When H is on the tangent at B or B′, the curve described by points on the axis have cusps; when H lies between these points, the curves are looped, and the associated herpolhode has points of inflexion.

In steady precessional motion $\kappa=0$, and the focal ellipse coalesces with the line SS′; now $f=0$ and $K=\frac{1}{2}\pi$, so that the apsidal angle

(20) $$\Psi=\frac{HS}{OS}\tfrac{1}{2}\pi.$$

If μ denotes the constant angular velocity of precession,

$$\mu T=\Psi,\ mT=\frac{OD}{OS}\tfrac{1}{2}\pi,$$

so that

(21) $$\frac{\mu}{m}=\frac{HS}{OD}.$$

The steady motion relations

(22) $$P=N\mu-A\mu^2\cos\alpha,\ n=A\mu\sin^2\alpha+N\cos\alpha,$$

when α denotes, instead of θ_3, the constant inclination of the axis to the vertical, will be found, on eliminating μ, to be equivalent to the geometrical relation

(23) $$OQ\,.\,OQ'=\tfrac{1}{4}OD^2\sin^2\alpha,$$

so that O lies on a certain hyperbola, $xy=\frac{1}{4}OD^2$, referred to HQ, HQ′ the asymptotes as axes; thus given N and α, a geometrical construction will determine the solution of the problem.

Having selected OD arbitrarily, the hyperbola is drawn, and then having laid off HQ′ to scale, draw Q′O at right angles to the asymptote HQ′ to meet the hyperbola in O; the tangent to the hyperbola at O will meet the asymptotes in S and S′.

The second solution will depend on the second point O′ in which Q′O cuts the hyperbola. To realise the state of motion shown in Fig. 28, the point O on the hyperbola must be close to the asymptote.

It is very desirable that a penultimate case of this nature should be worked out completely. We have the requisite analysis for the calculation of the algebraical case when there are 22 cusps, but the work would require the arithmetical courage of a Dewar, now unfortunately no longer available.

Supposing that in consequence of the friction of the pivot the motion has steadied down to uniform precession, then a (following / heading) tap on the spindle, to (hurry / delay) the precession makes O move along OQ and produces a focal (ellipse / hyperbola) and the axis (rises / falls).

A tap in the vertical plane makes O start out normally to the plane, and the lines HQ, HQ′ are now generating lines of Darboux's hyperboloid, in an intermediate position.

Once the limits θ_2 and θ_3 are assigned, and the corresponding apsidal angle Ψ, a regular curve satisfying these conditions drawn empirically will give an idea of the complete curve described by the axis.

But if it is desired to plot a number of intermediate points from tabular matter of the elliptic functions, we are baffled by the mixture of the real and imaginary arguments of the theta-functions required in the calculation of ψ and ϕ, although θ is readily calculated by equation (17). A courageous attempt at this computation is made in IV. 8, by Herr Blumenthal, but the hidden rocks of error are numerous and plentiful enough to make this procedure dangerous. If the calculation of a number of guiding points between the extreme points of a branch of the spherical curve is required, we had better utilise Jacobi's theorem, that the curve described in a horizontal plane round the vertical OG by the extremity of the vector OH of resultant angular momentum is a Poinsot herpolhode; and having plotted this herpolhode, the vertical plane defined by ψ may be drawn perpendicular to the tangent HK of the herpolhode, while a simple relation of the form

(24) $$\cos\theta+2\frac{OH^2}{OD^2}=\frac{k}{2AP}=\text{ch}\,\theta_1+\cos\theta_2+\cos\theta_3,$$

will give the corresponding value of θ, and hence the spherical curve, or its projection, orthographic or stereographic, can be plotted to any desired accuracy.

This theorem of Jacobi is almost self-evident when interpreted by means of Darboux's representation of the motion by the deformable articulated hyperboloid.

In this method the rod OG is held in the vertical position, and the point H is guided round the herpolhode; and then OG, connected by the articulation, will imitate the movement of the axis of the top; for a quadric surface can be drawn through H coaxial with the articulated hyperboloid, and normal to HP at H, and the squares of the semi-axes of this quadric will be, by a well-known theorem of solid geometry

(25) $$HQ\,.\,HV,\ HQ\,.\,HT,\ HQ\,.\,HP,$$

with proper attention to sign; and these being fixed lengths, the quadric is a fixed quadric.

Its equation may be written

(26) $$Ax^2+By^2+Cz^2=D\delta^2,$$

with

(27) $$\delta=HQ;\quad \frac{D}{A}=\frac{HV}{HQ},\ \frac{D}{B}=\frac{HT}{HQ},\ \frac{D}{C}=\frac{HP}{HQ}(\pm),$$

the $\pm$ sign being taken according as Q and V, T, P are on the (same / opposite) sides of H.

