THE HARVEIAN ORATION.

1872.

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Hanc Magni illius Gulielmi Harveii senis octogenarii imaginem, qui sanguinis circuitum primus monstravit, medicinamque rationalem instituit, ad picturam archetypam, quam in suo servat museo, effictam, honoris causâ hic ponendam curavit Richardus Mead, Med. Reg. A.D. 1739. (*a*)

THE HARVEIAN ORATION

DELIVERED AT THE

ROYAL COLLEGE OF PHYSICIANS

JUNE 26, 1872:

BEING AN

ANALYSIS OF HARVEY'S EXERCISES ON GENERATION.

BY

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LONDON:
LONGMANS, GREEN, AND CO.
1872.

TO

GEORGE BURROWS, M.D. F.R.S.

COLL. CAII CANTAB.

PRESIDENT OF THE ROYAL COLLEGE OF PHYSICIANS OF LONDON

THIS ORATION

DELIVERED BY HIS DESIRE

IS DEDICATED.

THE HARVEIAN ORATION.

1872.

President and Fellows,

This day serves to recall an event which, two hundred and fifteen years ago, must have been the occasion of much sorrow to the Fellows of our College then assembled. On the 26th of June, in 1657, Harvey was carried to his grave, a long train of his friends and colleagues following far beyond the city walls (*b*, *c*).

But of Harvey dead it is not my purpose further to speak. Rather let us regard him as living still among us, in the records of his works, in the memory of the benefits which he conferred upon this College, and in the bright example of his character and mind.

On any occasion on which the countrymen of Harvey meet, with the object of carrying out his

expressed wish, that annually an oration should be delivered, no difficulty need be felt on the part of him who is appointed to that duty in finding a subject suitable to the purpose. And although, in accordance with custom, such address need have no reference to the founder further than with a view of recalling his desire to mind, that the orator should 'exhort the members of the College to study and search out the secrets of Nature by way of experiment,' yet, should the speaker find in Harvey's works matter which may have been selected by himself for particular study and investigation, he would naturally take that subject as furnishing him with the best material. It is on this ground, therefore, that I have taken the subject of *Generation*, as exemplified in the celebrated *Exercises* of Harvey, which, although constituting by no means the more important of his two great works, yet forms the larger one, and that which, at the same time, is perhaps the least generally read (*d*). It does not appear, moreover, from an examination of former orations, that this subject has been selected before; so that here I have the advantage—if, indeed, it be an advantage—of occupying untrodden ground.

In order that we may the better understand Harvey's position when he commenced those studies—of which the ultimate fruit was his celebrated treatise on Generation—it is desirable to bear in mind the prevalent physiological doctrines of that day. Harvey found the teachers of this branch of physiology divided into two principal parties. According to the teaching of Aristotle, the principles of generation were the male and the female, she contributing the matter, he the form; and immediately after conception the vital principle, and the first particle of the future fœtus—namely, the heart, in animals having red blood—were formed from the menstrual blood in the uterus. On the other hand, the followers of Galen, with whom were the physicians, taught that the semen of both parents combined furnished the offspring, which resembled one or other according as this or that predominated, and that by virtue of such predominance it became either male or female.

Neither of these doctrines, however, gave satisfaction to Harvey, but the contrary. 'That they are erroneous and hasty conclusions,' he says, 'is easily made to appear: like phantoms of darkness,

they suddenly vanish before the light of anatomical inquiry;' nor, he adds, 'is any long refutation necessary when the truth can be seen with one's proper eyes—where the inquirer, by simple inspection, finds everything in conformity with reason; and where, at the same time, he is made to understand how unsafe, how base a thing it is to receive instruction from others' comments without examination of the objects themselves, the rather as the book of Nature lies so open, and is so easy of consultation.'

That Harvey assigned to himself the path of direct observation, as the only one which could satisfy him, is rendered plain by what I have just quoted. And in what way, and by what reflections, he intended to sweeten his labour, appears further from another passage, in which he has recorded his thoughts in language so illustrative of his own mind and character that I cannot resist giving this also. 'Nor is there any just cause,' says Harvey, 'wherefore the labour should deter anyone, and neither indeed would the way I propose be felt as so barren and lonely, but for the custom or vice of the age we live in, when men, inclined to idleness, prefer going wrong with the

many to becoming wise with the few, through dint of toil and outlay of money. And truly in such pursuits it is sweet not merely to toil, but even to grow weary, when the pains of discovering are amply compensated by the pleasures of discovery. It were disgraceful, therefore, with this most spacious and admirable realm of nature before us, and where the reward ever exceeds the promise, did we take the reports of others upon trust, and go on coining crude problems out of these, and on them hanging knotty and captious and petty disputations. Nature is herself to be addressed; the paths she shows us are to be boldly trodden; for thus, and whilst we consult our proper senses, from inferior advancing to superior levels, shall we penetrate at length into the heart of her mystery.'

That Harvey designed to write a systematic work on generation upon a large scale cannot, I think, for a moment be questioned by anyone who carefully examines these celebrated Exercises. But that the work which has come down to us under this title is not that complete one which Harvey had contemplated, and must at one time have hoped to finish, is, I think, equally removed

from doubt. In fact, the seventy-two exercises of which the treatise mainly consists should be regarded rather as constituting the materials out of which a more perfect book should be constructed (*e*).

Many circumstances appear to lend colour to this view, but more particularly the great unwillingness of the author to part with it in its present form. This we learn from Sir George Ent, to whom, perhaps, we are indebted for its publication at all, or, at any rate, during Harvey's life, and who thus graphically describes the circumstances under which he became possessed of it. Having waited upon Harvey, who had then in a great measure retired from public life, Ent, after some introductory conversation, proceeds to unfold the object of his visit by representing to the great physiologist that the world was still looking for some further work from his hands. To this Harvey replies, 'And would you be the man who should recommend me to quit the peaceful haven where I now pass my life, and launch again upon the faithless sea? You know full well what a storm my former lucubrations raised. Much better is it oftentimes to grow wise at home and

in private, than by publishing what you have amassed with infinite labour, to stir up tempests that may rob you of peace of mind for the rest of your days.' Ultimately, however, the persuasive power of Ent appears to have overcome the reluctance of Harvey, who, giving up his papers, consented to their publication, either immediately or at some future time. Ent, having thus accomplished his purpose, retires with Harvey's portfolio of notes under his arm, feeling, as he says, like another Jason, laden with the golden fleece; and, after eagerly examining the contents, he hastens to carry out his promise of undertaking the correction of the press, and ultimately of performing what he terms the 'midwife's part,' by ushering into the light 'this product of his colleague's genius' (*f*).

But here it should be remarked that these Exercises bear no evidence of having been carefully revised by the author previous to publication. Indeed, it is obvious that this was not the case, otherwise numerous continually recurring passages would have been omitted or abbreviated, and statements which appear in a certain sense to be antagonistic to each other would doubtless have

been reconciled or explained. On account of this omission, which is the more to be regretted in a work bearing evidence of much devoted labour, and of the application to it of a mind of great power, very considerable and almost insuperable difficulties are sometimes encountered in the attempt to arrive at the author's precise meaning in regard to certain important particulars of which he treats.

Harvey commences his work on the generation of animals with the study of the egg; and, after explaining what he understands by an egg, he proceeds to select two examples which are marked out for special investigation.

The egg of the common fowl being readily obtainable, and admitting of comparatively easy observation, this is selected as Harvey's first study. But this particular path had been already trodden by two previous observers: viz. Aristotle among the ancients, and Fabricius of Aquapendente among more recent authors. Neither of these, however, had carried their observations to an extent sufficient to satisfy Harvey's mind; and accordingly we find him setting to work, and by his own labours endeavouring to supply what

appeared to be wanting in the observations of either or both of these (*g*).

After devoting no fewer than sixty-two exercises to this special object, he proceeds to select a second example from the viviparous class; not, however, without first pointing out the artificial nature of the distinction between oviparous and viviparous reproduction. He asserts that such a division does not satisfy him, inasmuch as all animals whatsoever may be said, in a certain sense, to proceed from ova, and are entitled respectively oviparous or viviparous, rather in respect of their mode of bringing forth than of their first formation.

The second example chosen is from the viviparous class—and here he had advantages which neither of his predecessors possessed; for the liberality of the King,* his master, had placed at his disposal the costly occupants of the royal parks, and from these he was permitted to select as many examples as might serve his purpose. Of this privilege Harvey fully availed himself; and to this opportunity we are indebted for those valuable and original observations on the gestation

* Charles I.

of the hind and doe which constitute some of the most valuable portions of Harvey's work. Interwoven with these observations, we find constant reference to the doctrines of Aristotle and of Fabricius, together with occasional quotations of the opinions of others; and when to these are added the speculations of Harvey himself, which we find scattered through every portion not only of the Exercises but also of the four additional essays with which the work concludes, we shall have enumerated the leading features of Harvey's remarkable and most interesting treatise.

Remarkable and most interesting it may well be termed, when we consider the circumstances under which its composition was attempted; for scarcely were any of the facts yet discovered upon which a consistent theory of generation might be based. Not one, indeed, of the main points which constitute the foundation of our present views regarding the physiology of this subject, had yet been ascertained. A long interval had still to be bridged over before the first of these elementary facts was fully established. And when now, looking back upon the past, we see with what persevering industry, and by what a long

series of observation, conducted by many fellow-labourers, or rather by many labourers working in the same direction, the knowledge which we now possess has been gradually and slowly acquired, and contrast this with the comparative ignorance —it might almost be said the absolute darkness— which prevailed in Harvey's day, we may well contemplate with admiration the courage and energy of the man who, in the face of such difficulties, could assign to himself the task of composing a systematic work on the subject of generation.

