APPENDIX.

Note 1. The Duration of Life among Birds.

There is less exact knowledge upon this subject than we might expect, considering the existing number of ornithologists and ornithological societies with their numerous publications. It has neither been possible nor necessary for my purpose to look up all the widely-scattered references which are to be found upon the subject. Many of these are doubtless unknown to me; for we are still in want of a compilation of accurately determined observations in this department of zoology. I print the few facts which I have been able to collect, as a slight contribution towards such a compilation.

Small singing birds live from eight to eighteen years: the nightingale, in captivity, eight years, but longer according to some writers: the blackbird, in captivity, twelve years, but both these birds live longer in the natural state. A 'half-bred nightingale built its nest for nine consecutive years in the same garden' (Naumann, 'Vögel Deutschlands,' p. 76).

Canary birds in captivity attain an age of twelve to fifteen years (l. c., p. 76).

Ravens have lived for almost a hundred years in captivity (l. c., Bd. I. p. 125).

Magpies in captivity live twenty years, and, 'without doubt,' much longer in the natural state (l. c., p. 346).

Parrots 'in captivity have reached upwards of a hundred years' (l. c., p. 125).

A single instance of the cuckoo (alluded to in the text) is mentioned by Naumann as reaching the age of thirty-two years (l. c., p. 76).

Fowls live ten to twenty years, the golden pheasant fifteen years, the turkey sixteen years, and the pigeon ten years (Oken, 'Naturgeschichte, Vögel,' p. 387).

A golden eagle which 'died at Vienna in the year 1719, had been captured 104 years previously' (Brehm, 'Leben der Vögel,' p. 72).

A falcon (species not mentioned) is said to have attained an age of 162 years (Knauer, 'Der Naturhistoriker,' Vienna, 1880).

A white-headed vulture which was taken in 1706 died in the Zoological Gardens at Vienna (Schönbrunn) in 1824, thus living 118 years in captivity (l. c.).

The example of the bearded vulture, mentioned in the text, is quoted from Schinz's 'Vögel der Schweiz,' p. 196.

The wild goose must live for upwards of 100 years, according to Naumann (l. c., p. 127). The proof of this is not, however, forthcoming. A wild goose which had been wounded reached its eighteenth year in captivity.

Swans are said to have lived 300 years (?), (Naumann, l. c., p. 127).

It is evident that observations upon the duration of life in wild birds can only rarely be made, and that they are usually the result of chance and cannot be verified. It is on this account all the more to be desired that every ascertained fact should be collected.

If the long life of birds has been correctly interpreted as compensation for their feeble fertility and for the great mortality of their young, it will be possible to estimate the length of life in a species, without direct observation, if we only know its fertility and the percentage of individuals destroyed. This percentage can, however, at best, be known only as an average. If we consider, for example, the enormous number of sea birds which breed in summer on the rocks and cliffs of the northern seas, and if we remember that the majority of these birds lay but one, or at most two eggs yearly, and that their young are exposed to very many destructive agencies, we are forced to the conclusion that they must possess a very long life, so that the breeding period may be many times repeated. Their number does not diminish. Year after year countless numbers of these birds cover the rocks, from summit to sea line; millions of them rest there, and rise in the air like a thick cloud whenever they are disturbed. Even in those localities which are every year visited by man in order to effect their capture, the number does not appear to decrease, unless the birds are disturbed and are therefore prompted to seek other breeding-places. From the small island of St. Kilda, off Scotland, 20,000 young gannets (*Sula*) and an immense number of eggs are annually collected;

and although this bird only lays a single egg yearly and takes four years to attain maturity, the numbers do not diminish[1]. 30,000 sea-gulls' eggs and 20,000 terns' eggs are yearly exported *from the breeding-places on the island of Sylt, but in this case* it appears that a systematic disturbance of the birds is avoided by the collectors, and no decrease in their numbers has yet taken place[2]. The destruction of northern birds is not only caused by man, but also by various predaceous mammals and birds. Indeed the dense mass of birds which throng the cliffs is a cause of destruction to many of the young and to the eggs, which are pushed over the edge of the rocks. According to Brehm the foot of these cliffs is 'always covered with blood and the dead bodies of fledglings.'

Such birds must attain a great age or they would have been *exterminated long ago: the minimum duration of* life necessary for the maintenance of the species must in their case be a very high one.

Note 2. The Duration of Life among Mammals.

The statements upon this subject in the text are taken from many sources; from Giebel's 'Säugethiere,' from Oken's 'Naturgeschichte,' from Brehm's 'Illustrirtem Thierleben,' and from an essay of Knauer in the 'Naturhistoriker,' Vienna, 1880.

Note 3. The Duration of Life among Mature Insects.

A short statement of the best established facts which I have been able to find is given below. I have omitted the lengthening of imaginal life which is due to hybernation in certain species. In almost all orders of insects there are certain species which emerge from the pupa in the autumn, but which first reproduce in the following spring. The time spent in the torpid condition during winter cannot of course be reckoned with the active life of the species, for its vital activity is either entirely suspended for a time by freezing (*Anabiosis*: Preyer[3]), or it is at any rate never more than a *vita minima*, with a reduction of assimilation to its lowest point.

[1] Oken, 'Naturgeschichte,' Stuttgart, 1837, Bd. IV. Abth. 1.

[2] Brehm, 'Leben der Vögel,' p. 278.

[3] 'Naturwissenschaftliche Thatsachen und Probleme,' Populäre Vorträge, Berlin, 1880; *vide* Appendix.

The following account does not make any claim to contain all or even most of the facts scattered through the enormous mass of entomological literature, and much less all that is privately known by individual entomologists. It must therefore be looked upon as merely a first attempt, a nucleus, around which the principal facts can be gradually collected. It is unnecessary to give any special information as to the duration of larval life, for numerous and exact observations upon this part of the subject are contained in all entomological works.

I. Orthoptera.

Gryllotalpa. The eggs are laid in June or July, and the young are hatched in from two to three weeks; they live through the winter, and become sexually mature in the following May or June. 'When the female has deposited her eggs, her body collapses, and afterwards she does not survive much longer than a month.' 'According as the females are younger or older, they live a longer or shorter life, and hence some females are even found in the autumn' (Rösel, 'Insektenbelustigungen,' Bd. II. p. 92). Rösel believes that the female watches the eggs until they are hatched, and this explains the fact that she outlives the process of oviposition by about a month. It is not stated whether the males die at an earlier period.

Gryllus campestris becomes sexually mature in May, and sings from June till October, 'when they all die' (Oken, 'Naturgeschichte,' Bd. II. Abth. iii. p. 1527). It is hardly probable that any single individual lives for the whole summer; probably, as in the case of *Gryllotalpa*, the end of the life of those individuals which first become mature, overlaps the beginning of the life of others which reach maturity at a later date.

Locusta viridissima and *L. verrucivora* are mature at the end of August; they lay their eggs in the earth during the first half of September and then die. It is probable that the females do not live for more than four weeks in the mature state. It is not known whether the males of this or other species of locusts live for a shorter period.

I have found *Locusta cantans* in plenty, from the beginning of September to the end of the month. In captivity they die after depositing their eggs: the males are probably more short-lived, for

towards the middle and end of September they are much less plentiful than the females.