An accent will serve to distinguish the case where a fixed quadric rolls on the plane through H perpendicular to HP; and now we see why the same polhode described by H with respect to the axis of the articulated hyperboloid has associated with it two distinct herpolhodes.

(*To be continued.*)

LIFE-HISTORY OF THE PARASITES OF MALARIA.

THE parasites which cause malarial fevers in human beings belong to a very homogeneous group, other species of which are found in certain bats and birds. The life-history of the three species of this group which have been completely studied is as follows. The youngest parasites exist as amœbulæ or myxopods within the red blood corpuscles of the vertebrate host. Each amœbula possesses a nucleus and nucleolus; and its movements vary in extent and rapidity with the species, but, in the case of birds, never encroach upon the nucleus of the corpuscle. The amœbulæ increase in size; and, as they do so, tend to lose their movements and to accumulate in their ectoplasm certain black granules, the pigment or melanin, which are the product of assimilation of the hæmoglobin of the corpuscle. In from one to several days the parasites reach their highest development within the vertebrate host, and become either (*a*) sporocytes or (*b*) gametocytes.

The sporocytes, which are produced asexually, contain spores which vary in number according to the species. The spores do not possess any appreciable cell-wall. When they are mature the corpuscle which contains them bursts and allows them to fall into the serum. They then attach themselves to fresh blood corpuscles, and continue the propagation of the parasites indefinitely in the vertebrate host. The residuum of the sporocyte, consisting chiefly of the pigment, is taken up by the phagocytes of the host for eventual disposal in the host.

The gametocytes, while in the blood of the vertebrate host, are still contained in the shell of the corpuscle.

In some species their general form and appearance is very like that of the sporocytes before the spores are differentiated; in another, however, they possess a special crescentic form. They continue to circulate in the blood for some days, or even weeks (according to the species), without change; but when they are drawn into the alimentary canal of certain suctorial insects, they undergo further development. In a few minutes after finding themselves in their new position, they break from the enclosing corpuscle by a kind of expansion, swell up slightly, and then commence their sexual functions. The male gametocytes emit a variable number of microgametes, which escape into the serum of the ingested blood, leaving behind a residuum consisting chiefly of pigment—as in the case of the sporocytes. The individual microgametes are delicate but very active filaments, consisting chiefly of chromatin, and sometimes seen to have a slight swelling at one point of their length—in the middle, when free, according to my observations. After escape from the male gametocyte, the microgametes seek the female gametocytes, which consist each of a single motionless macrogamete. One microgamete now enters bodily into a macrogamete and fertilises it, producing a zygote.

The further history of the zygote has been traced, as regards three species of this group of parasites, in certain kinds of mosquitoes. After being fertilised, it acquires the power of escaping the phagocytes of the ingested blood which surround it, of working its way through the mass of blood, of passing through the thickness of the stomach (middle intestine) of the mosquito, and of affixing itself to the outer surface of the organ. Here the zygotes are first found as oval cells about 8-10 μ in diameter. They still contain the granules of pigment which the macrogametes possessed before fertilisation. Growing rapidly, they soon acquire a capsule, and begin to protrude into the body-cavity of the mosquito. From an early period the nucleus divides into a number of portions—zygotomeres—each containing a fragment of chromatin. As growth advances, the zygotomeres become spherical blastophores, bearing each a large number of delicate, filamentous zygotoblasts on their external surface—each zygotoblast being affixed to the surface of the blastophore by one extremity. As maturity is approached the zygote, though still attached to the outer wall of the insect's stomach, protrudes freely into the body-cavity; its pigment tends to disappear; and lastly, the blastophores disappear, leaving the capsule packed with thousands of zygotoblasts. Maturity is reached in from one to three weeks, according to the external temperature, when the zygote reaches a size of 60 μ or more. The capsule then ruptures, pouring the zygotoblasts into the insect's blood.

The zygotoblasts are now seen to be delicate flagellulæ or mastigopods, about 12-16 μ in length, with the chromatin and one or two unstained areas in the middle, and two opposite tapering flagella. I have not, however, observed any notable movement in them, probably on account of the necessary dissecting medium. After being discharged into the insect's blood, these bodies are carried away by the current into all parts of the tissues, and finally effect an entry into the large grape-like cells of the salivary gland—especially the cells of the short middle lobe—where they accumulate in very large numbers. From the cells of this gland they pass into the duct which runs to the extremity of the middle stylet, the lingula, and thence escape during haustellation into the blood of a new vertebrate host. Here, it must be supposed, the flagellulæ attack the corpuscles and become the intra-corpuscular amœbulæ with which we started.