Nor must we forget that the microscope, infinitely the most important instrument of research now possessed by physiologists, was at this period practically unknown. We do, indeed, find indications of some simple inventions with which magnifying power must have been associated, though they may not, perhaps, have been used for optical purposes, at a very early date indeed; and possibly of this nature were those burning glasses to which Aristophanes, in his comedy of *The Clouds*, makes reference (*h*). Moreover, lenses, such as are now used by engravers, are said to have been found in the ruins of Herculaneum.

And even Harvey himself had some knowledge of magnifying or burning glasses; for, in speaking of different modes of producing fire, he says, 'Nor even is a spark necessary, since by the solar rays transmitted through a small piece of glass, and concentrated to a focus, fire may be immediately produced, and the largest things be set on flames.' But down to a period ten years later than Harvey's death, when the discovery of the spermatozoa was first announced by Leeuwenhoek, the microscope was so little known, and, even when known at all, existed in such an imperfect form, that Leeuwenhoek found it necessary to construct with his own hands not only the lenses, but even the framework of the very primitive instruments with which he conducted his observations (*i*).

One other point may also be noticed with reference to Harvey's original design. His observations were not limited to the vertebrate series, from which he had selected the two typical examples just named, but they were also extended to the invertebrates. This we may gather from several passages occurring in his work, but more particularly from the statement which he made to

Ent as one ground of objection against parting with his papers—namely, that they must be held to be imperfect, as not containing his investigations on the generation of Insects—a class which is second to none in the whole range of the animal kingdom for the information which it affords in the study of this process. Harvey appears to have bestowed much care upon these, and his distress at the loss of them was correspondingly great. As Aubrey describes it, 'they contained many curious observations; but these, together with his goods at his lodgings at Whitehall, were plundered at the beginning of the Rebellion; and he often said that, of all the losses he sustained, no griefe was so crucifying to him as the losse of these papers, which for love or money he could never retrieve or obtain' (*k*).

From this brief reference to the general scope and purpose of Harvey's work on generation, I pass on to notice more particularly some of its leading features, and to compare them with the established facts and doctrines of the present time; and, if any apology be needed for the tracing out of these in a certain historical order, I trust it will be found in the fact that many of our present

views can be shown to have their representatives in the doctrines of a past age; and that what we occasionally regard as discoveries have been anticipated, in thought at least, by many of our predecessors.

And, by way of introduction, I will proceed to consider what were Harvey's views in regard to the commencement of animal life. The dictum, 'Omne animal ex ovo,' or, as often quoted, 'Omne vivum ex ovo,' is commonly ascribed to Harvey; but, if any one desire to find in the Exercises this phrase, in the aphoristic shape here quoted, he will, I think, be disappointed (*l*). There can be no question that the expression 'Omne vivum ex ovo' serves to represent in general terms the particular doctrine which it was a main purpose of Harvey to teach. It cannot, however, be said to be his exclusive doctrine, since he frequently uses certain qualifying phrases. Nor is it quite clear that he is averse from admitting the possibility of so-called spontaneous generation; as, for example, in the twenty-eighth exercise, where he says that 'some animals arise spontaneously, or, as is commonly said, by putrefaction.'

But, not to dwell here upon this last subject, to

which, if time permit, I hope to return later on, we may proceed to inquire what Harvey understood by an egg. It would be easy to select passages illustrative of each of the particulars just noticed; but no single one, perhaps, could be found more generally representing his views than the following, taken from his sixty-third Exercise. After referring to the statement of Fabricius that the greater number of animals are engendered from eggs, he says, as it were impatiently: 'Now we, at the very commencement of our observations, affirmed that *all* animals are, in a certain manner, produced from eggs; for in the same sense and order in which a chick is formed and developed out of an egg, equally in the same manner is the fœtus of viviparous animals engendered from a pre-existing conception. Both species of generation constitute one and the same thing; and the beginning of either is termed an egg, or at least something which by analogy may be so regarded.' And then he goes on to say, 'For it is generally admitted, and is indeed manifest, that all embryos, even of man himself, are procreated from some conception or a certain primordium. And the matter stands thus: that

which in things arising spontaneously is a primordium, in plants is seed, and in oviparous animals an ovum.'

Further, it is a prominent feature in the work of Harvey, that he held the doctrine of epigenesis, of which he was one of the earliest advocates, against that of metamorphosis, in the sense in which it was maintained by Fabricius, as well as that of evolution or preformation, the favourite doctrine, more especially of a later time. Harvey leaves us in no doubt as to what he means by epigenesis. In his forty-fifth and fifty-first Exercises, as well as elsewhere, he says, that from his history 'it appears clear, that the generation of the chick from the egg is the result of epigenesis rather than of metamorphosis; and all its parts are not fashioned simultaneously, but emerge in their due succession and order.' That there first exists a particular genital particle, in virtue of which, as from a beginning, all other parts proceed. That the origin, growth and consummation are brought about by a method of nutrition, and that at length the fœtus is thus produced. This is Harvey's doctrine of epigenesis, as stated by himself. And if we were to follow out these views to a later period,

we should find him supported by Malpighi and by Wolff; while, on the other hand, carrying the investigation in an opposite direction, we should find Haller and Bonnet entirely opposed to these views. Haller maintained that the parts of the fœtus, although invisible, nevertheless exist in the egg, and that these, becoming gradually expanded or unfolded by degrees, constituted the embryo. But Bonnet's views represented another phase of the same doctrine, for he maintained that not only are all the parts of the fœtus pre-existent in the ovum, but that all germs, past and prospective—those that have been, and those that are yet to be born—were all existent in the ovary of the original parent; that these germs lie dormant in their abode, until one or more are aroused by the exciting influence of the male; and that, consequently, there is not in nature the new formation of any animal.

But these speculations, in so far as they are opposed to the doctrine maintained by Harvey, might be easily let alone, were it not that the controversy thus raised has been sustained, though with sundry variations, ever since. And although the ground has been in some respects shifted, yet the terms

are retained, and the general principles involved in these two opposite doctrines represent the divergence of opinion exhibited by two opposite parties in the present day (*m*).

I will now venture to draw your attention to some of the leading facts regarding the process of generation which have been ascertained since Harvey wrote, and especially those of recent times.

This may be most conveniently done by considering, in the first place, that which each parent contributes to the process of generation, and then by showing in what manner these essential elements combine in order to lay the foundation of the future embryo.

Reversing the order adopted by Harvey, I will commence with the consideration of

The part which the male contributes to the process of generation, a subject of which Harvey had no real knowledge.

And this brings us at once to what is the most curious part in the history of those several discoveries which have led up to our present complete knowledge of the subject of generation. No physiological fact, perhaps, was ever established with greater difficulty than that of the necessity of the

sperm-cell, or spermatozoon, for supplying the material or means by which the fertilization of the ovum is accomplished.

Two hundred years and more have been occupied in the investigation of this part of the subject, and during this period the sperm-cell has been submitted to examination under microscopes of every form of construction, by observers, incompetent as well as most competent, and has given rise to numerous speculations, some of which may be said to represent the highest flight of human imagination, while others—and these, happily, the more numerous—bring us to the firm ground of sober truth. I cannot venture to take you through all this wilderness, which, on casting back our eyes, we see decaying or dead behind us (*n*). The more ridiculous fancies, the mushrooms of the day, perished of themselves long ago. But to other and more sturdy growths it was found necessary to apply the pruning-knife or the axe, until at last we have arrived at materials sufficiently definite to admit of our basing upon them sound and rational conclusions. Some, indeed, of the more important conjectures which from time to time have been offered regarding the use of the

spermatozoa must of necessity be noticed, in speaking of the mode in which the fertilization of the ovum is effected. It will suffice, therefore, if we now examine briefly the structure and mode of formation of these bodies, as far as microscopical examination has yet gone.

The sperm-cell appears to undergo a process of development closely analogous to that of the germ-cell, which we shall have presently to trace; and since no material variation is observable in the formation of the spermatozoa in the different classes of vertebrates, the description of any one may serve for that of the rest. Hitherto, in considering this subject, the term 'sperm-cell' has been employed as a general expression, and as the equivalent of spermatozoon; but in speaking now of the development of these bodies, a greater strictness must be observed. Taking the higher vertebrata as a type, the testes are found to contain in considerable quantity free cells, the so-called parent cells. Within each of these again are found several smaller cells, the daughter cells or vesicles of development—each daughter cell containing a separate spermatozoon. These, by their growth, burst through the delicate cell wall that confines

them, and escaping into the parent cell, become aggregated into bundles, or lie coiled in the interior. Ultimately this outer wall bursts, and the spermatozoa are set free: they are not, however, generally as yet fully developed; they appear to go through a further process of growth, which has much engaged the attention of microscopic observers of late, and which seems to have not altogether escaped the attention of Leeuwenhoek, their discoverer, if we may credit the very extraordinary illustrations which are to be found in his work, with considerable help, apparently, from the imagination of the artist (*o*).

