non-breeding units by the birds during their evolution would result in isolated populations of Mallophaga and was analogous to the situation found on a group of continental islands the populations of which had become isolated by the disappearance of land connexions. Later secondary infestations of Mallophaga from one host group to another are analogous to the trans-oceanic colonization of oceanic islands. Successive colonizations and the occupation of the different ecological niches on the body of the bird could explain the number of different genera and species of Mallophaga found on one host species. During the time that the Mallophaga were still partly free-living and before they had developed any close adaptation to life on the bird or to a particular bird species, interchange of host was presumably more frequent. Thus, although birds within an order or sub-order are usually parasitized by related mallophagan faunas which have presumably evolved on these orders, the origins of related mallophagan faunas on different orders are difficult to assess. In the affinities between mallophagan faunas of the birds[1], a diagram meant to demonstrate factually these affinities and not necessarily to suggest affinities between the host groups, the similarity of the mallophagan faunas of the Procellariiformes and those of the Charadriiformes, for example, may show no more than an ecological relationship, members of both orders living in the same environment. The fact that in general the species on the two orders are now well differentiated suggests that, if this distribution is due to secondary infestations, it could not have been recent and supports the theory that establishment on a new host took place mainly in the early days of the evolution of host and parasite.

Mr. P. F. Mattingly (British Museum, Natural History) stated that the complete restriction of human and simian malaria to anopheline vectors suggests that this group may originally have evolved mainly as feeders on mammals. Bird malaria, on the other hand, was carried exclusively by culicine mosquitoes which might thus have originated as feeders on birds. The fact that human filariasis was carried by both anopheline and culicine mosquitoes suggested that it may have entered the system comparatively recently. The comparative physiology and biochemistry of blood-meal utilization in mosquitoes had been very inadequately studied. This was a particularly promising field for research which might throw light on many problems.

Prof. G. C. Varley (Oxford) believed that host specificity needed careful definition. Not only must both host and parasite be accurately identified, but also those cases where a parasite can only complete part of its development must be distinguished. Published lists unfortunately often gave equal emphasis to unique records and to regular parasite relationships.

Prof. Baer considered that the relation between a parasite and a group of hosts, related by ecology or phylogeny, was biologically significant, whereas the relation between one parasite and one host meant little.

Prof. Baer believed that the biochemical approach to species determination should be encouraged in the way that Dr. Wright was applying it to snails, and that isolated proteins and carbohydrate fractions from hosts and parasites might be used.

Dr. J. Sandground (New York) described his experience with onchocerciasis in Guatemala and in the Gold Coast, and referred to his demonstration some twenty years ago that the parasites in the New and Old World were identical. He believed that much more work remained to be done in onchocerciasis before the infection could be understood adequately and before control would be easy.

WILLIAM KERSHAW

[1] Clay, T., First Symposium on Host Specificity among Parasites of Vertebrates, Neuchâtel, 120 (1957).

ANIMAL CLOCKS

THE significance of rhythmic activities in animal physiology is becoming increasingly evident to-day. For this reason, the symposium on 'animal clocks' held in York on September 4, by Section D (Zoology) of the British Association for the Advancement of Science, was well timed. During the morning sessions, Dr. L. Harrison Matthews, section president, was in the chair.

The first speaker, Prof. F. A. Brown, jun. (Northwestern University), described recent research carried out in his laboratory. In 1948 he had established that the frequency of the rhythm of colour change in fiddler-crabs was independent of temperature over a 20-deg. C. range. Later it was shown that this 'indicator' process was itself regulated by a more fundamental rhythmic element and that two control centres were involved. Although the concept of an autonomous clock is retained by most investigators, Prof. Brown now postulated that the periodisms which comprise basic biological clock systems are imposed by environmental changes even in conditions hitherto presumed to be constant. This hypothesis he supported by a detailed statistical analysis of data obtained by means of an automatic recording respirometer from organisms as unrelated as fiddler-crabs and potatoes which had been hermetically sealed in constant conditions including pressure, for several days at a time.

Although other speakers did not agree with this view, all must have been stimulated to look more carefully at their own data. Unfortunately, it has so far proved almost impossible to devise a really critical experiment that will differentiate between an innate clock mechanism and one derived from exogenous sources, since it appears possible, by analogy, to alter the position of the hands of the clock relative to the works. Just as it is difficult to conceive of a distance-judging mechanism independent of space, so a clock system presumably requires some fixed points of reference.

In a paper on the influence of the environment on the cyclical biting-behaviour of mosquitoes, Dr. A. J. Haddow (director of the East African Virus Research Institute) pointed out that every species so far studied has shown a 24-hr. periodicity. In some, this is merely nocturnal or diurnal, but in others most of the activity is confined to one or two short and precisely delimited periods. These, while usually very constant for a given environment, may be entirely different in another. Further, they may show very striking differences at different levels above ground within the same environment. At present, no single explanation fits all known cases.