Four points require notice. (1) There are reasons for supposing that the gametocytes are or may be produced by the conjugation of two or more amœbulæ in one corpuscle. (2) The gametocytes of several species show, after escape from the corpuscle, one or more minute spherical bodies attached to their margin; which I assume to represent polar bodies. (3) The young zygote of at least one species (of crows) possesses, shortly after fertilisation, somewhat active powers of locomotion. (4) The mature zygotes of at least two species often contain large, brown, thick-shelled, cylindrical bodies, the nature of which has not yet been elucidated, and which may be parasitic fungi of the mosquito.

A brief history of how these facts came to be ascertained may be of interest. Laveran discovered the human parasites in 1880; and Danilewsky those of birds, some years later. Golgi established the law of endogenous reproduction by means of spores in 1885; and noted the differences in the various human species. Later, several Italian writers observed the distinction between the sporocytes and the gametocytes, but failed to understand the nature and object of these latter forms. The escape of the microgametes can be witnessed *in vitro*; and a dispute now arose as to the meaning of these bodies. Antolisei, Grassi, Bignami, Labbé and others held that they are products of death and degeneration *in vitro*. On the other hand, Laveran, Danilewsky and Mannaberg supposed them to represent the highest development of the organisms, while the last writer thought that they were meant for an exogenous saprophytic existence—without, however, suggesting the mode of their escape. In 1894 Manson concluded that the gametocytes are intended to continue the species outside the vertebrate host; and that they escape into the stomach of a suctorial insect, and then give rise to flagellulæ—as he considered the microgametes to be—which in turn develop in the tissues of the insect. He founded these views chiefly on the fact that the microgametes escape from the gametocyte only after abstraction of the blood from the vertebrate host. Laveran had already surmised that the mosquito is the alternative host of the human parasites; and Manson now claimed the mosquito as the suctorial insect referred to.

Early in 1895 I attacked the subject experimentally in India, on the lines laid down by Manson. Owing to the difficulty of the investigation and to the use of wrong species of mosquitoes, I failed for more than two years in reaching positive results. In August 1897, however, on employing two species of Anopheles fed on patients containing the crescentic gametocytes, I found the zygotes in various stages of growth attached to the wall of the insect's stomach. My work was now interrupted; but next year I succeeded in following out the life-history of the zygotes of one of the parasites of birds in their development in *Culex pipiens*. The zygotoblasts were found in the salivary glands of the mosquitoes; and lastly, in July 1898, I succeeded in infecting a large number of healthy birds by the bites of infected insects.

Meanwhile (1898) MacCallum had discovered the true nature of the microgametes by actually witnessing the sexual act *in vitro*, while Metchnikoff, and Simond had found microgamates also in *Coccidium oviforme* and *C. salimandrae*; so that the exact relationship between the gametocytes in the blood of the vertebrate (intermediary) hosts and the zygotes found by me in the mosquitoes (definitive hosts) became quite evident.

My results were published by Manson in August 1898, and were confirmed by Daniels, of the Malaria Commission of the Royal Society, in December. It was now easy to extend my observations to other species of the group, a work, however, which I was unable to undertake. In November and December 1898, Grassi, Bignami and Bastianelli cultivated two of the human parasites in a third species of Anopheles, *A. claviger*, Fabr., and succeeded in infecting several healthy persons. Shortly afterwards Koch confirmed the principal observations which had been made.

If we can exterminate the malaria-bearing species of mosquito in a locality, we may expect to prevent the propagation of the parasites there; I trust, therefore, that these investigations will not remain without practical results.

It may be useful to add a note regarding the somewhat confused matter of the classification and nomenclature of the various species. I divide those of men and birds into two genera, named as follows:—

Family: HÆMAMŒBIDÆ, Wasielewski.

Genus I. *Haemamoeba*, Grassi and Feletti. *The mature gametocytes are similar in form to the mature sporocytes before the spores have been differentiated.*

Species 1: *Haemamoeba Danilewskii*, Grassi and Feletti. Syn.: *Laverania Danilewskii*, Grassi and Feletti, in part; *Halteridium Danilewskii*, Labbé; &c. Several varieties—possibly distinct species. Parasite of pigeons, jays, crows, &c.

Species 2: *Haemamoeba relicta*, Grassi and Feletti. Syn.: *Haemamoeba relicta* + *H. subpraecox* + *H. subimmaculata*, Grassi and Feletti; *Proteosoma Grassii*, Labbé; &c. Parasite of sparrows, larks, &c.

Species 3: *Haemamoeba malariae*, Grassi and Feletti. Syn.: *Haemamoeba Laverani*, Labbé, in part. Parasite of quartan fever of man.

Species 4: *Haemamoeba vivax*, Grassi and Feletti. Syn.: *Haemamoeba Laverani*, Labbé, in part. Parasite of tertian fever of man.