When fully formed, the spermatozoa present very remarkable differences in different classes and species. These relate chiefly to the part commonly termed the body or head—for the caudal appendage is very similar in all, the chief difference being in its greater or less length. The variations just mentioned may possibly have reference to the mode of penetration of the spermatozoon within the ovum, according to the greater or less thickness of the enveloping membrane of the latter; but that which microscopic observers are at this time most intent on discovering is the nature and arrangement

of those small granular particles which constitute as yet all that has been distinctly seen in the interior of the body, and which respond to the test of staining with carmine precisely in the same way as the granular contents of the ovum, while much observation has been expended and much speculation hazarded in the effort to determine the means by which the vibratory motion of the spermatozoon is effected. But even if nothing more satisfactory can be discovered than that which is already known, we may still safely regard this little portion of granular matter as constituting the living material that confers fertilisation upon the ovum, while we may look upon the vibratile appendage as the instrument by which this is carried to its destination, and the continuance of its motion as the sign that the power of conferring fertility is still retained.

We may next turn our attention to

The part which the female contributes to the process of generation.

'Propter solum uterum est mulier id quod est' is an aphorism often quoted, and originating with Van Helmont, a contemporary of Harvey (*p*); but the idea which it is intended to convey of the greater

influence and importance of the uterus was the dominant one long anterior to Van Helmont's day. Take, for example, what Aretæus says of it in his wonderful description of that organ, and of its mode of producing hysteria and various other affections. 'In the middle of the flanks of woman lies the womb, a female viscus, closely resembling an animal; for it is moved of itself hither and thither in the female, also upwards in a direct line to below the cartilage of the thorax, and also obliquely to the right or to the left, either to the liver or spleen; and, in a word, it is altogether erratic.' Then, after describing the preference of the uterus for certain odours and its aversion to others, so that it advances towards the one or flees from the other, Aretæus concludes by saying that, 'on the whole, the womb is like an animal within an animal.' The leading idea which underlies all this extravagant expression is obvious enough. It is plain that Aretæus intended to represent the uterus as the principal agent in the production of those symptoms which he here, however imperfectly, endeavours to describe. Doubtless here the term 'uterus' is made to include the ovary, with the rest of the reproductive organs;

and in this sense, as a comprehensive expression, we may be excused for employing it, as we still do, in the conventional language of the present day. But the time has long arrived when physiology, and especially pathology, might derive advantage from greater precision in the separate use of these several terms. In a physiological sense, the uterus, together with every portion of the generative apparatus, should be regarded as an appendage of the ovary. In many animals it has not even an existence, as in Fishes and Batrachians, where the ova are expelled previously to fertilisation, and no uterus is needed. But in those classes in which it is found, the office of the uterus must be regarded as supplementary to that of the ovary. Its presence there, indeed, is necessary to complete the act of reproduction in its regular course, since it is the organ which receives and nourishes the ovum after conception, and it is the part which serves for its expulsion when sufficiently developed. But these are offices obviously subordinate to those of the ovary. On the other hand, the ovary is that part in which the generative element, essential to the act of reproduction, is first formed. It is that part which appears to regulate, in a great

measure, the growth of the body, and to determine the periodical recurrence of conception and of other functions. When the ovary is artificially removed from the body, the individual becomes unsexed; and when its functional activity declines or ceases, the power of exercising the generative faculty is altogether lost.

In every sense, then, the ovary must be regarded as the more important organ; yet its structure was little known in the times of which we are now speaking, and consequently its offices and homologies were entirely misunderstood. By Harvey the ovaries, in accordance with the then prevailing custom in regard to human anatomy, are almost always termed the testes; though he does, indeed, suggest that the ovaries appear to bear analogy to the male gland as regards Fishes. The merit of having been the first to announce an opinion that the so-called testis is to be regarded as analogous to the ovary is due to De Graaf, who in 1667 gave a full account, with most accurate illustrations, not only of the ovary, but also of the ovicapsule as well as of the corpus luteum. In his well-known work he describes the use of the ovary as being to generate, to nourish, and to bring to maturity the

ova; and further, he suggests that these should be termed ovaria rather than testes, since no similarity either in form or in contents can be traced between the two.

We must, indeed, wait until a much later date before we arrive at a time when the structure and functions of the ovary and its contents began to be thoroughly understood, and this period may be fairly considered as having its commencement with the discovery, in 1825, of the 'germinal vesicle' in the ovarian ovum of Birds by Purkinje, followed, two years later, by the observation of the ovum in the Mammalia by Baer.

It had been a cherished view, up to a comparatively recent date, that the number of Graafian follicles contained in each human ovarium, and representing so many ova, was ordinarily from twelve to twenty, and that, if these became exhausted by frequent abortion or child-bearing, the limit of human fecundity would be reached. But this notion, doubtless, arose from the circumstance that only the more developed follicles had been observed. It required the microscope to demonstrate the fact that, so far from the number being thus limited, the difficulty consists rather in estimating

them, especially in young subjects, where a single section of an ovary serves to display a hundred or more ovicapsules and ova: and it matters little at how early a period of life we commence the investigation, for occasionally in the ovarium even of the fœtus some traces of commencing formation of ova may be found. At first, nothing is distinguishable in the mammalian ovary but an uniform mass of primary cells and cell-nuclei; then, when the follicle or ovisac is about to form, little round or ovoidal aggregations of primary cells may be observed, constituting groups that are distributed in considerable numbers throughout the ovary. Within each of these little groups is soon perceived the germinal vesicle. This we may regard as the essential portion of every ovum; and from this little nucleated germ-cell man, in common with the rest of the vertebrata, takes his origin.

By the gradual evolution and multiplication of granular cells and oil-globules, much greater in amount in some classes than in others, the yelk is formed, sometimes obscuring the germinal vesicle; while at the same time, surrounding each of these little groups of cells, is perceived a delicate transparent tunic, the ovisac in its first stage of

formation ; the yelk receiving its limitation by the addition of a fine vitelline membrane. In animals that produce and emit vast numbers of ova at one time, these become ripened simultaneously, and when the spawning season arrives they are expelled in quick succession, or in one or more masses ; but when the number of the progeny is smaller, a corresponding number of ova becomes ripened in succession, and these are gradually found approaching the margin of the ovary or projecting above its surface.

The formation of the ovarian ovum being completed, the next most important step in the process of reproduction is about to take place—viz. its escape from the ovary. If now the ovum be examined, it will be found to present certain differences in its constitution, according to the class to which it belongs. In the mammalian ovum, the yelk or vitellus containing the element which is to supply the germinal portion with additional materials for growth and development during the interval which elapses between its detachment from the ovary and its arrival at the uterus, is comparatively small ; for the passage is rapid, occupying generally no more than a few days, and the ovum,

having once reached the uterus, draws its nutrition from this latter source. But in birds, for example, where the embryo is entirely dependent for its materials of growth upon what it carries with it from the ovary, together with such additional matter as the oviduct supplies, a very large portion of food-substance must necessarily be provided. And it is to this element of the ovum in birds and some reptiles that its great bulk as well as brilliant colouring are due. Hence the division in such cases into a smaller or germinal portion—the germ-yelk and a larger food-yelk, destined for the supply of materials for subsequent nutrition. And here we are reminded of that excellent definition of an ovum which Aristotle has given, and which appears applicable to it, more or less, in all stages ; namely, that 'an ovum is that from part of which an animal is engendered, and the remainder of which is food for the thing engendered.'

In thus reviewing these initial steps in the process of reproduction, we cannot fail to be struck by one leading circumstance common to them all—namely, the profusion in which the reproductive material, under the form of those separate fragments, each of which we term an

ovum, is provided in every class. Only in those animals possessing soft and distensible bodies, can the whole or greater part of this material become ripened and brought to perfection; and even here, where the ripened ova amount sometimes to millions, the process must be gradual; for, after the oviposit has taken place, there may still be seen, within the ovisacs, the preparations for those which are to follow in the next breeding season. But as we ascend higher in the scale, and come to animals producing a smaller progeny at one time, or even to those that are commonly uniparient, the difference consists not so much in a proportionate diminution of the number of germs or ova originally formed as of those that ultimately come to perfection; for, in some of the Mammalia at least, it is probably calculating below the mark if we say that many hundred original germs are provided to meet the contingency of a single act of birth. Of these, therefore, the greater part can never be ripened at all, but must perish in the seat of their original formation (*q*); and, further, if those which are ripened and emitted do not become fertilized shortly after that event, these equally perish.

In order to trace out this matter further, we

must now turn our attention in another direction, and inquire what provision has been made to meet this latter contingency. The essential part of every ovum appears to be the germinal vesicle; but, unless the contents of another elementary cell be brought into contact with, and possibly mingle its contents with, those of the ovum, and, as it is now supposed, of the germinal vesicle itself, no further important stage in the process of reproduction can be reached.

We have therefore to consider

The nature of the process by which the ovum becomes fertilized. Until very lately, the efforts of all the observers who had closely examined the ovum, with a view to ascertain whether the spermatozoon actually gained entrance within the ovum, had been defeated. That they did so enter was the opinion of Leeuwenhoek, who also imagined that, having arrived there, they became by metamorphosis the future embryo; and this opinion was entertained, to a certain extent, by Prevost and Dumas. By Dr. Barry the nearest approximation was made to the actual discovery of the penetration of these bodies within the ovum; but, although he saw them frequently upon, and even within, the soft zona pellucida,

by which the ovum is surrounded, he still was not able to trace them with any certainty further. So also was Mr. Newport baffled in all those first experiments, of which he gave an interesting account to the Royal Society in 1850. Not until these observations had been extended was he able to announce that he had actually witnessed the passage of the spermatozoon through the membrana vitelli. The fact thus established has since been confirmed by Dr. Ransom in regard to fishes, where the passage of the spermatozoon takes place through a special pore or micropyle (*r*).