Acridium migratorium 'dies after the eggs are laid' (Oken, 'Naturgeschichte').

The male *Termes* probably live for a short time only, although exact observations upon the point are wanting. The females 'seem sometimes to live four or five years,' as I gather from a letter from Dr. Hagen, of Cambridge, Mass., U.S.A.

Ephemeridae. Rösel, speaking of *Ephemera vulgata* ('Insekten-belustigungen,' Bd. II. der Wasserinsekten, 2^te^ Klasse, p. 60 et seq.), says:—'Their flight commences at sunset, and comes to an end before midnight, when the dew begins to fall.' 'The pairing generally takes place at night and lasts but a short time. As soon as the insects have shed their last skin, in the afternoon or evening, they fly about in thousands, and pair almost immediately; but by the next day they are all dead. They continue to emerge for many days, so that when yesterday's swarm is dead, to-day a new swarm is seen emerging from the water towards the evening.' 'They not only drop their eggs in the water, but wherever they may happen to be,—on trees, bushes, or the earth. Birds, trout and other fish lie in wait for them.'

Dr. Hagen writes to me—'It is only in certain species that life is so short. The female *Palingenia* does not live long enough to complete the last moult of the sub-imago. I believe that a female imago has never been seen. The male imago, often half in its sub-imago skin, fertilizes the female sub-imago and immediately the contents of both ovaries are extruded, and the insect dies. It is quite possible that the eggs pass out by rupturing the abdominal segments.'

Libellula. All dragon-flies live in the imago condition for some weeks; at first they are not capable of reproduction, but after a few days they pair.

Lepisma saccharina. An individual lived for two years in a pill-box, without any food except perhaps a little *Lycopodium* dust[1].

II. Neuroptera.

Phryganids 'live in the imago stage for at least a week and probably longer, apparently without taking food' (letter from Dr. Hagen).

[1] 'Entomolog. Mag.,' vol. i. p. 527, 1833.

According to the latest researches *Phryganea grandis*[1] never contains food in its alimentary canal, but only air, although it contains the latter in such quantities that the anterior end of the chylific ventricle is dilated by it.

III. Strepsiptera.

The larva requires for its development a rather shorter time than that which is necessary for the grub of the bee into the body of which it has bored. The pupa stage lasts eight to ten days. The male, which flies about in a most impetuous manner, lives only two to three hours, while the female lives for some days. Possibly the pairing does not take place until the female is two to three days old. The viviparous female seems to produce young only once in a lifetime, and then dies: it is at present uncertain whether she also produces young parthenogenetically (cf. Siebold, 'Ueber Paedogenesis der Strepsipteren,' Zeitschr. f. Wissensch. Zool., Band. XX, 1870).

IV. Hemiptera.

Aphis. Bonnet ('Observations sur les Pucerons,' Paris, 1745) had a parthenogenetic female of *Aphis euonymi* in his possession for thirty-one days, from its birth, during which time it brought forth ninety-five larvae. Gleichen kept a parthenogenetic female of *Aphis mali* fifteen to twenty-three days.

Aphis foliorum ulmi. The mother of a colony which leaves the egg in May is 2‴ long at the end of July: it therefore lives for at least two and a half months (De Geer, 'Abhandlungen zur Geschichte der Insekten,' 1783, III. p. 53).

Phylloxera vastatrix. The males are merely ephemeral sexual organisms, they have no proboscis and no alimentary canal, and die immediately after fertilizing the female.

Pemphigus terebinthi. The male as well as the female sexual individuals are wingless and without a proboscis; they cannot take food and consequently live but a short time,—far shorter than the parthenogenetic females of the same species (Derbès, 'Note sur les aphides du pistachier térébinthe,' Ann. des sci. nat., Tom. XVII, 1872).

Cicada. In spite of the numerous and laborious descriptions of

[1] Imhof, 'Beiträge zur Anatomie der *Perla maxima*,' Inaug. Diss., Aarau, 1881.

the Cicadas which have appeared during the last two centuries, I can only find precise statements as to the duration of life in the mature insect in a single species. P. Kalm, writing upon the North American *Cicada septemdecim*, which sometimes appears in countless numbers, states that 'six weeks after (such a swarm had been first seen) they had all disappeared.' Hildreth puts the life of the female at from twenty to twenty-five days. This agrees with the fact that the Cicada lays many hundred eggs (Hildreth states a thousand); sixteen to twenty at a time being inserted into a hole which is bored in wood, so that the female takes some time to lay her eggs (Oken, 'Naturgeschichte,' 2ter Bd. 3te Abth. p. 1588 et seq.).

Acanthia lectularia. No observations have been made upon the bed bug from which the normal length of its life can be ascertained, but many statements tend to show that it is exceedingly long-lived, and this is advantageous for a parasite of which the food (and consequently growth and reproduction) is extremely precarious. They can endure starvation for an astonishingly long period, and can survive the most intense cold. Leunis ('Zoologie,' p. 659) mentions the case of a female which was shut up in a box and orgotten: after six months' starvation it was found not only alive but surrounded by a circle of lively young ones. Göze found bugs in the hangings of an old bed which had not been used for six years: 'they appeared white like paper.' I have myself observed a similar case, in which the starving animals were quite transparent. De Geer placed some bugs in an unheated room in the cold winter of 1772, when the thermometer fell to $-33°C$: they passed the whole winter in a state of torpidity, but revived in the following May. (De Geer, Bd. III. p. 165, and Oken, 'Naturgeschichte,' 2ter Bd. 3te Abth. p. 1613.)

V. Diptera.

Pulex irritans. Oken says of the flea ('Naturgeschichte,' Bd. II. Abth. 2, p. 759) that 'death follows the deposition of the eggs in the course of two or three days, even if the opportunity of sucking blood is given them.' The length of time which intervenes between the emergence from the cocoon and fertilization or the deposition of eggs is not stated.

Sarcophaga carnaria. The female fly dies ten to twelve hours after the birth of the viviparous larvae; the time intervening

between the exit from the cocoon and the birth of the young is not given (Oken, quoting Réaumur, 'Mém. p. s. à l'hist. Insectes,' Paris, 1740–48, IV).

Musca domestica. In the summer the common house-fly begins to lay eggs eight days after leaving the cocoon: she then lays several times. (See Gleichen, 'Geschichte der gemeinen Stubenfliege,' Nuremberg, 1764.)

Eristalis tenax. The larva of this large fly lives in liquid manure, and has been described and figured by Réaumur as the rat-tailed larva. I kept a female which had just emerged from the cocoon, from August 30th till October 4th, in a large gauze-covered glass vessel. The insect soon learnt to move freely about in its prison, without attempting to escape; it flew round in circles, with a characteristic buzzing sound, and obtained abundant nourishment from a solution of sugar, provided for it. From September 12th it ceased to fly about, except when frightened, when it would fly a little way off. I thought that it was about to die, but matters took an unexpected turn, and on the 26th of September it laid a large packet of eggs, and again on the 29th of the same month another packet of similar size. The flight of the animal had been probably impeded by the weight of the mass of ripe eggs in its body. The deposition of eggs was probably considerably retarded in this case, because fertilization had not taken place. The fly died on the 4th of October, having thus lived for thirty-five days. Unfortunately, I have been unable to make any experiments as to the duration of life in the female when males are also present.