Genus II: *Haemomenas*, gen. nov. Syn.: *Laverania*, in part + *Haemamoeba*, in part, Grassi and Feletti. *The gametocytes have a special crescentic form.*

Species: *Haemomenas praecox*, Grassi and Feletti. Syn.: *Haemamoeba praecox* + *H. immaculata* + *Laverania malariae*, Grassi and Feletti; *Haemamoeba Laverani*, Labbé, in part; &c. Several varieties—possibly distinct species Parasite of the irregular, remittent, pernicious or æstivo-autumnal fever of man.

The two species lately discovered by Dionisi in bats appear to belong, one to one genus, and the other to the other genus. Two species described in frogs do not contain pigment, and require further study. Grassi and Feletti's arrangement is very confused, chiefly on account of their combining *H. Danilewskii* with the crescentic gametocytes of *H. praecox* in a separate genus, *Laverania*. Labbé admits only one human species, and yet erects two genera for the avian species. The double spore-clusters of *H. Danilewskii*, on which he lays much stress, are not always found, and are at the best due, I think, merely to the presence of the nucleus compressing so large a parasite. There is little to justify generic differences between the four species of *Haemamoeba*. On the other hand, the last species given above is sharply divided from the rest.

The zygotes of three species have been found to develop in mosquitoes as follows:—

Haemamoeba relicta in *Culex pipiens*.

Haemamoeba vivax in *Anopheles claviger*.

Haemomenas praecox in two undetermined species of Anopheles in India, and in *Anopheles claviger* in Italy.

The development is the same in all, but slight differences in details have been noticed between *H. vivax* and *H. falcipara* in the mosquito.

The terminology employed above has been adopted in consultation with Prof. Herdman, F.R.S. Some of it has already been used in this connection by Mesnil, and by Grassi and Dionisi. Nuttall has recently given a very full account of the subject in the *Centralblatt für Bakteriologie*.

RONALD ROSS.

SCIENCE AND EDUCATION.

TWENTY years have passed since Huxley said, at the opening of Mason College, Birmingham: "How often have we not been told that the study of physical science is incompetent to confer culture; that it touches none of the higher problems of life; and what is worse, that the continual devotion to scientific studies tends to generate a narrow and bigoted belief in the applicability of scientific methods to the search after truth of all kinds? How frequently one has reason to observe that no reply to a troublesome argument tells so well as calling its author a 'mere scientific specialist.' And, I am afraid it is not permissible to speak of this form of opposition to scientific education in the past tense." . . .

The exact applicability of these words in this year of grace is as good an example of the slowness of progress as could be wished. It is still urged almost as persistently as ever, and with the weight of university authority, that the only avenue to culture is by way of classics and the humanities. Has nothing come of the example of men like Huxley, Darwin, and the host of other widely-read, and deeply-educated, students of nature who, having borne their testimony, have gone over to the great majority?

These thoughts follow naturally from recent events in connection with the discussions and suggestions anent the constitution of the proposed Board of Education. The retirement of Sir John Donnelly from the secretaryship of the Science and Art Department led to the appointment of Sir George Kekewich to the vacant position, and for the future he will rule educational affairs both at South Kensington and Whitehall. In addition, two principal assistant secretaries were appointed, one for each of the departments referred to. These arrangements have disturbed the minds of the champions of that ill-defined section of educational work known as secondary education. After due representations Sir John Gorst stated, in the House of Commons, in reply to a question of Prof. Jebb, that a third official will be later appointed as assistant secretary for secondary education. This decision resulted in a correspondence which has brought to mind Huxley's addresses on education.

When a distinguished scholar and, on most subjects, broad-minded thinker, as Sir William Anson is, expresses himself in words like the following, which are taken from a letter in the *Times* of July 27, some sort of protest seems absolutely necessary.

"The attitude of those who are interested in secondary education, properly so-called, as distinct from elementary education on the one hand and instruction in science and art or technical education on the other."

"Scientific teaching alone will not produce the educated man, and the scientific expert may not be the best judge of the value of literary and historical studies, or of the respective parts which science and the humanities should play, even in an education which is mainly scientific."

"It is very important if the educational forces are to be brought into line, if the youth of the country are not merely to acquire some useful knowledge, but to become educated men—that where secondary education is given at all it should be given well, and that wherever it is given some one should watch over its interests and see that in the competition of humane and technical studies a due proportion is observed."

A number of unjustifiable conclusions may be derived from this letter; and it is therefore worth while to deal with a few of the points in it.

In the first place, it is tacitly assumed that some kind of secondary education exists in which instruction neither in science nor in art is given. The synonymous use of technical education and instruction in science and art must be passed over, though it provides a suggestive