These observations, therefore, have for ever set at rest this question, so long debated, as regards the vertebrate ovum (*s*); and although, on account of the highly refracting nature of the material by which the spermatozoon becomes surrounded, immediately on reaching the interior of the ovum, it is generally lost to view, so that its condition can no longer be traced, still they serve to show in what way the material, of whatever nature it may be, which the body of the spermatozoon contains, may be brought into direct contact with that which constitutes the essential part of the female product or ovum.

The most important changes immediately following fertilization are these: Already in the ripe ova, previous to impregnation, and as a preparation for it, it is noticed that the germinal vesicle has disappeared. This disappearance has been accounted for upon the supposition that a process of cell-development takes place in its interior, and that, the cell-wall being thus ruptured or dissolved, the contents become equally dispersed through the yelk (*t*). Now, if this be the real explanation of the disappearance of the germinal vessel, which all observers agree in stating is not the result of impregnation, but takes place prior to that event, then it goes far to discredit those views which have been sometimes entertained with regard to the immediate agency of the spermatozoa in effecting the fertilisation of the ovum—namely, that it is in the nature of a mere catalytic action; while they add force to the belief that the contents of the spermatozoon become equally diffused through the yelk, together with those of the germinal vesicle, and by their combination initiate those further changes in it which serve to announce that impregnation of the ovum has been already effected.

The phenomena which next ensue, when occurring in the Mammalia, are all observable in the Fallopian tube, the general if not the constant seat of impregnation throughout this class. The first distinct evidence that the power of the spermatozoon has been efficiently exerted upon the ovum, is afforded by the occurrence of a small interspace between the yelk and its outer covering, the so-called zona pellucida, occasioned by the shrinking or contraction of the yelk within the latter, which interspace is filled by a transparent fluid, while one or two small granular bodies—the appearance of which about this time has given rise to much speculation regarding their use—are frequently observed between the yelk and the zona pellucida. As soon as these changes have taken place, the yelk, volvox-like, begins to rotate—the rotation being supposed to be effected by the aid of cilia, which in some instances have been observed clothing its surface. I am not aware that any explanation has yet been offered of the purpose of the rotation in this instance, and yet so commonly has it been observed that it doubtless has a meaning; and this account of it offers itself to my mind. The

rotation being the first important event that ensues, after the spermatozoon has gained entrance within the ovum, its occurrence would be coincident with the time at which the breaking up of the spermatozoon and the dispersion of its contents among those of the germinal vesicle is *supposed* to occur. Now, if the purpose be an equal distribution and admixture of these two throughout the yelk, then no means can be well imagined better suited for effecting this object than the rotatory movement of which I am now speaking (*u*). And now, following out the changes which the ovum further undergoes, consequent on impregnation, the 'segmentation' of the yelk commences. This consists in a spontaneous cleavage of it—at first into two, then four, equal parts, each exhibiting a nucleus, and so on in a kind of geometrical progression, until it is broken up into a mass of finely-divided nucleated particles, between which it is probable that the original sperm-force, or sperm-material, becomes equally divided. This process of complete disintegration of the yelk affects, apparently, the whole or greater portion of the mammalian ovum; but in others, as in birds, a part only becomes so

affected, the larger portion being reserved for nutrition as food-yelk (*v*).

A few questions of the greatest interest may now be considered. We have now arrived at two ultimate facts: ultimate, at least, as far as our present knowledge is concerned, and so far as our present means of investigation have enabled us to go. And these are the sperm-cell and the germ-cell, as constituting the essential elements which by their combination give origin to the future being. And whatever may result from further investigation respecting the structure and offices of these two elementary organisms, they must apparently be regarded as the cardinal points around which should be gathered all the information that subsequent research may develop.

This, then, must appear to be the proper moment for considering some important particulars which seem to have a direct bearing upon this subject. But, in endeavouring to arrive at the truth, it is important that we should eliminate from the investigation of certain now well-ascertained facts all external sources of fallacy; such, for example, as appear to have no better foundation than that of popular prejudice or fancy. I

am tempted, therefore, to say a word here regarding that supposed influence of the imagination which, from time immemorial down almost to the present day, has been generally believed to be exercised by one or other parent, but chiefly by the mother, upon the development of the offspring. Nor, as far as I can judge, has this belief yet altogether died out. But 'which of us by taking thought can add one cubit to his stature?'* or how, supposing that such power existed, could it be exercised, let us say, in the first place, by the *male*, seeing that we now know how the spermatozoa are formed in developmental cells that go through a gradual process of ripening and completion, not apparently much under the dominion of the mind? Nor can we get more satisfaction out of the opposite case, and show how *maternal* influence can be supposed to operate. Is it while the ovum is encased in the Graafian follicle, surrounded by the little bed of granules in which it then lies? Or, next, while passing down the Fallopian tube, when it may be compared to a rolling stone, having scarcely even contact with the structures of the mother? Or lastly, when, arrived

* St. Matt. vi. 27.

in the uterus, it draws its supply of nutriment through the placenta? But the placenta has no nerves, and he would be a bold physiologist to declare that nervous impressions could be conveyed by means of the general current of the blood. Nor do we get more satisfaction when we come to examine the several classes of cases in which this *un-*'scientific use of the imagination' is supposed to be operative. Emotion, as well as accident, may undoubtedly cause premature expulsion of the ovum, but that is not a true exercise of the imagination. The broken bones occasionally observed in the fœtus, and formerly connected with the witnessing of painful sights during pregnancy, are now known to be caused by spasmodic action of the uterus. The various malformations that depend upon arrest of development, erratic as these may appear, are obedient to certain laws, for even in deformity a certain order is preserved. And so, also, of the 'marks,' 'moles,' and other defects that are alleged as giving evidence of this remarkable power. None seem to be in any way connected with mental force, which, even if it could be so exercised, seems to be employed in the manner here repre-

sented chiefly to produce evil results. In whatever way we view the matter, it seems to elude our grasp. It is like the rainbow, which often appears so near, and yet, when we endeavour to approach it, baffles pursuit—a pretty parti-coloured play of light, as unsubstantial as the mist upon which it depends for its existence (*w*).

Passing on, therefore, from these speculations, I proceed to subjects of a more practical kind.

The natural law of parentage is sufficiently represented in the popular notion that 'like begets like;' that the child at its birth is only so far dissimilar from the parent as to need but a certain amount of growth and development to make the resemblance more or less perfect, at least as regards the general characteristics of the individual. And this seems to extend to special peculiarities, which may be handed down from one generation to another, and appear in the form of certain characteristic or other natural endowments; or they may be exhibited in the shape of various diseases, defects, or malformations, which may have affected the parents possibly for several generations. But in these cases it does not follow that like *always* begets like—at least, not

apparently. The malformations, defects, or special characteristics may die out, or the course of transmission may be interrupted. The disease or peculiarity may not appear again for one or more generations; or it may be limited to certain lines of transmission, as through the males only, or through the females only, of the family; and in these again, according to certain restrictions.

It is probably little known how much Harvey had thought upon this subject of hereditary transmission, and how very clearly and concisely he expresses his own views upon several matters which, under new names, are at this moment exciting the greatest attention. 'In reference to the subject of family likeness,' says Harvey, 'we may be permitted to inquire as to the reason why the offspring should at one time bear a stronger resemblance to the father, at another to the mother, and at a third to progenitors, both maternal and paternal, further removed; particularly in cases where at one bout, and at the same moment, several ova are fecundated. And this, too, is a remarkable fact, that virtues and vices, marks and moles, and even particular dispositions to disease, are transmitted by parents to their

offspring; and that, while some inherit in this way, all do not. Among our poultry, some are courageous and pugnaciously inclined, and will sooner die than yield and flee from an adversary; their descendants once or twice removed, however, unless they have come of equally well-bred parents, gradually lose this quality; according to the adage, "the brave are begotten by the brave." In various other species of animals, and particularly in the human family, a certain nobility of race is observed; numerous qualities, in fact, both of mind and body, are derived by hereditary descent. "Every fourth birth," says Pliny, "the mark of the Dacian family is repeated on the arm." Why may not the thoughts, opinions, and manners now prevalent, many years hence return again after an intermediate period of neglect?'

This disposition to *atavism*, or the reverting to an ancestral type or pattern after it has been lost or kept in abeyance through one or more successive generations, of which Harvey gives so clear a statement, has of late received great attention; and its study, more particularly in the hands of Dr. Prosper Lucas, has brought to light many most interesting examples. Mr. F. Galton has

attempted a farther development of it, in a paper read before the Royal Society so recently, that no report has yet appeared of it in their *Proceedings*. As far as I can ascertain, however, the object of the author is the discussion of the question, whether it be impossible to define the connection between relatives in a way that should do justice to the *latent* elements, which every creature inherits and may bequeath, but which give no sign of their existence in its own person. This difficulty, he considers, may be avoided by tracing the intervals of descent from the origin of life in each generation, and not from one adult to another. He recognises three well-defined stages in each of these intervals. First, the ovum, in which all the elements are confounded and no structure exists; then the embryo and the adult, in both of which they are separated into personal and latent. Then, by tracing out the process by which each stage in either of the lines was derived from its predecessor, he discovers the true relation of a man to either of his parents, and this he shows to have a twofold character—one part passing by the *latent*, the other by the *personal* line. The first of these Mr. Galton regards as the most

important, though only collateral, because it descends through five steps to the parental *ovum*, and thence descends through three other steps to the parental *person*. The other—the personal line—though of minor importance, is nearer and quite direct, and it descends through three steps. As an example, he takes brothers and sisters, whose descent passes only through *three* parallel steps, though it is derived from *four* variable sources, which are the latent and personal contributions of either parent.