VI. Lepidoptera.

I am especially indebted to Mr. W. H. Edwards [1], of Coalburgh, W. Virginia, and to Dr. Speyer, of Rhoden, for valuable letters relating to this order.

The latter writes, speaking of the duration of life in imagos generally:—'It is, to my mind, improbable that any butterfly can live as an imago for a twelvemonth. Specimens which have lived through the winter are only rarely seen in August, even when the summer is late. A worn specimen of *Vanessa cardui* has, for

[1] Mr. Edwards has meanwhile published these communications in full; cf. 'On the length of life of Butterflies,' Canadian Entomologist, 1881, p. 205.

instance, been found at this time' ('Entomolog. Nachrichten,' 1881, p. 146).

In answer to my question as to whether the fact that certain Lepidoptera take no solid or liquid food, and are, in fact, without a functional mouth, may be considered as evidence for an adaptation of the length of life to the rapid deposition of eggs, Dr. Speyer replies:—'The wingless females of the *Psychidae* do not seem to possess a mouth, at any rate I cannot find one in *Psyche unicolor* (*graminella*). They do not leave the case during life, and certainly do not drink water. The same is true of the wingless female of *Heterogynis*, and of *Orgyia ericae*, and probably of all the females of the genus *Orgyia*; and as far as I can judge from cabinet specimens, it is probably true of the males of *Heterogynis* and *Psyche*. I have never seen the day-flying *Saturnidae*, *Bombycidae*, and other Lepidoptera with a rudimentary proboscis, settle in damp places, or suck any moist substance, and I doubt if they would ever do this. The sucking apparatus is probably deficient.'

In answer to my question as to whether the males of any species of butterfly or moth are known to pass a life of different length from that of the female, Dr. Speyer stated that he knew of no observations on this point.

The following are the only instances of well-established direct observations upon single individuals, in my possession[1]:—

Pieris napi, var. *bryoniae* ♂ and ♀, captured on the wing: lived in confinement ten days, and were then killed.

Vanessa prorsa lived at most ten days in confinement.

Vanessa urticae lived ten to thirteen days in confinement.

Papilio ajax. According to a letter from Mr. W. H. Edwards, the female, when she leaves the pupa, contains unripe eggs in her body, and lives for about six weeks—calculating from the first appearance of this butterfly to the disappearance of the same generation[2]. The males live longer, and continue to fly when very worn and exhausted. A worn female is very seldom seen;—'I believe the female does not live long after laying her eggs, but this takes some days, and probably two weeks.'

Lycaena violacea. According to Mr. Edwards, the first brood of this species lives three to four weeks at the most.

[1] When no authority is given, the observations are my own.

[2] In the paper quoted above, Edwards, after weighing all the evidence, reduces the length of life from three to four weeks.

Smerinthus tiliae. A female, which had just emerged from the pupa, was caught on June 24th; on the 29th pairing took place; on the 1st of July she laid about eighty eggs, and died the following day. She lived nine days, taking no food during this period, and she only survived the deposition of eggs by a single day.

Macroglossa stellatarum. A female, captured on the wing and already fertilized, lived in confinement from June 28th to July 4th. During this time she laid about eighty eggs, at intervals and singly; she then disappeared, and must have died, although the body could not be found among the grass at the bottom of the cage in which she was confined.

Saturnia pyri. A pair which quitted the cocoons on the 24th or 25th of April, remained in coitu from the 26th until May 2nd—six or seven days; the female then laid a number of eggs, and died.

Psyche graminella. The fertilized female lives some days, and the unfertilized female over a week (Speyer).

Solenobia triquetrella. 'The parthenogenetic form (I refer to the one which I have shown to be parthenogenetic in Oken's 'Isis,' 1846, p. 30) lays a mass of eggs in the abandoned case, soon after emergence. The oviposition causes her body to shrivel up, and some hours afterwards she dies. The non-parthenogenetic female of the same species remains for many days, waiting to be fertilized; if this does not occur, she lives over a week.' 'The parthenogenetic female lives for hardly a day, and the same is true of the parthenogenetic females of another species of *Solenobia*' (*S. inconspicuella*?). Letter from Dr. Speyer.

Psyche calcella, O. The males live a very short time; 'those which leave the cocoon in the evening are found dead on the following morning, with their wings fallen off, at the bottom of their cage.' Dr. Speyer.

Eupithecia, sp. (*Geometridae*), 'when well-fed, live for three to four weeks in confinement; the males fertilize the females frequently, and the latter continue to lay eggs when they are very feeble, and are incapable of creeping or flying.' Dr. Speyer.

The conclusions and speculations in the text seem to be sufficiently supported from this short series of observations. There remains, as we see, much to be done in this field, and it would well repay a lepidopterist to undertake some exact observations upon the length of life in different butterflies and moths, with

reference to the conditions of life—the mode of egg-laying, the degeneracy of the wings, and of the external mouth-parts or the closure of the mouth itself. It would be well to ascertain whether such closure does really take place, as it undoubtedly does in certain plant-lice.

VII. Coleoptera.

Melolontha vulgaris. Cockchafers, which I kept in an airy cage with fresh food and abundant moisture, did not in any case live longer than thirty-nine days. One female only, out of a total number of forty-nine, lived for this period; a second lived thirty-six days, a third thirty-five, and a fourth and fifth twenty-four days; all the rest died earlier. Of the males, only one lived as long as twenty-nine days. These periods are less by some days than the true maximum duration of life, for the beetles were captured in the field, and had lived for at least a day; but the difference cannot be great, when we remember that out of forty-nine beetles, only three females lived thirty-five to thirty-nine days, and only one male twenty-nine days. Those that died earlier had probably lived for some considerable time before being caught.

Exact experiments with pupae which have survived the winter would show whether the female really lives for ten days more than the male, or whether the results of my experiment were merely accidental. I may add that coitus frequently took place during the period of captivity. One pair, observed in this condition on the 17th, separated in the evening; they paired again on the morning of the 18th, and separated in the middle of the day. Coitus took place between another pair on the 22nd, and again on the 26th.

I watched the gradual approach of death in many individuals: some days before it ensued, the insects became sluggish, ceased to fly and to eat, and only crept a little way off when disturbed: they then fell to the ground and remained motionless, apparently dead, but moved their legs when irritated, and sometimes automatically. Death came on gradually and imperceptibly; from time to time there was a slow movement of the legs, and at last, after some hours, all signs of life ceased.

In one case only I found bacteria present in great numbers in the blood and tissues; in the other individuals which had recently

died, the only noticeable change was the unusual dryness of the tissues.

Carabus auratus. An experiment with an individual, caught on May 27th, gave the length of life at fourteen days; this is probably below the average, since the beetles are found, in the wild state, from the end of May until the beginning of July.

Lucanus cervus. Captured individuals, kept in confinement, and fed on a solution of sugar, never lived longer than fourteen days, and as a rule not so long. The beetles appear in June and July, and certainly cannot live much over a month. As is the case with many beetles appearing during certain months, the length of the individual life is shorter than the period over which they are found. Accurate information, especially as to any difference between the lengths of life in the sexes, is not obtainable.

