

BUCHANAN'S MANUAL OF ANATOMY

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A MANUAL OF ANATOMY

CHAPTER I

TERMINOLOGY AND RELATIVE POSITIONS

Termini situm et directionem partium corporis indicantis

THE word **anatomy**, used in the strict sense, implies the knowledge of what can be studied by the process of dissection. **Morphology** is the name given to the more scientific aspect of anatomical research—the reason why, and the method by which, the various anatomical structures have reached their present conditions. In modern times the term “anatomy” is frequently used in a wide general sense, covering both descriptive and morphological anatomy. **Comparative anatomy**, the structure of animals other than man, is an essential foundation for human morphology. **Embryology**, the study of the development of the body, is an extension of direct anatomical investigation on the one hand, and, on the other hand, particularly when the study of human and other types is carried on together, it is a second fundamental support for the superstructure of morphology. **Histology**, the examination and study by the microscope of the minute structure of tissues and organs, is microscopical anatomy, anatomical research pushed to the farthest visual limits of practical value.

Anatomy, the plain descriptive structure of the body, is a subject of primary importance to the medical man. If he wishes to understand what has happened—either from injury or disease—to produce some abnormal physical condition, he must first know the normal state; this knowledge is necessary for scientific diagnosis and frequently for scientific treatment. Hence it comes that the well-equipped physician or surgeon possesses a good working knowledge of the anatomy of the body as well as of the functions of its parts, some information on morphology to give him a deeper understanding of the matter and a sufficient acquaintance with histology and embryonic development to enable him to grasp more fully some of the pathological problems which he has to consider. It may be said here, for the benefit of those who are as yet students, with little or no clinical experience, that there are practically no items of anatomical information which may not be of value—to-morrow if not to-day—if they are known; their value cannot be apparent if they are not known. The more detailed the knowledge possessed by the practitioner, the more useful and the more frequently useful he will find it and the firmer will be the standpoint from which he views the clinical problems before him.

The anatomy of the body must be studied on the actual human frame itself. It may be pointed out in this connection that dissection and investigation of the cadaver must be amplified by the study of the living body and by the examination of X-ray findings. Text books on anatomy must be looked on as mere explanatory guides to

actual anatomy, as summaries and co-ordinations of what is observed during practical study, and as convenient references when occasion arises. They must not be considered to be anatomy itself.

The descriptions of anatomical findings, whether in a book or as the record of some investigations, must rest on certain fixed and recognized foundations. Unless this rule is respected the anatomical description, which ought to be absolutely exact and unmistakable, becomes chaotic and misleading. One of the first things that the student of anatomy must learn and understand is the proper use and meaning of the terms of position; these have fixed and definite values and should never be used in any other sense than those generally recognized by anatomists as correct.

It is traditional with human anatomists that the human body is described in the upright posture. Although this convention is one of obvious convenience it is apparent that the extension of human terminology of position into the realms of comparative anatomy and even into human embryology may lead to confusion. Many efforts have been made to construct a system of positional nomenclature that may be applied to upright man, pronograde mammal and flexed embryo with equal accuracy. All such schemes were, however, rejected by the so-called Birmingham Revision Committee. In their report on nomenclature it is stated that "the attempt to introduce descriptive terms which shall be equally applicable to the erect attitude, the foetus in utero and the pronograde vertebrate has created many difficulties and does not commend itself to the Committee. Although such a modification might be an advantage to Anatomists, Morphologists, Embryologists and Zoologists, it would certainly be an endless source of difficulty and confusion to the very much larger group that comprises medical students, qualified practitioners and consultants."

So far as the terms applicable to the head and neck and trunk are concerned, there is no great danger of confusion. The terms recognized in accepted nomenclature are mostly self-explanatory, but it is better that they should receive definition at the outset (see Fig. 1).

Anterior and **Posterior** indicate positions nearer to the front surface or the back of the body and, familiar though they are, they should be replaced by the more scientific and less ambiguous terms **Ventral** and **Dorsal**, which are applicable both to erect man and pronograde mammals. **Superior** and **Inferior** indicate positions near the top of the head or the soles of the feet. In reference to the trunk they are far better replaced by the general terms **Cranial** or **Cephalic** and **Caudal**, and in the limbs by **Proximal** and **Distal**. **Lateral** and **Medial** are terms applied to indicate relation to the median plane of the body in a dorsi-ventral (sagittal) direction. As will be explained later, these positional terms should not be applied to the limbs.