Now, if there be any value in what has been already said of the special attributes of the sperm-cell and germ-cell, then, with reference to any qualities that may be transmitted from parent to offspring, so far as these can be conveyed by any material of communication, they can only be so transmitted from the male through the sperm-cell, and by parity of reason, though the case is here not so simple, from the female through the germ-cell. And here we seem to be getting back to the views of Seneca, whose description, taken in a figurative sense, represents the matter in much the same light. 'For,' says Seneca, 'in the semen is comprised the entire cause of the future man, and

the unborn babe has written within it the law of a beard and a hoary head. For the whole body and the load of future years are already traced in delicate and obscure outlines in its constitution.'

Further, with regard to the hereditary transmission of diseases and deformities: that some persons are more prone than others to suffer special forms of disease, which, upon investigation, may be ascertained to have affected one or other of their parents, and this possibly through several generations, is a circumstance now so well known and generally acknowledged, that it has come to form an important basis of calculation with insurance societies when estimating the probable duration of human life in given cases. But most writers upon this subject, which is commonly spoken of by the not very correct title of the 'hereditary transmission of disease,' since all that we can certainly affirm of it is that the tendency is transmitted, have hitherto taken little or no notice of its *sexual* limitation. Detached cases exemplifying this remarkable circumstance have been from time to time recorded, and the matter may have received a passing notice from a few authors. Moreover, it had been long previously known that a sexual limitation often

characterised the prevalence of certain malformations when observed to occur in lineal descent, sometimes through many generations; but no one appears to have taken up the subject as one deserving of systematic inquiry regarding both diseases and malformations, until Dr. Prosper Lucas and Mr. Sedgwick brought together numerous cases, with a view to illustrate this peculiar limitation. Regarding diseases, the cases collected are chiefly illustrative of the mode in which a tendency to phthisis, asthma, gout, hæmorrhage, insanity, cutaneous and many other affections, are handed down from progenitors similarly affected, and are thus limited in their lines of transmission. But the inquiry, when extended to certain peculiarities or defects, such as the general colour of the skin, colour or form of the iris, defects in the organs of vision or hearing, colour-blindness, arrests of development, congenital deficiencies of fingers and toes, or the webbing of these, or the opposite condition, viz. supernumerary digits (polydactylism), affords results tending more or less in the same direction, as furnishing examples of a sexual limitation in atavic descent.

The general conclusions at which Mr. Sedgwick

arrives, after a careful analysis of his cases, are, that sexual limitation in the transmission of disease is more common in the male than in the female; that such a limitation may affect either the development or the transmission of a given disease; and these two conditions are often antagonistic to each other, as in those cases where the *appearance* of the malformation or disease is strictly limited to the males, its *transmission* being quite as strictly limited to the female sex, occasioning the phenomenon of *double atavism*, as where neither sons nor daughters ever inherit their father's diseases, but only the grandsons in the third and fifth generations, by transmission through the females of the second and fourth generations.

This part of the subject has been very fully discussed by Dr. Prosper Lucas, and also, under the title of prepotency in the transmission of character, by Mr. Darwin. But it becomes extremely complicated on account of this prepotency being found to run now more strongly in one sex than in the other, and again equally in both sexes; while further complications appear to arise on account of the secondary sexual characters. The greater part of those, however, who have taken up this subject,

agree in this, that peculiarities *first* appearing in either sex, though not in any way necessarily or invariably connected with that sex, strongly tend to be inherited by the offspring of the same sex, but are often transmitted in a latent state through the opposite sex.

It would doubtless, therefore, very much aid our comprehension of this difficult subject of a sexual limitation of disease, if we could arrive at a more complete knowledge of the causes which primarily determine the division of sex into male and female, and that according to certain definite proportions; as well as of those conditions which in so remarkable a manner occasionally disturb that proportion.

In the English edition of Blumenbach's *Institutions of Physiology*, which appeared just fifty years ago, the following note by the translator will be found: 'Sir Everard Home has published a singular hypothesis. He suggests that the sex is not determined at the first formation of the individual, but that the parts of generation are originally so situated, and of such a nature, that they are capable of becoming either male or female organs when the sex is subsequently fixed.' Now this hypothesis,

which then appeared so strange, and for which the data will be found in Sir Everard Home's paper in the eighty-ninth volume of *Philosophical Transactions*, has ceased to be an hypothesis, and has long since passed into the region of ascertained facts.

Many observers have given their attention to this subject, but none so fully as Kobelt. According to Kobelt, there exists in the embryo a condition of absolute indistinction of sex in every individual. This depends upon a co-existence of all the elementary reproductive structures of each; so that, prior to the division of sex, each individual possesses the parts necessary to form either the male or the female, but yet without any true exhibition of bi-sexuality.

The nature of the first impulse towards a division of sex is entirely unknown, but the several elements out of which the fully formed organs are to be developed manifest a tendency to change in two opposite directions; in the one case suffering retrogression, in the other showing advance. The generative gland may at this time be converted into testis or ovary, and, through the duplex excretory duct, that of the Wolffian body for the male,

and the duct of Müller for the female, the capability of conversion into either sex exists at this time in every individual. The development of one and the stationary condition or disappearance of the other of these ducts, together with the changes taking place in the generative gland itself, render now the beginning of the division of sex anatomically discoverable.

I have endeavoured to determine, by observation, at what time this precise change occurs. In a human embryo of the fourth week, of which I have published a description (*x*), no trace of an ovary or generative gland was discoverable, but only slight indications of the Wolffian bodies. In another embryo, measuring 5 lines in length, the generative gland was only just discerned; while in another, measuring 8 lines, the distinctive characteristics of the ovary could be perceived. It may be said that in the human embryo the ovary cannot be discerned earlier than between the fifth and the seventh weeks, nor is it possible, previously to this, to distinguish the ovary from the testis.

Of the precise conditions which determine this division of sex, we are at this moment, as just

stated, in perfect ignorance; although numerous most interesting facts have been collected regarding the circumstances of the begetting; such as the relative condition of the parents, regarded as the two factors; their relative ages; the *equality* of their potency in regard to the production of sex, or a *preponderance* on one or other side of a tendency to produce males or females (in some cases so remarkable as to take the matter entirely out of the category of so-called chance or accident); the tendency, again, to the prevalence of a single sex in quadruple or quintuple births, and the almost constant occurrence of the same sex in duplex monsters. These are matters which may ultimately lead to a better understanding of the whole question; while, at the same time, they serve to show how little is as yet known beyond the bare ascertainment of these and similar facts.

Before I conclude, I will refer to one other subject, to which I have occasionally adverted in the course of this address.

Again and again, passages occur in Harvey's work which lead to the conviction that he is in some sense a supporter of the doctrine of 'equivocal' or 'spontaneous' generation. And as, when

noticing one of these, I stated that I would return to the subject, I feel myself pledged to say something more respecting it. But this must be very brief.

The notion that living things might arise spontaneously out of dead or putrefying matter, is undoubtedly amongst the oldest of all the doctrines relating to the several modes in which animated beings might be supposed to commence their existence. So consistent did this doctrine appear with the fact that scarcely is an animal dead before the carcase abounds with maggots and other living forms destined to devour it, but which nevertheless had no existence there before, that we cannot feel surprised if in those days, when the observant faculty of man was less keen than now, less sharpened by the constant practice of investigating facts, such a doctrine should meet with very general acceptance with regard to such cases as these.

It was not until eleven years after Harvey's death that the first distinct and systematic attack upon this doctrine of spontaneous generation was made by the distinguished Italian naturalist, a member of our own profession, Francesco Redi.

The experiments which he instituted with a view of testing this question were of the simplest description, but they aimed directly at the root of this matter. And the arguments which he deduced from them were unanswerable. Moreover, simple as they were, they have formed the basis of almost every experiment which has been since made with a view to determine the same or similar questions in analogous cases. Redi's experiments were intended to show that, whenever external agents, such as flies, were prevented from coming into direct contact with putrefying meat, by tying a piece of gauze over the vessel which contained it, such as would exclude the flies but not the air, no maggots were ever produced in the meat, although the ova which the flies had deposited externally were freely hatched in this situation.

But Redi's experiments sufficed to test this matter only in respect of such coarse examples as those just quoted. Their direct purpose was to show that, in those cases, the real mode of origin of the animals had escaped detection. They could not, however, fail to suggest to him the idea that, in all like cases, where living creatures seemed to arise out of dead matter, a similar

cause was in operation, and the real explanation of their apparently spontaneous origin was to be found in the fact that their germs had been derived from some external source. In this form, the question seems to have slumbered for a period of more than eighty years, when, in the middle of the last century, it was again taken up by Needham, who, aided by the distinguished French naturalist Buffon, set to work to revive the ancient doctrine, though now under a new phase.