The complexity of natural internal timing mechanisms was illustrated by Dr. Janet Harker (Department of Zoology, Cambridge), who described a series of elegant experiments by which she had been able to slow down part of the mechanism. In cockroaches a hormone has now been discovered which increases the activity of the animal, and which is secreted in strict 24-hr. cycles. This hormonal clock can be stopped by chilling the secretory cells while the rest of the body is kept at a normal temperature, and when this is done a second clock associated with the nervous system is revealed. When the secretory clock is allowed to start again, provided it has not got too far out of time with the nervous clock, it is reset by the latter. However, in normal conditions the secretory clock acts as the master-clock, and since, like the nervous clock, it is not affected by sudden short changes in light conditions, the diurnal activity rhythm of the animal is little upset by such changes. This may be important, in Nature, for animals which experience short periods of darkness during the day (for example, by going under a stone), or light at night (for example, bright moonlight or artificial light). If these minor changes in light conditions were to reset the clock, the animal would soon get out of time with day and night. On the other hand, the fact that the secretory cycle can be affected by the nervous system clock towards the beginning and end of the dark period, and the activity rhythm can be immediately reset at these times, suggests a way in which the animal can allow for changing day-length.

The morning session closed with an account by Dr. C. S. Pittendrigh (Princeton University) of a coupled oscillator model for studying the behaviour of the innate circadian ('about a day') rhythm of cells and organisms. Its further utility was noted in explaining recent discoveries in thermo- and photoperiodism. Studies on the effects of single perturbations of the oscillator by light or temperature reflect the behaviour of a common underlying biological mechanism: in some organisms, the phase of a rhythm can be shifted by a light signal as short as 1/2,000 sec. It was concluded that the cell must comprise many diverse circadian oscillations, and disturbances of their mutual phase relations may lead to physiological stress or damage.

Prof. G. C. Varley (University of Oxford) presided over the afternoon sessions in which plant clocks were described by Dr. M. B. Wilkins (King's College, London), with special reference to his own observations on excised leaves of *Bryophyllum fedtschenkoi* placed in continuous darkness and temperature. These maintain a 22·4-hr. rhythm in the rate of carbon dioxide output for several days. The clock controlling the rhythm is extremely sensitive to changes in external conditions of temperature and illumination to which the leaves are subjected. Continuous illumination inhibits the clock which re-commences when darkness is restored, the phase of the subsequent rhythm being determined by the time at which the light was extinguished. The phase of a rhythm persisting in darkness is reset by applying a 3-hr. light treatment to the leaves between the peaks but not at the crest of a peak. Red light inhibits the rhythm, but blue light has no effect. A rhythm can be induced in illuminated leaves by reducing the light intensity by at least 80 per cent, and it was later found that the phase of such a rhythm could be reset by applying a 3-hr. dark treatment at the crest of a peak, but not between the peaks. The rhythm is inhibited when the tissue is placed in an atmosphere of nitrogen and its period varies with temperature. It is apparently unaffected by solutions of mitotic inhibitors such as phenylurethane and colchicine.

Dr. C. G. Butler (head of the Bee Research Department, Rothamsted Experimental Station) then surveyed the development of knowledge regarding the time-sense of the honey-bee since its fortuitous discovery in June 1905 by the famous naturalist, A. Forel. It was not until more than twenty years later that Ingeborg Beling carried out her extensive experiments in which bees were trained to visit a feeding place at different times of day under constant conditions. Later workers have since obtained data which support the view that a honey-bee's time-sense depends in some way upon metabolic rhythm, since it can be speeded up or slowed down by the use of appropriate drugs. Finally, bees trained in Paris to visit a feeding dish at a definite time each day have continued to maintain their feeding schedule under constant conditions after being flown to New York, thus demonstrating that the time-sense of the insects is endogenous.

Dr. A. J. Marshall (St. Bartholomew's Hospital Medical College) introduced an exotic note when he discussed the possible influence of the internal rhythm of reproduction in the control of trans-equatorial migration of birds flying between Europe and Africa and Tasmania and the Aleutian Islands. He pointed out that although something akin to a clock was involved, it had to be likened, nevertheless, to a somewhat imprecise, chain-store variety in that it had to be 'corrected' by environmental factors at least once during each annual cycle. Work carried out by Dr. D. L. Serventy and himself had made it clear that even when shearwater petrels (that breed on islands off the Southern Australian coast) were kept captive under widely varying conditions and day-length, they nevertheless came to breeding condition at the same time as the free birds that had made their astonishing circum-Pacific, trans-equatorial journey.

Next, Dr. J. L. Cloudsley-Thompson (King's College, London) discussed the synchronization of animal clocks in general, pointing out that endogenous rhythms are frequently correlated with environmental changes although they are not necessarily a direct response to them. Thus, if cockroaches are subjected to alternating 12-hr. periods of light and darkness, locomotion may actually begin shortly before the light is extinguished. We have therefore the concept of an innate rhythm synchronized by changes in environmental factors such as light, temperature and humidity which should be regarded as 'clues' rather than stimuli.