Internal and **External**, though at times employed loosely in other connections, should only be used in the description of body cavities and hollow viscera. **Superficial** and **Deep** are self-explanatory and indicate positions relative to the surface of the body or solid organ.

Vertical, Horizontal and **Transverse** need no special definition when it is realized that they apply to the upright trunk. In addition to these terms there are the names employed to designate imaginary planes in the body. Such a plane may be conceived as passing anywhere through the body in a dorsi-ventral direction and this is termed the **Sagittal** plane. The **Median Sagittal** plane passes through the body from the mid line of the dorsal surface to the mid line of the ventral surface, and **Lateral Sagittal** planes lie parallel to it towards the sides of the body. The **Coronal** plane is at right angles to the sagittal

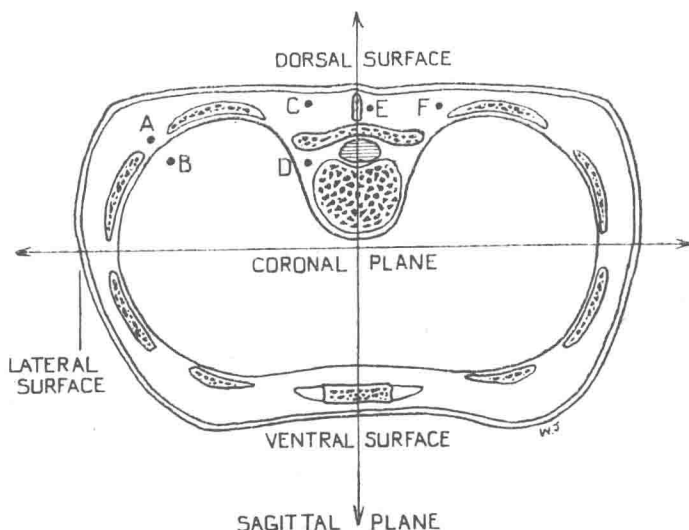


FIG. 1.—TRANSVERSE SECTION OF THE BODY TO EXPLAIN THE TERMINOLOGY OF POSITION.

The point "A" is *external* to "B" which is *internal*.

The point "C" is *superficial* to "D" which is *deep*.

The point "E" is *medial* to "F" which is *lateral*.

and, like it, may pass anywhere through the body between the ventral and dorsal surfaces.

If ventral and dorsal are used to the exclusion of anterior and posterior, and cranial and caudal to the exclusion of superior and inferior, there is no confusion in applying any of the above terms to the descriptive anatomy of pronograde animals or of embryonic stages.

The B.N.A. system of terminology included a further section of **Termini ad extremitates spectantes**. For an unstated reason these useful terms were omitted from the tables of nomenclature approved by the "Birmingham Revision." In the original B.N.A. terminology (1895) there were included the antithetic terms **Proximal** and **Distal**, **Radial** and **Ulnar**, and **Tibial** and **Fibular**. In the German revisions of 1931 and 1936 the additional terms **Volar** and **Dorsal**, and **Plantar** and

Dorsal are sanctioned. It is essential that these terms are incorporated into our accepted nomenclature, since no unequivocal account may be given of the anatomy of the limbs if their employment is omitted. For centuries medical students have wondered how it comes about that the thumb, which seems so obviously akin to the big toe, should be on the outer side of the hand while the big toe is on the inner side of the foot. The confusion of the medical student is due to the centuries-old folly of the human anatomist who has conceived that the structure of man should be described, not only in the erect position, but with the arms dropped to the sides and the palms of the hands directed straight forwards. This ancient folly must continue