Isolated accounts of remarkably long lives among beetles are to be found scattered throughout the literature of the subject. Dr. Hagen, of Cambridge, Mass., has been kind enough to draw my attention to these, and to send me some observations of his own.

Cerambyx heros. One individual lived in confinement from August until the following year [1].

Saperda carcharias. An individual lived from the 5th of July until the 24th of July of the next year [1].

Buprestis splendens. A living individual was removed from a desk which had stood in a London counting-house for thirty years; from the condition of the wood it was evident that the larva had been in it before the desk was made [1].

Blaps mortisaga. One individual lived three months, and two others three years.

Blaps fatidica. One individual which was left in a box and forgotten, was found alive when the box was opened six years afterwards.

Blaps obtusa. One lived a year and a half in confinement.

Eleodes grandis and *E. dentipes.* Eight of these beetles from California were kept in confinement and without food for two years by Dr. Gissler, of Brooklyn; they were then sent to Dr. Hagen who kept them another year.

Goliathus cacicus. One individual lived in a hot-house for five months.

[1] 'Entomolog. Mag.,' vol. i. p. 527, 1823.

In addition to these cases, Dr. Hagen writes to me: 'Among the beetles which live for more than a year,—*Blaps*, *Pasimachus*, (*Carabidae*)—and among ants, almost thirty per cent. are found with the cuticle worn out and cracked, and the powerful mandibles so greatly worn down that species were formerly founded upon this point. The mandibles are sometimes worn down to the hypodermis.'

From the data before me I am inclined to believe that in certain beetles the normal length of life extends over some years, and this is especially the case with the *Blapidae*. It seems probable that in these cases another factor is present,—a *vita minima*, or apparent death, a sinking of the vital processes to a minimum in consequence of starvation, which we might call the hunger sleep, after the analogy of winter sleep. The winter sleep is usually ascribed to cold alone, and some insects certainly become so torpid that they appear to be dead when the temperature is low. But cold does not affect all insects in this way. Among bees, for example, the activity of the insects diminishes to a marked extent at the beginning of winter, but if the temperature continues to fall, they become active again, run about, and as the bee-keepers say, 'try to warm themselves by exercise'; by this means they keep some life in them. If the frost is very severe, they die. In the tropics the period of hibernation for many animals coincides with the time of maximum heat and drought. This shows that the organism can be brought into the condition of a *vita minima* in various ways, and it would not be at all remarkable if such a state were induced in certain insects by hunger. Exact experiments however are the only means by which such a suggestion can be tested, and I have already commenced a series of experiments. The fact that certain beetles live without food for many years (even six) can hardly be explained on any other supposition, for these insects consume a fair amount of food under normal conditions, and it is inconceivable that they could live for years without food, if the metabolism were carried on with its usual energy.

A very striking example, showing that longevity may be induced by the lengthening of the period of reproductive activity, is communicated to me by Dr. Adler in the following note: 'Three years ago I accidentally noticed that ovoviviparous development takes place in *Chrysomela varians*,—a fact which I afterwards discovered had been already described by another entomologist.

'The egg passes through all the developmental stages in the ovary; when these are completed the egg is laid, and a minute or two afterwards the larva breaks through the egg-shell. In each division of the ovary the eggs undergo development one at a time; it therefore follows that they are laid at considerable intervals, so that a long life becomes necessary in order to ensure the development of a sufficiently long series of eggs. Hence it comes about that the females live a full year. Among other species of *Chrysomela* two generations succeed each other in a year, and the duration of life in the individual varies from a few months to half a year.'

VIII. Hymenoptera.

Cynipidae. I have been unable to find any accurate accounts of the duration of life in the imagos of saw-flies or ichneumons; but on the other hand I owe to the kindness of Dr. Adler, an excellent observer of the *Cynipidae*, the precise accounts of that family which are in my possession. I asked Dr. Adler the general question as to whether there was any variation in the duration of life among the *Cynipidae* corresponding to the conditions under which the deposition of eggs took place; whether those species which lay many eggs, or of which the oviposition is laborious and protracted, lived longer than those species which lay relatively few eggs, or easily and quickly find the suitable places in which to deposit them.

Dr. Adler fully confirmed my suppositions and supported them by the following statements:—

'The summer generation of *Neuroterus* (*Spathegaster*) has the shortest life of all *Cynipidae*. Whether captured or reared from the galls I have only kept them alive on an average for three to four days. In this generation the work of oviposition requires the shortest time and the least expenditure of energy, for the eggs are simply laid on the surface of a leaf. The number of eggs in the ovary is also smaller than that of other species, averaging about 200. This form of *Cynips* can easily lay 100 eggs a day.

'The summer generation of *Dryophanta* (*Spathegaster Taschenbergi, verrucosus*, etc.) lives somewhat longer; I have kept them in confinement for six to eight days. The oviposition requires a considerable expenditure of time and strength, for the ovipositor has to pierce the rather tough mid-rib or vein of a leaf. The number of eggs in the ovary averages 300 to 400.

'The summer generation of *Andricus*, which belongs to the extensive genus *Aphilotrix*, have also a long life. I have kept the smaller *Andricus* (such as *A. nudus*, *A. cirratus*, *A. noduli*) alive for a week, and the larger (*A. inflator*, *A. curvator*, *A. ramuli*) for two weeks. The smaller species pierce the young buds when quite soft, but the larger ones bore through the fully grown buds protected by tough scales. The ovary of the former contains 400 to 500 eggs, that of the latter over 600.

'The agamic winter generations live much longer. The species of *Neuroterus* have the shortest life; they live for two weeks at the outside; on the other hand, species of *Aphilotrix* live quite four weeks, and *Dryophanta* and *Biorhiza* even longer. I have kept *Dryophanta scutellaris* alive for three months. The number of eggs in these agamic *Cynipidae* is much larger: *Dryophanta* and *Aphilotrix* contain 1200 and *Neuroterus* about 1000.'

It is evidently, therefore, a general rule that the duration of life is directly proportional to the number of eggs and to the time and energy expended in oviposition. It must of course be understood that, here as in all other instances, these are not the only factors which determine the duration of life, but many other factors, at present unknown, may be in combination with them and assist in producing the result. For example, it is very probable that the time of year at which the imagos appear exerts some indirect influence. The long-lived *Biorhiza* emerges from the gall in the middle of winter, and at once begins to deposit eggs in the oak buds. Although the insect is not sensitive to low temperature, for I have myself seen oviposition proceeding when the thermometer stood at 5° R., yet very severe frost would certainly lead to interruption and would cause the insect to shelter itself among dead leaves on the ground. Such interruptions may be of long duration and frequently repeated, so that the remarkably long life of this species may perhaps be looked upon as an adaptation to its winter life.

Ants. *Lasius flavus* lays its eggs in the autumn, and the young larvae pass the winter in the nest. The males and females leave the cocoons in June, and pair during July and August. The males fly out of the nest with the females, but they do not return to it; 'they die shortly after pairing.' It is also believed that the females do not return to the nest, but found new colonies; this point is

however one of the most uncertain in the natural history of ants. On the other hand it is quite certain that the female may live for years within the nest, continuing to lay fertilized eggs. Old females are sometimes found in the colony, with their jaws worn down to the hypodermis.