The field cricket, *Gryllus campestris*, placed in aktograph apparatus, can be seen to be active in the day-time with a rhythm that is endogenous and independent of temperature. When the 24-hr. periodicity has died away, however, after weeks in constant conditions, it can be re-established by a single exposure to light or by a return to higher temperatures after a period at 5° C. The cricket's clock can be reset in this way, even when activity is completely suppressed by drought.

Although light intensity is the chief factor by which animal clocks are synchronized, regular temperature changes can also be effective. When night-active animals such as white rats, deer mice and millipedes are placed in constant light, it is found that their rhythms tend to be delayed while those of day-active forms are accelerated. The converse often occurs in constant darkness. In this way, diurnal rhythms can be shifted as the days lengthen or draw in according to the season. Synchronization with environmental changes cannot be achieved both at dawn and dusk as the time of each of these is altering. The 'clue' tends to be dusk in the case of nocturnal forms, dawn in that of day-active animals.

The symposium concluded with a paper by Dr. Mary C. Lobban (Department of Physiology, Cambridge), who said that in most communities man's activities are geared to a 24-hr. day. The clock which governs this periodicity is often difficult to reset, as those who travel great distances at the speed of modern aircraft well know. It is, however, possible to separate different physiological rhythms and to get them adapted to different degrees and at different rates. Recent work with indigenous Arctic peoples—Indians and Eskimos—indicates that environmental factors may influence physiological diurnal rhythms more than was hitherto thought. Temperature and physical exertion may well exert a profound effect in deciding whether an individual will become adapted successfully to a new time routine and even whether he will become adapted at all.

Both sessions were followed by lively discussions which served to emphasize the diversity of approaches to be found among workers on rhythmic phenomena. For example, Dr. William Gooddy (London) noted that no definition of a clock had been given by any speaker: the papers were concerned with the forms of rhythms and their possible causes. The definition of a clock as some form of regularly repeated natural phenomenon implies the presence of an observer, and each speaker had mentioned only those rhythmic processes which he had selected to be clock-forms for him. Since it is possible to study innumerable time systems, from the human time sense to the 'tides' inside single cells, the multiplicity and interaction of the mechanisms are evident. It might be wise to investigate organisms with nervous systems separately from plants. Though the cycles of some systems are related to the great events of astronomical observation, they will be modified by all other systems, perhaps giving rise to circadian cycles rather than exact 24-hr. cycles. Final or simple rhythms of an organism, including those described, must represent the average effect of all the possible clock forms observable by biologists in that organism. Too much analytical work on a system in isolation might obscure the general principles which may one day explain the mysteries of the human time sense.

Mr. P. F. Mattingly (London) pointed out that the study of arthropod-borne virus diseases had made it abundantly clear, despite the isolation of the virus in an intracellular environment, that its evolution has been conditioned by external factors no less than has that of the host. The integration of cyclical rhythms in animals is not merely a physiological problem but forms the basis of organic evolution itself.

Dr. E. T. Burtt (Newcastle upon Tyne) inquired whether different rhythmic activities might not profitably be regarded as portions of a continuous spectrum, but Dr. Cloudsley-Thompson replied that he believed there to be a hierarchy of mutually regulatory rhythmic patterns. Another speaker suggested that perhaps too much work had been devoted to arthropods, since inter-cellular transference of hormones is not the same in these animals as in vertebrates. (An instance is afforded by the sex hormones, the inter-cellular movement of which is so much reduced among insects that mosaic individuals can be formed.)

Dr. Sydney Smith (Cambridge) emphasized the dangers of lumping together a number of unrelated phenomena under ill-defined names such as rhythmic, or cellular activity—a trait as seductive as it is misleading. Finally, Dr. Harker pointed out that under conditions of desiccation the distribution of hormones within the insect body becomes blocked, owing to reduction in the amount of blood. This would explain the phenomenon observed in the field cricket.

J. L. CLOUDSLEY-THOMPSON

THE CONTINUED PROGRESS OF SATELLITE 1958δ_2 *(SPUTNIK III)*

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THE progress of the third Russian Earth satellite, 1958δ_2, from launching on May 15, 1958, until October 31, has already been reviewed by D. G. King-Hele[1]. From the latter date the responsibility of following the progress of the satellite and predicting its flight was taken over by the Radio Research Station, Slough.

For prediction purposes a period – time curve has been plotted, using radio and optical observations, and this is shown in Fig. 1. It is noticeable that the slope of the curve has been decreasing steadily throughout the period December–April: from November 1 to December 20, 1958, the mean rate of change of period was about 1·26 sec./day; from December 20 to February 28 about 1·17 sec./day; and from February 28 to March 31 about 1·11 sec./day. This decrease in slope, which arises from a lessening of atmospheric drag, is very probably a consequence of the fact that the southerly latitude of perigee, the point in the orbit at which the satellite experiences the greatest atmospheric drag, has been increasing since October 24, the date on which it crossed the equator. This movement has resulted in a net increase in the height of perigee above the Earth's surface, since the rate at which the Earth's radius has been decreasing with latitude has been greater than the rate at which the perigee distance of the orbit has been decreasing. A lessening