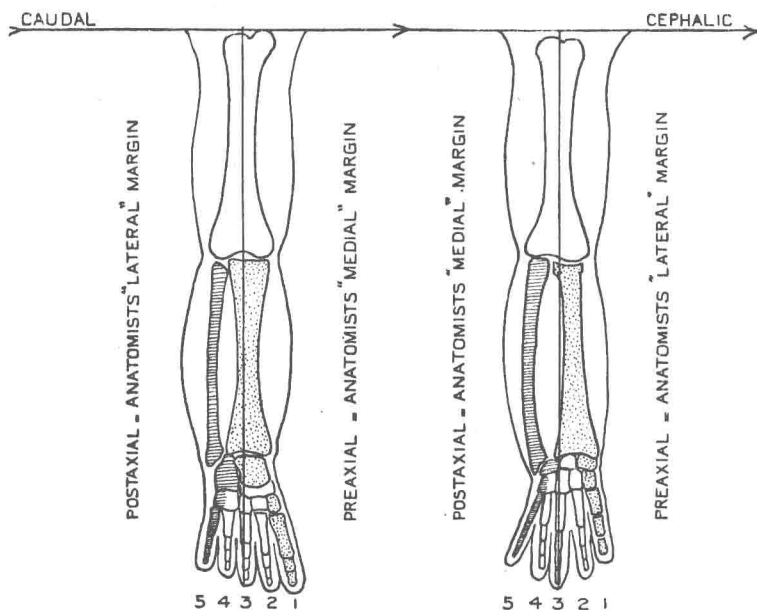


FIG. 2.—THE LIMBS OF THE RIGHT SIDE TO SHOW THE HOMOLOGIES OF THE PARTS AS A GUIDE TO NOMENCLATURE.

to create confusion and this confusion is made the worse by the Birmingham retention of medial and lateral as the only descriptive terms employed in connection with the limbs. It is quite apparent that if man is described in the absurd, so-called, "anatomical position" the inner side of the fore limb, which is nearer to the middle line of the body is the ulnar side, whereas the inner side of the leg is the tibial side. Later in his studies the student will learn that the ulna is homologous with the fibula and not with the tibia and that the muscles of the thumb are homologous with those of the big toe and not the little toe. Most of these difficulties are removed if the terms medial and lateral are deleted from the descriptive anatomy of the limbs. More of them

are resolved if we adhere to the terms radial and tibial and ulnar and fibular. But it is far better to employ terms that are equally applicable to both limbs and so economize in the use of words and at the same time gain in accuracy of expression. Fortunately such well known terms are available and it is high time they were in habitual use in human descriptive anatomy. The ideal terminology for both limbs is that which defines a central axis for the limb and a preaxial and postaxial margin when the limb is placed in its primitive position. The preaxial margin of the fore limb is the radial side and that of the hind limb, the tibial side. The five digits are numbered 1 to 5 from preaxial to postaxial margin of the hand and foot, and the third digit continues the axis of the limb. The terminology employed here for the limbs will therefore embrace the terms **Proximal** and **Distal** instead of Superior and Inferior. **Plantar** and **Dorsal** and **Palmar** and **Dorsal** will be used for the two surfaces of the hands and feet and **Preaxial** will, so far as possible, substitute Radial and Tibial, while **Postaxial** will be used instead of Ulnar and Fibular wherever occasion seems to demand it. Medial and Lateral, except where they form parts of the accepted names of structures, will be deleted. The application of this simple system of terms is made clear in Fig. 2. We have, therefore, agreed that we can postulate a median axis for the trunk—the median sagittal plane—and a median axis for each limb—the axial plane. This conception entails a further necessary convention in terminology, for movements of the whole limb should be described in relation to the median axis of the trunk, whereas movements of parts of the limb should be described in relation to the median axis of the limb. We therefore speak of **Abduction** and **Adduction** of the whole limb as it is moved further from or nearer to the median sagittal plane and abduction and adduction of the digits as they are moved further from or nearer to the axial line of the limb. The hand and foot have palmar