Breeding experiments confirm these statements. P. Huber[1] and Christ have already put the life of the female at three to four years, and Sir John Lubbock, who has been lately occupied with the natural history of ants, was able to keep a female worker of *Formica sanguinea* alive for five years; and he has been kind enough to write and inform me that two females of *Formica fusca*, which he captured in a wood together with ten workers, in December 1874, are still alive (July 1881), so that these insects live as imagos for six and a half years or more[2].

[1] 'Recherches sur les mœurs des Fourmis indigènes,' Genève, 1810.

[2] These two female ants were still alive on the 25th of September following Sir John Lubbock's letter, so that they live at least seven years. Cf. 'Observations on Ants, Bees, and Wasps,' Part VIII. p. 385; Linn. Soc. Journ. Zool., vol. xv. 1881.

[Sir John Lubbock has kindly given me further information upon the duration of life of these two queen ants. Since the receipt of his letter, the facts have been published in the Journal of the Linnean Society (Zoology), vol. xx. p. 133. I quote in full the passage which refers to these ants:—

'Longevity.—It may be remembered that my nests have enabled me to keep ants under observation for long periods, and that I have identified workers of *Lasius niger* and *Formica fusca* which were at least seven years old, and two queens of *Formica fusca* which have lived with me ever since December 1874. One of these queens, after ailing for some days, died on the 30th July, 1887. She must then have been more than thirteen years old. I was at first afraid that the other one might be affected by the death of her companion. She lived, however, until the 8th August, 1888, when she must have been nearly fifteen years old, and is therefore by far the oldest insect on record.

'Moreover, what is very extraordinary, she continued to lay fertile eggs. This remarkable fact is most interesting from a physiological point of view. Fertilization took place in 1874 at the latest. There has been no male in the nest since then, and, moreover, it is, I believe, well established that queen ants and queen bees are fertilized once for all. Hence the spermatozoa of 1874 must have retained their life and energy for thirteen years, a fact, I believe, unparalleled in physiology.'

* * * * * * *

'I had another queen of *Formica fusca* which lived to be thirteen years old, and I have now a queen of *Lasius niger* which is more than nine years old, and still lays fertile eggs, which produce female ants.'

Both the above-mentioned queens may have been considerably older, for it is impossible to estimate their age at the time of capture. It is only certain (as Sir John Lubbock informs me in his letter) that 'they must have been at least nine months old (when captured), as the eggs of *F. fusca* are laid in March or early in April.' The queens became gradually 'somewhat lethargic and stiff in their movements

On the other hand, Sir John Lubbock never succeeded in keeping the males 'alive longer than a few weeks.' Both the older and more recent observers agree in stating that female ants, like queen bees, are always protected as completely as possible from injury and danger. Dr. A. Forel, whose thorough knowledge of Swiss ants is well known, writes to me,—'The female ants are only once fertilized, and are then tended by the workers, being cleaned and fed in the middle of the nest: one often finds them with only three legs, and with their chitinous armour greatly worn. They never leave the centre of the nest, and their only duty is to lay eggs.'

With regard to the workers, Forel believes that their constitution would enable them to live as long as the females (as the experiments of Lubbock also indicate), and the fact that in the wild state they generally die sooner than the females is 'certainly connected with the fact that they are exposed to far greater dangers.' The same relation seems also to obtain among bees, but with them it has not been shown that in confinement the workers live as long as the queens.

Bees. According to von Berlepsch[1] the queen may as an exception live for five years, but as a rule survives only two or three years. The workers always seem to live for a much shorter period, generally less than a year. Direct experiments upon isolated or confined bees, or upon marked individuals in the wild state, do not prove this, but the statistics obtained by bee-keepers confirm the above. Every winter the numbers in a hive diminish from 12,000–20,000 to 2000–3000. The queen lays the largest number of eggs in the spring, and the workers which die before the winter are replaced by those which emerge in the summer, autumn or during a mild winter. The queen lays eggs at such a variable rate throughout the year that the above-mentioned inequality in numbers is explained. The workers do not often live for more than six to seven months, and at the time of their greatest labour, (May to July), only three months. An attempt to calculate the length of life of the workers and drones by taking stock at the end of

(before their death), but there was no loss of any limb nor any abrasion.' This last observation seems to indicate that queen ants may live for a much longer period in the wild state, for it is stated above that the chitin is often greatly worn, and some of the limbs lost (see pp. 48, 51, and 52).—E. B. P.]

[1] A. von Berlepsch, 'Die Biene und ihre Zucht,' etc., 3rd ed.; Mannheim, 1872.

summer, gives six months for the former and four months for the latter[1].

The drones do not as a rule live so long as four months, for they meet with a violent death before the end of this period. The well-known slaughter of the drones is not, according to the latest observations, brought about directly by means of the stings of the workers, but by these latter driving away the useless drones from the food so that they perish of starvation.

Wasps. It is interesting that among these near relations of the bees, the life of the female should be much shorter, corresponding to the much lower degree of specialization found in the colonies. The females of *Polistes gallica* and of *Vespa* not only lay eggs but take part in building the cells and in collecting food; they are therefore obliged to use all parts of the body more actively and especially the wings, and are exposed to greater danger from enemies.

It is well known from Leuckart's observations, that the so-called 'workers' of *Polistes gallica* and *Bombus* are not arrested females like the workers of a bee-hive, but are females which although certainly smaller, are in every way capable of being fertilized and of reproduction. Von Siebold has nevertheless proved that they are not fertilized, but reproduce parthenogenetically.

The fertilized female which survives the winter, commences to found a colony at the beginning of May: the larvae, which hatch from the first eggs, which are about fifteen in number, become pupae at the beginning of June, and the imagos appear towards the end of the same month. These are all small 'workers,' and they perform such good service in tending the second brood, that the latter attain the size of the female which founded the colony; only differing from her in the perfect condition of their wings, for by this time her wings are greatly worn away.

The males appear at the beginning of July; their spermatozoa are mature in August, and pairing then takes place with certain 'special females which require fertilization' which have in the meantime emerged from their cocoons. These are the females which live through the winter and found new colonies in the following spring. The old females of the previous winter die, and do not live

[1] E. Bevan, 'Ueber die Honigbiene und die Länge ihres Lebens;' abstract in Oken's 'Isis,' 1844, p. 506.

beyond the summer at the beginning of which they founded colonies. At the first appearance of frost, the young fertilized females seek out winter quarters; the males which never survive the winter, do not take this course, but perish in October. The parthenogenetic females, which remain in the nest during the nuptial flight, also perish.

The males of *Polistes gallica* do not live longer than three months—from July to the beginning of October; the parthenogenetic females live a fortnight longer at the outside—from the middle of June to October, but the later generations have a shorter life. The sexual females alone live for about a year, including the winter sleep.

A similar course of events takes place in the genus *Vespa*. In both these genera the possibility of reproduction is not restricted to a single female in the nest, but is shared by a number of females. In the genus *Apis* alone is the division of labour complete, so that only a single female (the queen) is at any one time capable of reproduction, a power which differentiates it from the sterile workers.