Buffon held the notion—in which, indeed, he has by no means stood alone—that all living creatures, whether animals or plants, were made up of separate organic molecules or living atoms, which are merely held together by some unknown force, in that particular form of association which serves to characterise the individual plant or animal; but that, on the occurrence of death, all these atoms are set free, and, while still retaining their vitality, become, when portions of the animal or the plant are infused in water, developed into so many infusorial animalcules.

Needham, falling in with these views, but seeing also that they were antagonistic to the now well-known observations of Redi, proceeded

to put them to the test of a like experiment, varying it only according to the circumstances. By boiling the infusion, and afterwards, as he supposed, effectually excluding the air and continuing the heat, Needham concluded that he had destroyed all germs that might have previously existed in the solution, and at the same time prevented the entrance of any others that might be supposed to be floating in the air. The results of those experiments appeared directly to contradict the conclusions arrived at by Redi, and to resuscitate the old idea of spontaneous generation.

But they were not destined to remain in this condition; for, sixteen years later, Spallanzani, by a series of more carefully-devised experiments, appeared to put Needham in the wrong, and to add further support to the views originally maintained by Redi. And now, again, another century has elapsed since these observations of Spallanzani; and, during this time the question of the spontaneous origin of animals has been repeatedly revived and tested by every form of ingeniously-devised experiment.

The case of insects imprisoned in the galls that

are found upon the oak and other analogous examples, have long ago received a satisfactory explanation. The spermatozoa having now ceased to be regarded as distinct animalcules, are now classed with ciliated cells, of which they constitute undoubtedly the most important and interesting example. The presence of entozoa within the bodies of other animals was for a long time the stronghold of those who, not being able to discover them in other situations, saw no way out of the difficulty except by assigning to these also a spontaneous origin. But in time it was discovered that, while in most animals produced according to the ordinary form of sexual generation, the offspring soon comes to resemble the parents, there were still others in which the new individuals differ at first from the parents and also from each other, and that it is not until after certain intermediate or alternate forms have been passed through that the last of the series returns to the state of the first parents; so that the non-recognition of the larval form broke the chain of evidence regarding the origin of some of the more perplexing examples of the entozoa. And now the discussion is maintained only in

respect of the infusoria. Regarding the origin of these, one side assumes that, whenever in animal or vegetable infusions living creatures seem to arise spontaneously, their presence is due to pre-existing germs, which in some form already occupy the infusion, or the air having access to it. The other side considers that, in obedience to laws which are in the nature of ordinary chemical and physical laws, and not such as are commonly termed vital, new centres of life may arise even out of non-living matter, without the intervention of a pre-existing germ.

Now, if we compare these views with what Harvey asserts, the following, I think, will be the result: When Harvey is speaking of things arising spontaneously, equivocally, or automatically (for he employs all these terms), he is generally referring to insects and creatures of that class, which, as I have already shown, were commonly in those days supposed to have a spontaneous origin. Some, he says, are born of their own accord, concocted out of matter spontaneously. And in another place he expresses it thus: 'In the same way are engendered both those creatures that are said to arise spontaneously,

by chance or accident, and derive their first matter or take their origin from putrefaction, filth, excrement, dew, or the parts of plants and animals, as well as those that arise congenerately from the semen of animals; because this is common to all living creatures—viz. that they derive their origin either from semen or eggs, whether the semen have proceeded from others of the same kind, or have come by chance or something else.' But he intends, I think, to draw a distinction; for in his twenty-eighth Exercise, speaking of the impossibility of the egg being rendered fruitful without the concurrence of the male, he says: 'But this view is opposed to the opinion of those who derive the origin of animals from the slime of the ground' (*y*).* And further, in another Exercise he seems to hit the whole of the matter, for he has it thus: 'But on these points we shall say more when we show that many animals, especially insects, arise and are propagated from elements and seeds so small as to be inconspicuous (like atoms flying in the air), scattered and dispersed here and there by the winds; and yet these animals are supposed to have arisen spontaneously or from decomposition,

* E limo terræ. See note (*y*).

because their ova are nowhere to be found.' And then he adds: 'This idea may be not without use to that school of philosophy which teaches that all things are produced from nothing.'

And now, having brought before you all that I think can be said respecting Harvey's doctrine on this particular subject, and having endeavoured to exhibit Harvey in such a light as to increase, if possible, the interest which we all feel in one who, by the force of his genius, raised himself to a foremost position among the physiologists of the world, I will bring this already too prolonged address to a conclusion with the following extract:

'Wherefore,' says Harvey, 'according to my opinion, *he* takes the right and pious view of the matter who derives all generation from the same eternal and omnipotent Deity, on whose nod the universe itself depends. Nor do I think that we are greatly to dispute about the name by which this first agent is to be called or worshipped; whether it be God, Nature, or the Soul of the universe—whatever the name employed—all still intend by it that which is the beginning and the end of all things; which exists from eternity and is almighty; which is author or creator, and, by

means of changing generations, the preserver and perpetuator of the fleeting things of mortal life; which is omnipresent, not less in the single and several operations of natural things than in the infinite universe; which, by his deity or providence, his art and mind divine, engenders all things; whether they arise spontaneously without any adequate efficient, or are the work of male and female associated together, or of a single sex, or of other intermediate instruments, here more numerous, there fewer; whether they be definite, or are equivocally or accidentally produced: all natural bodies are both the work and the instruments of that Supreme Good, for He also makes use of the motions, or forces, or vital principles, of animals in some certain way, to the perfection of the universe and the procreation of the several kinds of animated beings.'

NOTES.

Note (*a*) to Photograph facing Title-page.

THE bust in the Library of the College of Physicians, from which, by permission, the photograph facing the title-page has been taken, is supposed to be by Scheemakers. It was presented by Dr. Mead, October 1, 1730, and in the College, in Warwick Lane, was supported on a bracket, bearing the inscription quoted beneath, the photograph.

The personal appearance of Harvey is thus graphically described by Aubrey: 'In person Harvey was not tall, but of the lowest stature; round faced, olivaster (like wainscot) complexion; little eie, round, very black, full of spirit; his haire black as a raven, but quite white twenty years before he dyed.'—Aubrey, *Letters and Lives of Eminent Men*, 1813. Vol. II. page 382.

Note (*b*), page 1.

'COMITIA solennia trimestria 25° Junii 1657. Monentur Socii, ut togati prosequi velint exequias funeris D^ris^ Harvæi, postero die celebrandas.'—*The Roll of the Royal*

College of Physicians, by W. Munk, M.D., Vol. I., p. 130.

Note (*c*), page 1.

'He was buried,' Aubrey informs us, 'in a vault at Hempstead, in Essex, which his brother Eliab had built; he was lapt in lead, and on breast, in great letters, his name, Dr. William Harvey.'—Aubrey, *Loc. Citat.*

Note (*d*), page 2.

Exercitationes De Generatione Animalivm. Quibus accedunt quædam De Partu: de Membranis ac humoribus Vteri: & de Conceptione. Avtore Gvilielmo Harveo Anglo, in Collegio Medicorum Londinensium Anatomes & Chirurgiæ Professore. 1651.

The works of William Harvey, M.D., Physician to the King, Professor of Anatomy and Surgery to the College of Physicians, translated from the Latin by Robert Willis, M.D. Sydenham Society, 1847.

I willingly unite with the Orator of 1869 in here according my thanks to 'the learned translator of Harvey's works, to whom all Harveian orators must feel indebted.'—Dr. Owen Rees, *Harv. Oratn.* 1869.

Note (*e*), page 6.

Examined side by side, the two principal works of Harvey, regarded as the productions of the same author, offer a contrast as great, perhaps, as is to be found in

the whole range of literature. The Baconian and the Aristotelian systems have often been compared and contrasted. But seldom has it occurred that one and the same mind should exhibit, in such close juxta-position, the practical working of both methods. But this was a necessary consequence of the circumstances under which Harvey studied and wrote.

'In his work on the heart and blood,' says Dr. Willis, 'Harvey had all the essential facts of the subject clearly before him, and he used them at once in such masterly-wise that he left little or nothing for addition, either by himself or others.'—(Willis's *Translation of Harvey's Works.*) And Harvey's merit in this respect is the greater, because, having been trained in the Aristotelian Philosophy, he broke through the trammels of that school, and established the doctrine of the circulation upon the inductive method, affording herein a striking example of what Herschel has pointed out, viz. that this method 'had been practised in many instances, both antient and modern, by the mere instinct of mankind.' And although the 'Exercitatio Anatomica de Motu Cordis et Sanguinis' did not make its appearance until 1628, or eight years after Bacon's *Novum Organum*, there is every reason to believe that Harvey's work was actually written before that date, while his lectures, delivered before the College of Physicians, in which he is generally supposed to have fully expounded his views, were commenced as early as 1616.

If, then, this celebrated work affords a brilliant example of what the inductive method, under whatever name

pursued, can effect, so the 'Exercitationes de Generatione Animalium,' published in 1651, or twenty-three years subsequently, and which must have cost the author an infinitely greater amount of labour, exhibit an equally striking instance of what it is powerless to achieve where facts are wanting.