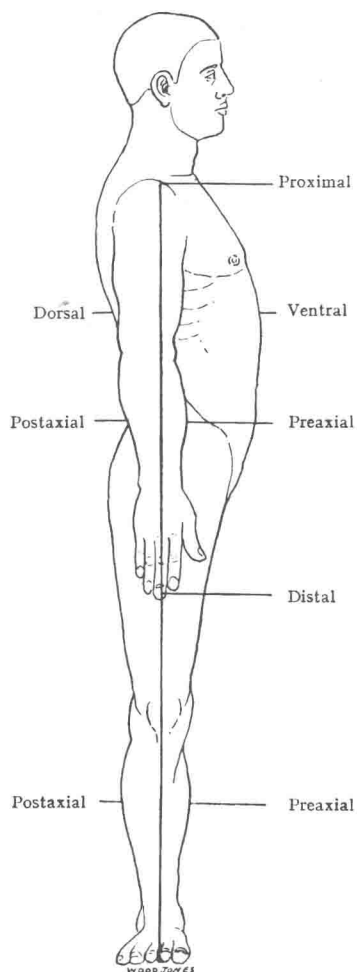


FIG. 3.—LATERAL VIEW OF THE ERECT FIGURE TO EXPLAIN THE TERMINOLOGY OF POSITION.

The leg has been rotated laterally so as to bring its preaxial margin to the front.

and plantar surfaces respectively and here we shall employ throughout the term **Flexion** for moving the terminal segments of the limb in a palmar or plantar direction and **Extension** for the reverse movement.

The traditional upright posture is therefore retained as the position in which the human body is described, but only such terms of position and direction are employed as are equally applicable to the body placed in any other position. Moreover, in picturing the body standing erect we do not assume that the arms are at the sides with the palms of the hands directed forwards, but that the palmar surface is directed towards the median sagittal plane with the thumb placed in front. The foot is not turned straight forwards but the whole limb is rotated outwards so that the heel is directed towards the median sagittal plane and the toes point laterally with the big toe placed in front. In this position the preaxial margins of both limbs face the front and the postaxial margins the back of the erect body as in Fig. 3.

CHAPTER II

THE DEVELOPMENT AND GROWTH OF THE HUMAN BODY

THE development of man, like that of every other form of life that reproduces sexually, starts from the union of two sex cells of very dissimilar appearance and potentiality. These two cells are the female sex cell or **ovum** and the male sex cell or **spermatozoon**. The ovum and spermatozoon are themselves the finished products that are derived from more primitive cells—the primordial sex cells. But though they are both derived from primordial sex cells, the method of their derivation and the degree of their specialization from their parent cells are very different, for while the mature ovum remains a large and primitive cell, the spermatozoon is extremely small and very highly specialized. Moreover, as the student has already learned in his preliminary studies, the female primordial cell gives rise to only one mature functional ovum but the divisions of the male primordial cell result in the production of four functional spermatozoa. One reason for this would seem to be that whereas the number of ova that can be fertilized and developed in the life time of any one female is strictly limited, the number of spermatozoa that are shed during the active sexual life of the male reaches astronomical figures. In the case of the female cell, as in the male, the stages of division through which it passes in development do, in fact, produce four end products, but three of these are the inconsiderable polar bodies which, so far as is known, simply disappear without fulfilling any functional rôle. It is only the fourth cell resulting from the divisions that becomes a mature ovum.

In the development of the sex cells, both male and female, there occurs one stage at which the dividing cell undergoes its reduction division, during which the number of chromosomes in the nucleus is halved in each of the two cells resulting from the division. In man, as a species, the number of chromosomes typical of all the cells of the body is forty-eight and therefore the mature sex cells of both sexes possess only twenty-four.

Each mature ovum and spermatozoon passes through four developmental phases known respectively as (1) **oogonium** and **spermatogonium**; (2) **primary oocyte** and **primary spermatocyte**; (3) **secondary oocyte** and **secondary spermatocyte**; (4) **ovum** and **spermatid**. From this stage the ovum becomes mature by mere growth and the spermatozoon by differentiation and specialization without further division (see Figs. 4 and 5). The phase at which the chromosome reduction takes place is the second in this series between the oogonium and the mature ovum and between the spermatogonium and the spermatozoon.

The mature human ovum is a very simple cell and is, among cells, a very large one. It measures from 0.25 to 0.3 of a millimetre in

diameter and is therefore within the limits of naked eye vision. With the exception of some of the larger neurons of the central nervous system, the ovum is the largest cell in the body. The human ovum may be described as a typical higher mammalian ovum, for all the higher mammals from elephants to mice start their lives from cells that are, in general, identical. Not only is the mature ovum a very large cell but it is also a very unspecialized one (see Fig. 6).