NOTE 4. THE DURATION OF LIFE OF THE LOWER MARINE ANIMALS.

I have only met with one definite statement in the literature of this part of the subject. It concerns a sea anemone,—which is a solitary and not a colonial form. The English zoologist Dalyell, in August, 1828, removed an *Actinia mesembryanthemum* from the sea and placed it in an aquarium [1]. It was a very fine individual, although it had not quite attained the largest size; and it must have been at least seven years old, as proved by comparison with other individuals reared from the egg. In the year 1848, it was about thirty years old, and in the twenty years during which it had been in captivity it had produced 334 young Actiniae. Prof. Dohrn, of Naples, tells me that this Actinia is still living to-day, and is shown as a curiosity to those who visit the Botanical Gardens in Edinburgh. It is now (1882) at least sixty-one years old [2].

[1] Dalyell, 'Rare and Remarkable Animals of Scotland,' vol. ii. p. 203; London, 1848.

[2] Mr. J. S. Haldane has kindly obtained details of the death of the sea anemone referred to by the author. It died, by a natural death, on August 4, 1887, after having appeared to become gradually weaker for some months previous to this date. It had lived ever since 1828 in the same small glass jar in which it was placed by Sir John Dalyell. It must have been at least 66 years old when it died.—E.B.P.]

Note 5. The Duration of Life in Indigenous Terrestrial and Fresh-water Mollusca.

I am indebted to Herr Clessin—the celebrated student of our mollusca—for some valuable notes upon our indigenous snails and bivalves (*Lamellibranchiata*). I could not incorporate them in the text, for a number of necessary details as to the conditions of life are at present entirely unknown, or are at least only known in a very fragmentary manner. No statistics as to the amount of destruction suffered by the young are available, and even the number of eggs produced annually is only known for a few species. I nevertheless include Herr Clessin's very interesting communications, as a commencement to the life statistics of the Mollusca.

(1) '*Vitrinae* are annual; the old animals die in the spring, after having produced the spawn from which the young develope. These continue to grow until the following spring.'

(2) 'The *Succineae* are mostly biennial; *Succinea putris* probably triennial. Fertilization takes place from June till the beginning of August, and the young develope until the autumn. *Succinea Pfeifferi* and *S. elegans* live through the winter, and the fact is proved by very distinct annual markings. Reproduction takes place in July and August of the following year, and they die in the autumn. They continue to grow until their death.'

(3) 'The shells of our native species of *Pupa*, *Clausilia*, and *Bulimus* (with the exception of *Bulimus detritus*) show but faint annual markings. They can hardly require more than two years for their complete development. The great number of living individuals with full-sized shells belonging to these genera, as compared with the number which possess smaller shells, makes it probable that these animals live in the mature condition longer than our other *Helicidae*. I have always found full-sized shells present in at least two-thirds of the individuals of these genera characterized by much-coiled shells—a proportion which I have never seen among our larger *Helicidae*. Nevertheless direct observations as to the length of life in the mature condition are still wanting.'

(4) 'The *Helicidae* live from two to four years; *Helix sericea*, *H. hispida*, two to three years; *H. hortensis*, *H. nemoralis*, *H. arbustorum*, as a rule three years; *H. pomatia* four years. Fertilization is not in these species strictly confined to any one time of year, but in the

case of old animals takes place in the spring, as soon as the winter sleep is over; while in the two-year-old animals it also happens later in the summer.'

(5) 'The *Hyalineae* are mostly biennial: they seldom live three years, and even in the largest species such an age is probably exceptional. The smallest *Hyalineae* and *Helicidae* live at most two years. The length of life is dependent upon the time at which the parents are fertilized, for this decides whether the young begin to shift for themselves early in the summer or later in the autumn, and so whether the first year's growth is large or small.'

(6) 'The species of *Limnaeus*, *Planorbis*, and *Ancylus* live two to three years, that is they take two to three years to attain the full size. *L. auricularis* is mostly biennial, *L. palustris* and *L. pereger* two to three years: I have found that the latter, in the mountains at Oberstorf in the Bavarian Alps, may exceptionally attain the age of four years, that is, it may possess three clearly defined annual markings, whilst the specimens from the plain never showed more than two.'

(7) 'The *Paludinidae* attain an age of three or four years.'

(8) 'The smaller bivalves, *Pisidium* and *Cyclas*, do not often live for more than two years: the larger *Najadae*, on the other hand, often live for more than ten years, and indeed they are not full grown until they possess ten to fourteen annual markings. It is possible that habitat may have great influence upon the length of life in this order.'

'*Unio* and *Anodonta* become sexually mature in the third to the fifth year.'

As far as I am aware but few statements exist upon the length of life in marine mollusca, and these are for the most part very inexact. The giant bivalve *Tridacna gigas* must attain an age of 60 to 100 years[1]. All *Cephalopods* live for at least over a year, and most of them well over ten years; and the giant forms, sometimes mistaken for 'sea-serpents,' must require many decades in which to attain such a remarkable size. L. Agassiz has determined the length of life in a large sea snail, *Natica heros*, by sorting a great number of individuals according to their sizes: he places it at 30 years[2].

[1] Bronn, 'Klassen und Ordnungen des Thierreichs,' Bd. III. p. 466; Leipzig.
[2] Bronn, l. c.

I am glad to be able to communicate an observation made at the Zoological Station at Naples upon the length of life in *Ascidians*. The beautiful white *Cionea intestinalis* has settled in great numbers in an aquarium at the Station, and Professor Dohrn tells me that it produces three generations annually, and that each individual lives for about five months, and then reproduces itself and dies. External conditions accounting for this early death have not been discovered.

It is known that the freshwater *Polyzoa* are annual, but it is not known whether the first individuals produced from a colony in the spring, live for the whole summer. The length of life is also unknown in single individuals of any marine Polyzoon.

Clessin's accurate statements upon the freshwater Mollusca, previously quoted, show that a surprisingly short length of life is the general rule. Only those forms of which the large size requires that many years shall elapse before the attainment of sexual maturity, live ten years or over (*Unio*, *Anodonta*); indeed, our largest native snail (*Helix pomatia*) only lives for four years, and many small species only one year, or two years if the former time is insufficient to render them sexually mature. These facts seem to indicate, as I think, that these molluscs are exposed to great destruction in the adult state, indeed to a greater extent than when they are young, or, at any rate, to an equal extent. The facts appear to be the reverse of those found among birds. The fertility is enormous; a single mussel contains several hundred thousand eggs; the destruction of young as compared with the number of eggs produced is distinctly smaller than in birds, therefore a much shorter duration of the life of each mature individual is rendered possible, and further becomes advantageous because the mature individuals are exposed to severe destruction.

However it can only be vaguely suggested that this is the case, for positive proofs are entirely absent. Perhaps the destruction of single mature individuals does not play so important a part as the destruction of their generative organs. The ravages of parasitic animals (*Trematodes*) in the internal organs of snails and bivalves are well known to zoologists. The ovaries of the latter are often entirely filled with parasites, and such animals are then incapable of reproduction.