Here the comparatively few facts with which Harvey had to deal were chiefly those which he had himself observed in regard to 'Development.' But respecting 'Generation' properly so termed, he could not, for reasons given in the text, have any actual knowledge—so that throughout these Exercises we find him continually wandering among metaphysical speculations, of the unsatisfactory nature of which he appears to be, to a certain extent, conscious, while compelled to adopt them, as affording the only method by which he could put together the very meagre amount of knowledge which his own observations, added to those of his predecessors, supplied. As an example of his favourite mode of reasoning, the following, taken from his 28th Exercise, headed 'The Egg is not produced without the Hen,' may suffice :—

'Neither, in like manner, in the present constitution of things, can a cock or hen ever be produced otherwise than from an egg. Thus the cock and the hen exist for the sake of the egg, and the egg, in the same way, is their antecedent cause; it were, therefore, reasonable to ask, with Plutarch, which of these was the prior, the egg or the fowl? Now the fowl is prior by nature, but the

egg is prior in time; for that which is the more excellent is naturally first; but that from which a certain thing is produced must be reputed first in respect of time. Or we may say: this egg is older than that fowl (the fowl having been produced from it); and, on the contrary, this fowl existed before that egg (which she has laid).

And here it may be interesting to quote what Aubrey says respecting Harvey's opinion of Bacon:—

'He (Harvey) had been physician to the Lord Chancellor Bacon, whom he esteemed very much for his witt and style, but would not allow him to be a great philosopher. Said he to me, He writes philosophy like a lord chancellor, speaking in derision.'—Aubrey, *Loc. Cit.*

Note (*f*), page 7.

'When I came home,' says Sir George Ent, 'and perused the pieces singly, I was amazed that so vast a treasure should have been so long hidden; and that while others with great parade exhibit to the world their stale trash, this person should seem to make so little account of his admirable observations.'

Note (*g*), page 9.

'I remember,' says Aubrey, 'he came several times to our College (Trin., Oxf.), to George Bathurst, B.D., who had a hen to hatch eggs in his chamber, which they daily opened, to see the progress and way of generation.'

'He did delight to be in the darke, and told me he could then best contemplate. He had a house at Combe, in Surrey, where he had caves made in the earth, in which, in summer time, he delighted to meditate. He was always very contemplative, and was curious in Anatomie. He made dissections of froggs, toads, and a number of animals, and had curious observations, which papers were plundered &c.'—Aubrey, *Loc. Cit.*

Note (*h*), page 11.

As this is probably the earliest reference to magnifying or burning glasses on record, it may be interesting to quote the passage :—

Strepsiades, a wealthy cultivator of the soil in the district of Cicynna, is represented as reduced to poverty by the extravagance of his son. He has heard of the new and wonderful art of reasoning, by which the Sophists professed to make the worst appear the better cause ; and hopes that, under the tuition of Socrates, he may attain to such skill and dexterity of arguing as will enable him to elude the actions for debt with which he is threatened by his creditors ; upon which the following conversation takes place between them :—

Strepsiades : I have found a very clever method of getting rid of my suit, so that you yourself would acknowledge it.

Socrates : Of what description ?

Strepsiades : Have you ever seen this stone in the

chemists' shops—the beautiful and transparent one, from which they kindle fire?

SOCRATES: Do you mean the burning glass?

STREPSIADES: I do. Come, what would you say, pray, if I were to take this, when the clerk were entering the suit, and were to stand at a distance, in the direction of the sun—thus—and melt out the letters of my suit?

SOCRATES: Cleverly done, by the Graces!—*Aristophanes*, '*The Clouds.*'

Note (*i*), page 12.

TWENTY-SIX of these microscopes, 'excelling those that have been hitherto made,' were formerly in the possession of the Royal Society, into whose hands they came under the following circumstances:—

During a period of fifty years, and up to the time of his decease in 1723, Leeuwenhoek was in the habit of constantly transmitting to the Society all his microscopical observations and discoveries. These, amounting to 125 papers, are inserted in the *Transactions*, while many more, together with letters from him, are preserved in the Archives. In gratitude for receiving and publishing his communications, Leeuwenhoek presented his microscopes to the Society, accompanying his present with the following note:—

Delft: 2 Aug. 1701.

'Hon^ble^ Gentlemen,

'I have a small black cabinet, lacker'd and gilded, which has five little drawers in it, wherein are contained

thirteen long and square tin boxes, covered with black leather. In each of these boxes are two ground microscopes—in all, six and twenty—which I did grind myself and set in silver; and most of the silver was what I had extracted from minerals and separated from the gold that was mixed with it; and an account of each glass goes along with them.

'This cabinet, with the aforesaid microscopes (which I shall make use of as long as I live), I have directed my only daughter to send to your Honours as soon as I am dead, as a mark of my gratitude and acknowledgment of the great honour which I have received from the Royal Society.'—Weld's *History of the Royal Society*, Vol. I., pp. 244–5.

Note (*k*), page 13.

This is the only point upon which we find, throughout Harvey's Exercises, any expressions of this kind uttered by himself. Something in the course of his observations having occurred to him, upon which he desired to get further information, he refers to the circumstance noticed by Aubrey in the following touching expressions:—'Whilst I speak of those matters, let gentle minds forgive me if, recalling the irreparable injuries I have suffered, I here give vent to a sigh. This is the cause of my sorrow. During our late troubles, and more than civil wars, certain rapacious hands stripped not only my house of all its furniture, but, what is subject of

far greater regret with me, my enemies abstracted from my museum the fruits of many years' toil; whence it has come to pass that many observations, particularly on the generation of insects, have perished.'

Note (*l*), page 14.

The two following passages, perhaps, afford the nearest approach to this aphorism:—

Nos autem asserimus, omnia omnino animalia, etiam vivipara, atque hominem adeo ipsum ex ovo progigni.—*Exercitatio I.*

and

Ovum esse primordium commune omnibus animalibus.—*Exercitatio LXII.*

Note (*m*), page 18.

Drelincourt, whose principal work was published two centuries ago, collected together two hundred and sixty-two groundless hypotheses relating to the process of generation; the exact number I give upon the authority of Blumenbach. But whether rightly estimated or not, the result of all this labour appears to have been, that Drelincourt's own theory came in turn to be regarded as constituting the two hundred and sixty-third.

Note (*n*), page 19.

'The seminal fluid of man and some animals examined by Leeuwenhoek appeared to him full of animalcula, which he named vermes, from their resemblance in figure and motion; but they were soon considered by philosophers as a phantom of the imagination, an illusion of the senses, or some imperfection of the microscope. They thought there was nothing real in what the Dutch philosopher had described.

'By others he was judged with less severity. They agreed that there was a number of corpuscula in the seminal fluid, but they denied they were animals, and thought them unorganised particles, which, from their subtility, were raised and evaporated sooner than the rest, thus forming a fermentation and motion in the fluid that created the idea of animation.

'The celebrated Linnæus adopts this opinion nearly. He thinks the vermiculi are only inert molecules, swimming like oil in the seminal fluid, moving and darting in various directions, as they are agitated or heated by the temperature of the fluid.

'Messieurs Needham and Buffon published their sentiments upon the question, which they have elevated to the subject of the animation of these microscopic beings; and it would appear that their theories are directly opposite. The first thinks they originate from the vegetative power acting upon the seminal fluid after it comes from the animal, by which it is necessitated to vegetate, to expand, to put itself in motion,

and to change into beings not yet animated, but simply vital.

'M. de Buffon, enamoured of his organic molecules, thinks he finds them in the vermiculi; and from a long detail of experiments and observations, endeavours to establish his theory upon the ruins of that of Lewenhoek.

'Who could imagine that so many disputes, and such opposition of sentiment, would arise upon a matter of fact?'—Spallanzani, *Tracts on the Nature of Animals and Vegetables*, 1799.

The original letter of Lewenhoeck,* bearing date November 1677, and announcing his discovery of the Spermatozoa, will be found in 'Phil.Trans.,' Vol. XII., of that year. Three-quarters of a century later, Dr. Parsons, Foreign Secretary to this Society, believed it to be 'extreme nonsense to imagine that the insignificant animals, called *spermatic animals*, can contribute anything towards propagation.' And even in far more recent times their existence has been denied in the most positive manner, as by Sir Everard Home, in his *Lectures on Comparative Anatomy*, Vol. V., 1828.

Note (*o*), page 21.

The accompanying illustration, designed, apparently, to represent three stages in the development of the spermatozoon, is a fac-simile of that which will be found

* His name is thus spelt in the signature of the letter referred to.

in the copy of Leeuwenhoek's work belonging to the Royal College of Physicians.—Continuat. *Arcan. Naturæ. Epistol.* 113, 1699. No. 68.

The most recent observations and illustrations of this subject since those of Kölliker. Physiologische Studien über die Samenflüssigkeit, Zeitschrift für Wissen (Zool. B. III.), and of R. Wagner and R. Leuckart (Cyclop. Anat.) will be found in the following :—

Ueber die Samenkörperchen und ihre Entwicklung. Von F. Schweiger-Seidel. Archiv für Mikroskopische Anat., M. Schultze, 1865.

Ueber die Genese der Samenkörper. Von La Valette St. George. Schultze's Archiv, 1865–67.

Beiträge zur vergleichenden Histologie des Molluskentypus. Von Franz Boll, Schultze's Archiv, Sup. 1869.

Nähere Mittheilungen über die Entwicklung und den Bau der Samenfäden der Insecten. Von O. Butschli. Kölliker Zeitschrift. 1871.

Note (*p*), page 22.

'Quod etiam in vtero non segnius occurrit : propter

solum vterum est mulier id quod est, barba caret, et licet humidiore habitu, celerius tamen pubescit.'