A simple living cell, in the form of an independently living unicellular organism, possesses three potentialities: it can repair itself, it can regenerate itself and it can reproduce itself. As cells become more specialized they lose these powers in varying degree. Of all the cells in the compound body of a higher animal, only the ovum retains

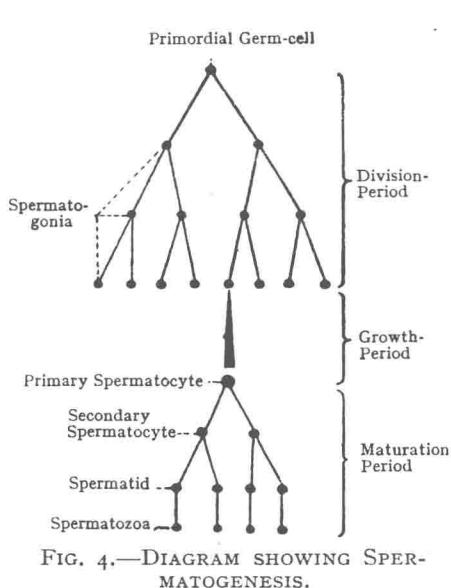


FIG. 4.—DIAGRAM SHOWING SPERMATOGENESIS.

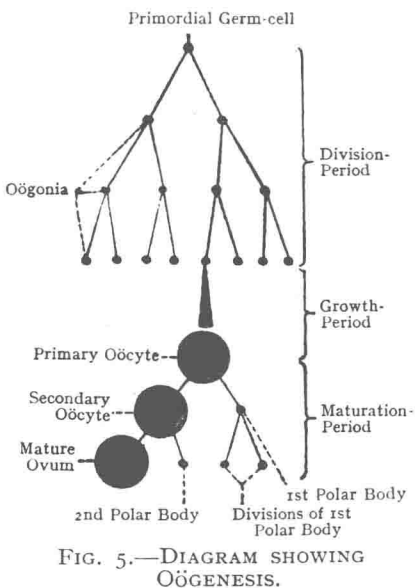


FIG. 5.—DIAGRAM SHOWING OÖGENESIS.

the power of development and reproduction, certain other cells are capable of regeneration and many, that have lost the power of regeneration, are capable of effecting repair. Among the lower vertebrates, whole organs and parts may be regenerated if they are lost, but this power wanes in the higher orders with increasing specialization. Although the regeneration of lost parts is beyond the power of any mammal, certain tissues, such as those of the neuron, still retain a very considerable ability to regenerate. The ovum is, therefore, distinguished as being a very primitive cell that manifests the retention of the primitive power of development and reproduction when the proper stimulus is applied to it. This stimulus is provided by the spermatozoon.

Compared with the ovum, the spermatozoon is an extremely small

cell, being one of the smallest in the body and, moreover, it is very highly specialized. While the ovum measures nearly 300μ in diameter, the total length of the spermatozoon is only a little over 50μ and the head, the only approximately spherical part of it, accounts for rather less than 5μ of this (see Fig. 6). It is obvious that one stimulus that the spermatozoon can exert on the ovum is the restoration of the specific number of chromosomes in the nucleus of the fertilized female cell. But since it is well known that among invertebrates and lower vertebrates the development of the ovum may be initiated by chemical or mechanical means without the intervention of a spermatozoon, it

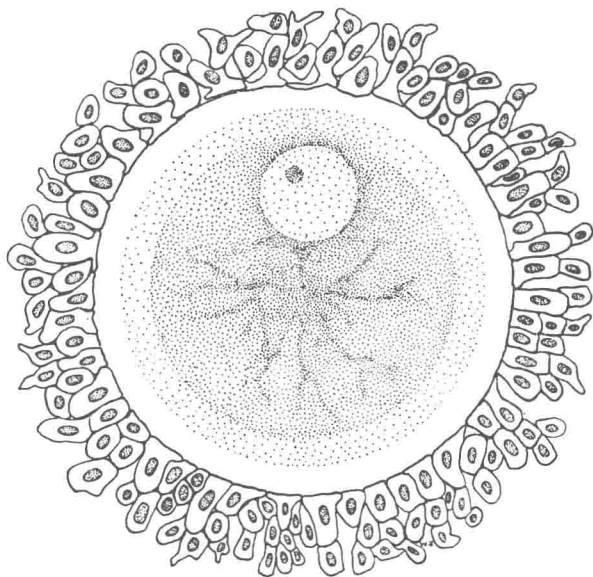


FIG. 6.—THE HUMAN OVUM WITH A SPERMATOZOOM DRAWN TO THE SAME SCALE.