Besides, molluscs have many enemies, which destroy them both

on land and in water. In the water,—fish, frogs, newts, ducks and other water-fowl, and on land many birds, the hedgehog, toads, etc., largely depend upon them for food.

If the principles developed in this essay apply to the freshwater Mollusca, we must then infer that snails which maintain the mature condition—the capability of reproduction—for one year, are in this state more exposed to destruction from the attacks of enemies than those species which remain sexually mature for two or three years, or that the latter suffer from a greater proportional loss of eggs and young.

Note 6. Unequal Length of Life in the two Sexes.

This inequality is frequently found among insects. The males of the remarkable little parasites infesting bees, the *Strepsiptera*, only live for two to three hours in the mature condition, while the wingless, maggot-like, female lives eight days: in this case, therefore, the female lives sixty-four times as long as the male. The explanation of these relations is obvious; a long life for the male would be useless to the species, while the relatively long life of the female is a necessity for the species, inasmuch as she is viviparous, and must nourish her young until their birth.

Again, the male of *Phylloxera vastatrix* lives for a much shorter period than the female, and is devoid of proboscis and stomach, and takes no food: it fertilizes the female as soon as the last skin has been shed and then dies.

Insects are not the only animals among which we find inequality in the length of life of the two sexes. Very little attention has been hitherto directed to this matter, and we therefore possess little or no accurate information as to the duration of life in the sexes, but in some cases we can draw inferences either from anatomical structure or from the mode of development. Thus, male *Rotifers* never possess mouth, stomach, or intestine, they cannot take food, and without doubt live much shorter lives than the females, which are provided with a complete alimentary canal. Again, the dwarf males of many parasitic *Copepods*—low Crustacea—and the 'complementary males' of *Cirrhipedes* (or barnacles) are devoid of stomach, and must live for a much shorter time than the females; and the male *Entoniscidae* (a family

of which the species are endo-parasitic in the larger Crustacea), although they can feed, die after fertilizing the females; while the latter then take to a parasitic life, produce eggs, and continue to live for some time. It is supposed that the dwarf male of *Bonellia viridis* does not live so long by several years as the hundred times larger female, and it too has no mouth to its alimentary canal. These examples might be further increased by reference to zoological literature.

In most cases the female lives longer than the male, and this needs no special explanation; but the converse relation is conceivable, when, for instance, the females are much rarer than the males, and the latter lose much time in seeking them. The above-mentioned case of *Aglia tau* probably belongs to this category.

We cannot always decide conclusively whether the life of one sex has been lengthened or that of the other shortened; both these changes must have taken place in different cases. There is no doubt that a lengthening of life in the female has arisen in the bees and ants, for both sexes of the saw-flies, which are believed to be the ancestors of bees, only live for a few weeks. But among the *Strepsiptera* the shorter life of the male must have been secondarily acquired, since we only rarely meet with such an extreme case in insects.

Note 7. Bees.

It has not been experimentally determined whether the workers, which are usually killed after some months, would live as long as the queen, if they were artificially protected from danger in the hive; but I think that this is probable, because it is the case among ants, and because the peculiarity of longevity must be latent in the egg. As is well known, the egg which gives rise to the queen is identical with that which produces a worker, and differences in the nutrition alone decide whether a queen or a worker shall be formed. It is therefore probable that the duration of life in queen and worker is potentially the same.

Note 8. Death of the Cells in higher Organisms.

The opinion has been often expressed that the inevitable appearance of normal 'death' is dependent on the wearing out of the

tissues in consequence of their functional activity. Bertin says, referring to animal life[1]:—'L'observation des faits y attache l'idée d'une terminaison fatale, bien que la raison ne découvre nullement les motifs de cette nécessité. Chez les êtres qui font partie du règne animal l'exercise même de la rénovation moléculaire finit par user le principe qui l'entretient sans doute parceque le travail d'échange ne s'accomplissant pas avec une perfection mathématique, il s'établit dans la figure, comme dans la substance de l'être vivant, une déviation insensible, et que l'accumulation des écarts finit par amener un type chimique ou morphologique incompatible avec la persistance de ce travail.'

Here the replacement of the used-up elements of tissue by new ones is not taken into account, but an attempt is made to show that the functions of the whole organism necessarily cause it to waste away. But the question at once arises, whether such a result does not depend upon the fact that the single histological elements, —the cells,—are worn out by the exercise of function. Bertin admits this to be the case, and this idea of the importance of changes in the cells themselves is everywhere gaining ground. But although we must admit that the histological elements do, as a matter of fact, wear out, in multicellular animals, this would not prove that, nor explain why, such changes must follow from the nature of the cell and the vital processes which take place within it. Such an admission would merely suggest the question:—how is it that the cells in the tissues of higher animals are worn out by their function, while cells which exist in the form of free and independent organisms possess the power of living for ever? Why should not the cells of any tissue, of which the equilibrium is momentarily disturbed by metabolism, be again restored, so that the same cells continue to perform their functions for ever:—why cannot they live without their properties suffering alteration? I have not sufficiently touched upon this point in the text, and as it is obviously important it demands further consideration.

In the first place, I think we may conclude with certainty from the unending duration of unicellular organisms, that such wearing out of tissue cells is a secondary adaptation, that the death of the cell, like general death, has arisen with the complex, higher organisms. Waste does not depend upon the intrinsic nature of the cells, as the

[1] Cf. the article 'Mort' in the 'Encyclop. Scienc. Méd.' vol. M. p. 520.

primitive organisms prove to us, but it has appeared as an adaptation of the cells to the new conditions by which they are surrounded when they come into combination, and thus form the cell-republic of the metazoan body. The replacement of cells in the tissues must be more advantageous for the functions of the whole organism than the unlimited activity of the same cells, inasmuch as the power of single cells would be much increased by this means. In certain cases, these advantages are obvious, as for example in many glands of which the secretions are made up of cast-off cells. Such cells must die and be separated from the organism, or the secretion would come to an end. In many cases, however, the facts are obscure, and await physiological investigation. But in the meantime we may draw some conclusions from the effects of growth, which are necessarily bound up with a certain rate of production of new cells. In the process of growth a certain degree of choice between the old cells which have performed their functions up to any particular time, and the new ones which have appeared between them, is as it were left to the organism.

The organism may thus, figuratively speaking, venture to demand from the various specific cells of tissues a greater amount of work than they are able to bear, during the normal length of their life, and with the normal amount of their strength. The advantages gained by the whole organism might more than compensate for the disadvantages which follow from the disappearance of single cells. The glandular secretions which are composed of cell-detritus, prove that the cells of a complex organism may acquire functions which result in the loosening of their connexion with the living cell-community of the body, and their final separation from it. And the same facts hold with the blood corpuscles, for the exercise of their function results in ultimate dissolution. Hence it is not only conceivable, but in every way probable, that many other functions in the higher organisms involve the death of the cells which perform them, not because the living cell is necessarily worn out and finally killed by the exercise of any ordinary vital process, but because the specific functions in the economy of the cell community which such cells undertake to perform, involve the death of the cells themselves. But the fact that such functions have appeared,—involving as they do the sacrifice of a great number of cells,—entirely depends upon the replacement of the old

by newly formed cells, that is by the process of reproduction in cells[1].

