effects of the stream can be observed with great clarity, and these yield the satellite lines discovered by Baxandall. There is a general tendency among spectroscopic binaries with periods of 2–5 days to give distorted velocity-curves simulating large eccentricities and values of ω in the vicinity of 40°, and statistical discussions by Miss Scott and others have shown that a large number of eccentricities of spectroscopic binaries must be spurious. Where the distortion of the velocity curve can be directly measured, a mass of gas is seen projected in front of the receding *A*-type star, beginning soon after the maximum radial velocity of the latter and preceding the beginning of the partial eclipse. It is very pronounced in *U* Cephei, but is only slightly indicated in *U* Sagittæ. An approximate picture of the flow of gas within the envelope, using the data from several stars, indicates roughly a Jacobian equipotential curve in the XY-plane. The amount of matter in a typical ring, on a rough estimate, is 10^{-8} times the mass of the brighter component. Assuming that the average tendency to expansion is less than 1 km./sec., most of the mass of the binary would be exhausted in 10^8 years. If angular momentum were lost with this mass, as seems probable, a system of the type of *U* Sagittæ or even of Plaskett's star could gradually evolve until it became a typical *W* Ursæ Majoris binary. If the evolutionary trend continued in the direction of bringing the two components together, some mechanism must exist to take care of the excess angular momentum; and here an interesting view is propounded: one possibility might be the transformation of a *W* Ursæ Majoris system into a slowly rotating red dwarf and a group of attending planets which absorb the greater portion of the angular momentum of the binary in their orbits.

DEVELOPMENTS IN THE HEAT TREATMENT OF MILK

THE Society of Dairy Technology, at its meeting at the Conway Hall, London, on April 21, discussed developments in the heat treatment of milk.

Mr. A. Rowlands dealt with the bacteriological aspects. He said that heat treatment is now accepted as an essential process in the handling of liquid milk and in the manufacture of most dairy products. Because of its relatively high resistance to heat, complete destruction of the tubercle bacillus is the accepted criterion of satisfactory heat treatment. There is abundant evidence of the large margin of safety provided by treatment of milk at 145–150° F. (62·8–65·6° C.) for thirty minutes as required in Great Britain for holder pasteurization. Nor is there any doubt about the safety of milk treated in commercial plants at 161° F. (71·7° C.) for fifteen seconds as required in the high-temperature short-time process: the holding time in commercial plants is, in general, appreciably longer than fifteen seconds. There is, however, need for a laboratory apparatus in which the time of heating and cooling is minimal and in which the time of holding can be controlled positively. Such an apparatus is necessary to obtain more exact information about the time–temperature combination required to destroy tubercle bacilli and other pathogens and non-pathogens in the higher temperature range.

Commercially, the improvement in the keeping quality of milk resulting from heat treatment is extremely important, and Mr. Rowlands said it is difficult to see how the community could be supplied with milk possessing an adequate keeping quality without heat treatment. Raw milk sometimes contains large numbers of thermoduric bacteria derived mainly from unsterile utensils used on farms, but, fortunately, these types have only a slight effect on the keeping quality of the pasteurized milk stored at normal household temperatures. At these temperatures spoilage is generally the result of contamination of milk after pasteurization from the surfaces of coolers, pipe-lines, storage tanks, bottle-fillers and bottles. Pasteurization, coupled with efficient cleaning and sterilization of all plant to prevent subsequent re-contamination, ensures a keeping quality adequate to satisfy consumer requirements. Nevertheless, the thermoduric bacteria derived from the raw milk sometimes make it difficult to comply with colony count standards which might be applied to the bottled milk. These thermoduric bacteria are for the most part slow dye-reducers and are unlikely to account for failure to comply with the half-hour methylene-blue test standard now in use officially for the examination of pasteurized milk in England and Wales.

Pasteurization does not destroy spores, and there is evidence that some spore formers cause stimulation of acid production by the lactic acid streptococci. Spore-forming aerobes are also associated with the fault 'broken' or 'bitty' cream; this fault is readily apparent in tea or coffee in the form of large particles of curdled cream floating on the surface. Research in progress at Shinfield has shown that the fault is caused by *Bacillus cereus* and *mycoides*; both produce an enzyme (lecithinase), and broken cream is thought to be associated with the action of this enzyme on the lecithin fraction of the fat-globule surface membrane.

Thermophiles, which were at one time a serious problem with the holder process of pasteurization, cause little trouble with the high-temperature short-time process. Temperatures used with the latter are above the optimum for the growth of thermophiles. Recently it has been found that thermophiles are sometimes concerned in the spoilage of sterilized milk. Thermophiles, the spores of which possess unusual resistance to heat, survive the commercial sterilization process and later proliferate at a stage during the slow cooling of the stacked bottles.

Dr. R. Seligman dealt with the history of pasteurization from the engineer's point of view. He divided the time which has elapsed since Pasteur's day into two periods, the first ending in 1922. During this period little attention was given by British engineers to the design and development of equipment for the heat treatment of milk, and Great Britain was obliged to depend largely on imported equipment. In contrast, during the second period most of the equipment developed and now in general use throughout the world had its origin in patents first granted to British engineers.

A German patent granted to Fesca in 1881 marked the first real contribution of the engineer in the field of heat treatment of milk. This was a continuous heater, and later, as the Danish or rotary pasteurizer, it was used extensively for many years in Europe and America. Internal tubular heaters, either with the tubes permanently fixed in position or with the inner tube detachable to facilitate cleaning, were developed early in the present century. Heaters of the latter type were used for regenerative heating, as were also surface heaters or coolers of the Baudelot type.

For low-temperature pasteurization, batch pasteurizers of the coil-vat or spray-vat type were in widespread use during the early years of the present century. Owing to the protracted period of heating and cooling, these possessed many disadvantages and were entirely unsuitable for dealing with large quantities of milk. Flow-retarding tanks in which the milk flowed continuously through a number of tanks in series were introduced by Heulings in 1895. Later, the so-called 'absolute' holders with independent heaters and coolers gained some prominence. Patents granted to a British engineer, Tarbet, in November 1922 marked a major advance in the process of holder pasteurization, for he was the first