The cells surrounding the ovum constitute the *corona radiata* and are derived from the Graafian follicle of the ovary. × 300.

is probable that the rôle of the spermatozoon in fertilization is not limited merely to chromosome restoration.

Concerning the origin of the primordial sex cells it is not possible to make dogmatic statements since two opposing views are held on the subject. The one is that they are developed *in situ* from the so-called germinal epithelium that covers the surface of the developing genital gland. The other is that they do not in reality arise in the germinal epithelium but are only segregated in the genital gland, having originally been set apart from the rest of the cells forming the body (somatic cells) at the very earliest stages of development. This

second hypothesis has been given wide currency in consequence of the support it affords to August Weissmann's theory of the Continuity of the Germ Plasm, which postulates that germ cells can only arise direct from previous germ cells and not from any of the somatic cells that constitute the body of the individual. Against the acceptance of this theory is the well known fact that after the complete removal of the sex glands in birds and mammals, regeneration of functional sex cells is known to occur. It would seem certain that in post-natal life sex cells may be derived from somatic cells, such as those of the germinal epithelium, and the only direct evidence at present available points to the definite conclusion that this is their normal source of origin in the embryo.

As for the shedding of the mature sex cells the most remarkable fact is the astonishing prodigality with which spermatozoa are produced. The normal ejaculate of man varies from some three to six cubic centimetres and each cubic centimetre contains between 75,000,000 and 100,000,000 living spermatozoa. Incredible though these numbers appear, there is definite clinical evidence to show that semen in which the number of spermatozoa falls any considerable degree below this extraordinary figure is incapable of effecting fertilization. In many lower forms of animal life, the disparity in numbers between the male and female sex cells is nothing like so great as it is in man, for the females of many invertebrates and lower vertebrates produce vast numbers of ova for fertilization in one act of insemination.

The mature human ovum is apparently shed spontaneously. In some mammals it is known that it may be shed in response to a stimulus and especially to the stimulus of coitus. Although it is possible that ovulation in response to coital stimulus may occur in the human female there is no direct evidence in support of the belief that it is at all a common happening. It appears to be the general rule that the shedding of the mature ovum takes place spontaneously and periodically and that ovulation occurs midway between two menstrual periods. Clinical observations tend to show that the ovum is shed very constantly from the sixteenth to the twelfth day before the onset of the next expected menstruation.

It is estimated that human ovaries have a potential production of some two hundred mature ova from each ovary or four hundred in all, and although this might appear to be a very lavish scale of production it must be remembered that for each ovum that is matured there are spermatozoa in the order of several hundred million. Certain mammals produce litters of twenty or more young at a pregnancy. In such animals it is known that the ova produced at any one ovulatory period exceeds even the large number of young begot, for all the ova shed, even if they are fertilized, do not succeed in developing into viable fetuses. On the other hand, it is known that certain mammals (Armadillos) that also produce large litters, never shed more than one ovum at one period of ovulation. In the first group, the litter consists of a number of young of varying sex and slightly varying

characters. In the second group all members of the litter are of the same sex and are so generally alike as to be termed identical, for they are all produced from a single ovum that has become divided into a number of separate embryos during the early stages of its development.