We cannot *a priori* dispute the possibility of the existence of tissues in which the cells are not worn out by the performance of function, but such an occurrence appears to be improbable when we recollect that the cells of all tissues owe their constitution to a very far-reaching process of division of labour, which leaves them comparatively one-sided, and involves the loss of many properties of the unicellular, self-sufficient organism. At any rate we only know of potential immortality in the cells which constitute independent unicellular organisms, and the nature of these is such that they are continually undergoing a complete process of reformation.

If we did not find any replacement of cells in the higher organism, we should be induced to look upon death itself as the direct result of the division of labour among the cells, and to conclude that the specific cells of tissues have lost, as a consequence of the one-sided development of their activities, the power of unending life, which belongs to all independent primitive cells. We should argue that they could only perform their functions for a certain time, and would then die, and with them the organism whose life is dependent upon their activity. The longer they are occupied with the performance of special functions, the less completely do they carry out the phenomena of life, and hence they lead to the appearance of retrogressive changes. But the replacement of cells is certain in many tissues (in glands, blood, etc), so that we can never seek a satisfactory explanation in the train of reasoning indicated above, but we must assume the existence of limits to the replacement of cells. In my opinion, we can find an explanation of this in the general relations of the single individual to its species, and to the whole of the external conditions of life; and this is the explanation which I have suggested and have attempted to work out in the text.

[1] Roux, in his work 'Der Kampf der Theile im Organismus,' Jena 1881, has attempted to explain the manner in which division of labour has arisen among the cells of the higher organisms, and to render intelligible the mechanical processes by which the purposeful adaptations of the organism have arisen.

Note 9. Death by Sudden Shock.

The most remarkable example of this kind of death known to me, is that of the male bees. It has been long known that the drone perishes while pairing, and it was usually believed that the queen bites it to death. Later observations have however shown that this is not the case, but that the male suddenly dies during copulation, and that the queen afterwards bites through the male intromittent organ, in order to free herself from the dead body. In this case death is obviously due to sudden excitement, for when the latter is artificially induced, death immediately follows. Von Berlepsch made some very interesting observations on this point, 'If one catches a drone by the wings, during the nuptial flight, and holds it free in the air without touching any other part, the penis is protruded and the animal instantly dies, becoming motionless as though killed by a shock. The same thing happens if one gently stimulates the dorsal surface of the drone on a similar occasion. The male is in such an excited and irritable condition that the slightest muscular movement or disturbance causes the penis to be protruded[1].' In this case death is caused by the so-called nervous shock. The humble-bees are not similarly constituted, for the male does not die after fertilizing the female, 'but withdraws its penis and flies away.' But the death of male bees, during pairing, must not be regarded as normal death. Experiment has shown that these insects can live for more than four months[2]. They do not, as a matter of fact, generally live so long; for—although the workers do not, as was formerly believed, kill them after the fertilization of the queen, by direct means—they prevent them from eating the honey and drive them from the hive, so that they die of hunger[3].

We must also look upon death which immediately, or very quickly, follows upon the deposition of eggs as death by sudden shock. The females of certain species of *Psychidae*, when they reproduce sexually, may remain alive for more than a week waiting for a male: after fertilization, however, they lay their eggs and die, while the parthenogenetic females of the same species lay their

[1] von Berlepsch, 'Die Biene und ihre Zucht,' etc.
[2] Oken, 'Isis,' 1844, p. 506.
[3] von Berlepsch, l. c., p. 165.

eggs and die immediately after leaving the cocoon; so that while the former live for many days, the latter do not last for more than twenty-four hours. 'The parthenogenetic form of *Solenobia triquetrella*, soon after emergence, lays all her eggs together in the empty case, becomes much shrunken, and dies in a few hours.' (Letter from Dr. Speyer, Rhoden.)

Note 10. Intermingling during the Fission of Unicellular Organisms [1].

Fission is quite symmetrical in *Amoebae*, so that it is impossible to recognise mother and daughter in the two resulting organisms. But in *Euglypha* and allied forms the existence of a shell introduces a distinguishing mark by which it is possible to discriminate between the products of fission; so that the offspring can be differentiated from the parent. The parent organism, before division, builds the parts of the shell for the daughter form. These parts are arranged on the surface of that part of the protoplasm, external to the old shell, which will be subsequently separated as the daughter-cell. On this part the spicules are arranged and unite to form the new shell. The division of the nucleus takes place after that of the protoplasm, so that the daughter-cell is for some time without a nucleus. Although we can in this species recognise the daughter-cell for some time after separation from the parent by the greater transparency of its younger shell, it is nevertheless impossible to admit that the characteristics of the two animals are in any way different, for just before the separation of the two individuals a circulation of the protoplasm through both shells takes place after the manner described in the text, and there is therefore a complete intermingling of the substance of the two bodies.

The difference between the products is even greater after transverse fission of the *Infusoria*, for a new anus must be formed at the anterior part and a new mouth posteriorly. It is not known whether any circulation of the protoplasm takes place, as in *Euglypha*. But even if this does not occur, there is no reason for

[1] Cf. August Gruber, 'Der Theilungsvorgang bei Euglypha alveolata,' and 'Die Theilung der monothalamen Rhizopoden,' Z. f. W. Z., Bd. XXXV. and XXXVI., p. 104, 1881.

believing that the two products of division possess a different duration of life.

The process of fission in the *Diatomaceae* seems to me to be theoretically important, because here, as in the previously-mentioned *Monothalamia* (*Euglypha*, etc.), the new silicious skeleton is built up within the primary organism, but not, as in *Euglypha*, for the new individual only, but for both parent and daughter-cell alike[1]. If we compare the diatom shell to a box, then the two halves of the old shell would form two lids, one for each of the products of fission, while a new box is built up afresh for each of them. In this case there is an absolute equality between the products of fission, so far as the shell is concerned.

Note 11. Regeneration.

A number of experiments have been recently undertaken, in connection with a prize thesis at Würzburg, in order to test the powers of regeneration possessed by various animals. In all essential respects the results confirm the statements of the older observers, such as Spallanzani. Carrière has also proved that snails can regenerate not only their horns and eyes, but also part of the head when it has been cut off, although he has shown that Spallanzani's old statement that they can regenerate the whole head, including the nervous system, is erroneous[2].

Note 12. The Duration of Life in Plants.

The title of the work on this subject mentioned in the Text is 'Die Lebensdauer und Vegetationsweise der Pflanzen, ihre Ursache und ihre Entwicklung,' F. Hildebrand, Engler's botanische Jahrbücher, Bd. II. 1. und 2. Heft, Leipzig, 1881.

Note 13.

[Many interesting facts and conclusions upon the subject of this essay will be found in a volume by Professor E. Ray Lankester, 'On comparative Longevity in Man and the lower Animals,' Macmillan and Co., 1870.—E. B. P.]

[1] Cf. Victor Hensen, 'Physiologie d. Zeugung,' p. 152.

[2] Cf. J. Carrière, 'Ueber Regeneration bei Landpulmonaten,' Tagebl. der 52. Versammlg. deutsch. Naturf. pp. 225-226.