Joannes Baptista van Helmont.

Tract. 46. Ignota actio regiminis 1648.

Note (*q*), page 30.

In the herring, 25,000 ova; in the lump-fish, 155,000 ova; in the holibut, 3,500,000 ova, have been estimated to fill the enlarged ovarian ovisacs.—Owen's *Comparative Anat. & Phys. of Vertebrates*, Vol. I.

Dr. Martin Barry calculated that in the ox the ovary would contain, in a cubic inch, 200,000,000 of ovisacs.

Note (*r*), page 32.

The discovery of a micropyle or special aperture for the entrance of the spermatozoa within the ovum was first made by J. Müller in the *Holothuria*. It has since been observed in the ova of many other invertebrata. In a considerable number of these it exists from an early period of the development of the ovum, and appears to proceed from the remains of the pedicle by which the ovum is originally connected with the ovarian substance. On the other hand, the first obscrvation of a micropyle in the vetebrata was made by Dr. Ransom, of Nottingham, in osseous fishes. Here the aperture appears to be situated at that side of the ovum towards which the germinal vesicle and disc are placed, and through this pore Dr. Ransom frequently observes the passage of

the spermatozoa to take place. Further, in these cases of the vertebrata, where no micropyle exists, but the ovum is surrounded by a soft gelatinous coating, the latter appears to be essential to the penetration of the spermatozoa within the vitelline membrane, since, if it is stripped off, impregnation of the ova cannot be effected.

Note (*s*), page 32.

The penetration of the spermatozoa within the ovum, in the *invertebrata*, had already been described by Dr. Nelson in his paper on the Reproduction of *Ascaris Mystax*, read before the Royal Society, June 1851.—*Phil. Trans.*, Part II., 1852.

Note (*t*), page 33.

Regarding *Osseous Fishes*, Dr. Ransom's observations show that the germinal vesicle, previous to its disappearance, is embedded below the superficial layer of yelk-substance, in a stratum of granular matter. At the time of rupture of the vesicle, he conceives that this granular matter, being mingled with the contents of the vesicle, the more immediately germinal part of the egg is formed from the mixture of the two.

Again, in *Ascaris Mystax*, in which the condition of the ovum in various stages has been traced with the utmost care by Dr. Nelson ('Phil. Trans.,' 1852, Part II.), the germinal vesicle is found to rupture when disintegration of the yelk has gone to a certain length, and its

disappearance is immediately followed by the transformation of the remaining vitelline granules. These transformed or altered granules are termed by him the embryonic granules, since they appear about the same time as the embryonic vesicle, and with it assist in forming the embryo.

Note (*u*), page 35.

The process of 'rotation' was first described in 1695 by Leeuwenhoek, who gives the following account of it in the embryo of the *Mussell* (Belg. Veen-oesters) of Musselen :—

'Innatas has conchas, quamprimum eas ex ovario exemeram, indidi tubo vitreo, eosque sic microscopio opposui, ac statim majore cum admiratione ac voluptate vidi, quomodo conchæ hæ nondum natæ, ac membranis adhuc involutæ, lente circumvolutarentur, neque id per breve aliquod tempus, sed quædam per tres horas continuas in hoc suo motu perseverabunt.'—Continuat. *Arcan. Nat. Epist.* 95, pages 26, 27. 1695.

This peculiar rotating movement has been observed in numerous instances in the ovum and early embryo. When occurring, it appears to set in soon after impregnation, commencing, as Bischoff asserts in the rabbit, prior to the cleavage of the yelk, and continuing sometimes, as in the mollusca, even up to a late period, in the formation of the embryo. One possible use of it has been suggested in the text, but this can obviously apply to it only in the first step of the process. Other purposes are

suggested in later stages by Nelson.—*Phil. Trans.*, 1852, Part I, p. 583; and by Hogg, *Quart. Journ. Micros. Science*, July 1854, p. 92.

Note (*v*), page 36.

THE progress which has been made in the study of the physiology of generation since Harvey's time cannot be better shown than by placing here, in juxta-position with what has been given in the text, Harvey's own views upon the subject, as exhibited in the following extracts:—

'In the dog, rabbit, and several other animals, I have found nothing in the uterus for several days after intercourse. I therefore regard it as demonstrated that, after fertile intercourse among viviparous as well as oviparous animals, there are no remains in the uterus either of the semen of the male or female emitted in the act; nothing produced by any mixture of these two fluids, as medical writers maintain; nothing of the menstrual blood present as "matter," in the way Aristotle will have it;—in a word, that there is not necessarily even a trace of the conception to be seen immediately after a fruitful union of the sexes. It is not true, consequently, that in a prolific connexion there must be any prepared matter in the uterus which the semen masculinum, acting as a coagulating agent, should congeal, concoct and fashion, or bring into a positive generative act, or, by drying its outer surface, include in membranes.'—Harvey, *Exer.* 68.

'It is to the uterus that the business of conception is chiefly entrusted: without this structure and its functions conception would be looked for in vain. But since it is certain that the semen of the male does not so much as reach the cavity of the uterus, much less continue long there, and that it carries with it a fecundating power by a kind of contagious property (not because it is then and there in actual contact, or operates, but because it previously had been in contact), the woman, after contact with the spermatic fluid in *coitu*, seems to receive influence and to become fecundated without the co-operation of any sensible corporeal agent, in the same way as iron touched by the magnet is endowed with its powers, and can attract other iron to itself. When the virtue is once received, the woman exercises a plastic power of generation, and produces a being after her own image.

'Yet it is matter of wonder where this faculty abides after intercourse is completed, and before the formation of the ovum or "conception." To what is this active power of the male committed? Is it to the uterus solely, or to the whole woman? Or is it to the uterus primarily, and to the woman secondarily? Or, lastly, does the woman conceive in the womb, as we see by the eye and think by the brain? "The functions of both" (uterus and brain) "are termed conceptions;" and just as a desire arises from a conception of the brain, and this conception springs from some external object of desire, so also from the male, as being the more perfect animal, and, as it were, the most natural object of desire, does

the natural conception arise in the uterus, even as the animal conception does in the brain.'—Harvey, *De Conceptione.*

'On the present occasion I shall only observe, if that which is called by the common name of "contagion," as arising from the contact of the spermatic fluid in intercourse, and which remains in the woman (without the actual presence of the semen), as the efficient cause of the future offspring—if, I say, this contagion (whether it be atoms, odorous particles, fermentation, or anything else) is not of the nature of any corporeal substance, it follows of necessity that it is incorporeal. And if, on further inquiry, it should appear that it is neither spirit nor demon, nor soul, nor any part of the soul, nor anything having a soul—as I believe can be proved by various arguments and experiments—what remains, since I am unable myself to conjecture anything besides—nor has anyone imagined ought else even in his dreams—but to confess myself at a standstill?'—Harvey, *De Conceptione.*

Note (*w*), page 39.

How long previous to about 1747 B C. this idea of the influence of the imagination may have existed, cannot of course be ascertained; but that Genesis xxx. contains the first record of it no one will, I think, dispute.

A popular belief, which has been handed down through thirty-six hundred years and more, may not, perhaps, be easily dispelled; yet, if those who may be

still influenced by it would carefully read that natural explanation of the phenomena in question, which the very next chapter affords, they would probably be the less inclined to give credence to what they will there find so plainly controverted.

Jacob having agreed to tend the flocks of Laban without wages, but on the condition that all the speckled and spotted cattle, the brown cattle among the sheep, and the spotted and speckled among the goats, should be selected by him, and constitute his only hire, adopted an expedient for increasing their number, which is thus recorded: 'And Jacob took him rods of green poplar, and of the hazel and chesnut; and pilled white strakes in them, and made the white appear which was in the rods. And he set the rods which he had pilled before the flocks, in the gutters in the watering-troughs, when the flocks came to drink, that they should conceive when they came to drink. And the flocks conceived before the rods, and brought forth cattle ring-straked, speckled, and spotted. And if he said thus, The speckled shall be thy wages; then all the cattle bare speckled: and if he said thus, The ring-straked shall be thy hire; then bare all the cattle ring-straked.'

But how entirely independent this expedient of the pilled rods was of the result which took place in the course of nature, as revealed to Jacob, the following chapter shows: 'And it came to pass at the time that the cattle conceived, that I lifted up mine eyes, and saw in a dream, and, behold, the rams which leaped upon the cattle were ring-straked, speckled, and grisled. And the

angel of God spake unto me in a dream, saying, Jacob: and I said, Here am I. And he said, Lift up now thine eyes, and see, all the rams which leap upon the cattle are ring-straked, speckled, and grisled: for I have seen all that Laban doeth unto thee.'

Note (*x*), page 49.

Article Uterus and its Appendages. — *Encyclop. of Anat. and Phys. Supplement*, and *Trans. Microscopical Society of London*, Vol. III., Part II., p. 65.

Note (*y*), page 57.

'Quod opinioni illi adversatur, quæ primum animalium ortum *e limo terræ* deducit.'—Harv. *Exercitatio* xxviii.

Compare with this passage the following:—

'Formavit igitur Dominus Deus hominem *de limo terræ*, et inspiravit in faciem ejus spiraculum vitæ, et factus est homo in animum viventem.'—*Bibliorum Sacrorum Vulgatæ versionis &c.*—Genesis, caput ii. v. 7.

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