Human multiple pregnancies are common enough but unfortunately we have no certain knowledge as to which of these two alternative methods is the one most commonly involved in their making. Two or more separate ova might be shed or one normal ovum might conceivably become divided during development. Presumably in the first case two or more opposite sexed or even same sexed, but non-identical, foetuses would result, whereas in the second the foetuses would all be of the same sex and identical in general characters. It is obvious that the human female may at times produce two or more mature ova at one act of ovulation or the normal single ovum may divide during its early developmental phases and produce two or perhaps even more embryos, or at times it would seem that the two processes may be combined. Decisive evidence as to the relative frequency of these different possibilities could only be obtained by the examination of the corpora lutea in the ovaries of a large series of women who have given birth to multiple offspring. Unfortunately, any precise knowledge of this very simple detail is lacking at the present time.

The fate of the mature sex cells, once they have been shed, depends upon the chance of their meeting and effecting fertilization. It is well known that the fertilized ovum of certain mammals, such as the Badger, may remain alive for a long while even if it undergoes no developmental changes. But if it remains unfertilized, its life is apparently a very short one. Naturally, most of the knowledge of the duration of life of the unfertilized ovum is derived from experiments on lower mammals, but there is considerable probability that these findings may be applied to man without risk of very wide error. The bulk of the evidence at present available would seem to show that the life of the unfertilized ovum is limited to a few hours. But before this conclusion is accepted as disposing of the matter there is one important fact to be taken into consideration. It is generally agreed that fertilization takes place in the Fallopian tubes. It is therefore obvious that the unfertilized ovum must live long enough to accomplish the very remarkable and apparently very difficult journey from the ovary to the tube in order to be fertilized. It has been shown experimentally that an ovum shed from the ovary of one side may enter the uterus by the Fallopian tube of the opposite side of the body and a consideration of the hazards of the anatomical route traversed in such a journey makes its accomplishment in the space of a few hours appear to be a very wonderful happening. It is perhaps safest to assume no more than that the unfertilized ovum must certainly live long enough to perform this journey with probably some time to spare; but we have as yet no definite knowledge as to the time this journey takes in the case of human females. It must also

be remembered that even this assumption entails the supposition that spermatozoa are already waiting in the outer portion of the Falloppian tube in order to secure fertilization. If the life of the unfertilized human ovum is in fact limited to only a few hours it would seem that coitus must always nearly coincide with its spontaneous shedding if it is to be fertilized.

As for the spermatozoa, modern teaching assumes that they inevitably lose their power of fertilization within as short a time as forty-eight hours after their deposition in the female genital tract. The fact that living and motile spermatozoa have been found in the Falloppian tubes after very much longer intervals is discounted by the assumption that motility long outlasts fertility and that sperms remaining motile after forty-eight hours are no longer capable of effecting fertilization. If this is indeed the case it is obvious that fertilization can only be effected if coitus takes place within a very short time of the spontaneous shedding of the short-lived ovum. It may be that this is in fact the case, but to assume that the mammalian spermatozoon is necessarily short-lived is to overlook the important fact that in some mammals, representing such widely different stocks as Marsupials and Bats, it is well known that spermatozoa may remain alive and fertile for many months after they are deposited in the female genital tract. Among lower vertebrates and certain invertebrates the life of the spermatozoon is well known to extend over a period of several years and perhaps in view of these facts the present teaching that the life of the human spermatozoon is of necessity a very brief one, should be accepted with some caution.

When fertilization does occur it normally takes place in the outer end of the tube. As we have seen, the time required for the ovum to reach the tube must necessarily be comparatively short if the ovum is actually only capable of living a few hours before fertilization. In the case of the spermatozoon, there is more direct evidence, derived mainly from experimental investigation in lower mammals. It has been found that in small animals, such as rats, the time occupied by the spermatozoon in passing up the female genital passages is a very short one and limited to a few minutes. In man it has been estimated that the spermatozoon may travel by its own motility at the rate of an inch in seven or eight minutes and that its total journey is probably accomplished in an hour or so. When ovum and spermatozoon meet, the male cell penetrates the ovum, the nuclei of the two sex cells come together and the well known phenomena associated with chromosome fusion and division take place.

The fertilized ovum now continues its journey along the Falloppian tube and, although its passage up to this stage appears to have been rapid, its rate of progress through the tube becomes considerably slowed. Apparently some three days are occupied in traversing the twelve centimetres of Falloppian tube from the ostium abdominale to the ostium uterinum by which it enters the uterus.

Having reached the uterus the fertilized ovum does not imme-