

Typical Development Where the Journey Begins The Intrauterine Stages and Perinatal Period

The history of man for nine months preceding his birth would, probably, be far more interesting, and contain events of greater moment than all three score and ten years that follow it.

Samuel Taylor Coleridge (1772–1834)

The child's first home, the mother's uterus, is almost always hospitable; nevertheless the 38 weeks (266 days or so) between conception and birth present more risks (notably during the first 8 weeks of life) than any similar span up to the ninth decade. They begin with fertilization. Despite the potential risks most babies arrive in the world outside their mother's body, on time and in a healthy state. The particular hazards that faced them are detailed in chapters 8 and 9.

The major milestones during pregnancy are the three trimesters that are defined by the physiology of fetal growth, dated from presumed conception:

- the first, encompassing the first 12 weeks
- the second, ending at 28 weeks, and
- the third, covering the remainder of the pregnancy.

Biologists and embryologists divide the period of gestation into three unequal sub-periods: the germinal, embryonic and fetal stages of prenatal development. These stages in the unborn child's journey and the birth are the subject of chapters 1 and 2.

The First Steps

And the first step, as you know, is always what matters most, particularly when we are dealing with those who are young and tender.

Plato (428–348 BC)

Conception: The Beginning of Life

We all set out on life's journey as a barely visible particle of matter, no more than a single fertilized cell, but one that contains in its 46 chromosomes an unimaginably vast store of information for shaping that life. The Chinese reckon the person's age not from the moment of birth (as we do) but from conception, adding on a full year for convenience. In fact, development begins about 266 days before birth when the spermatozoon (a male germ cell from the father) enters and fuses with an egg (ovum) from the mother. A newborn female has some two million eggs stored in her ovaries. Only a few hundred will be called upon during her life. Unlike normal body cells, the nucleus of an ovum contains only half of the genetic material, or chromosomes, required for full development. After puberty, an ovum ripens once every month in one of the woman's two ovaries, typically around the middle of the menstrual cycle. It is discharged into the corresponding Fallopian tube (oviduct), and begins its slow 15 cm journey toward the uterus, propelled by small hair-like cilia that line the tube. An unfertilized egg is the largest cell in the body.

The male equivalent of the ovum is produced in vast numbers by the testis. A sperm cell has a head containing the nucleus, and half the normal number of chromosomes. Attached to the head is a tail that propels the sperm (tadpole-like) towards the ovum. An estimated 500 million sperms are released by the male on ejaculation. One of the sperms that make their way into the oviduct during the time the ovum is making its descent may unite with the ovum resulting in the conception of a new individual. Only one sperm head can penetrate the ovum wall and fertilize the ovum. If not

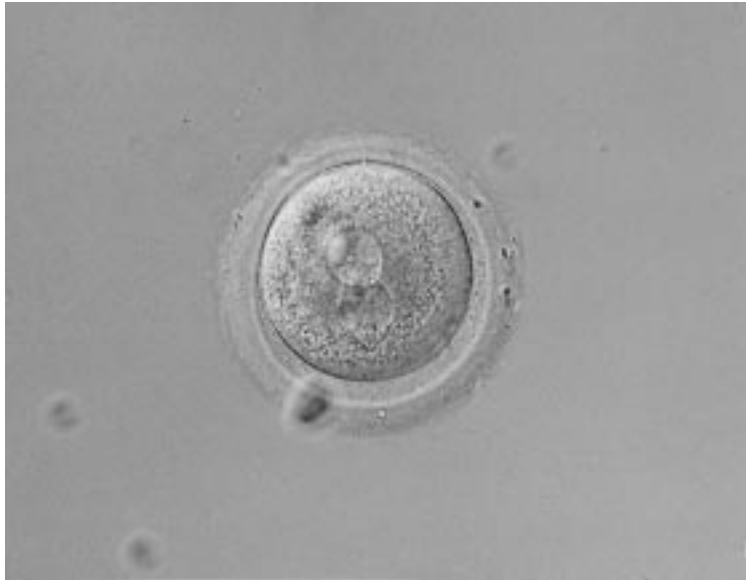


Figure 1 The moment of conception: the ovum is about to become a zygote following its penetration by a single sperm (CC Studio/Science Photo Library)

fertilized within 24 hours, the ovum dies and disintegrates in the uterus after a few days.

When fertilization is successful the sperm cell begins to disintegrate within a few hours, releasing its genetic content. The ovum also releases its genetic material, and a new cell nucleus forms around the hereditary information contributed by both parents. The new cell is referred to as a zygote. A biochemical reaction repels other sperm, thus preventing them from repeating the fertilization process. The process in which the two cells approach, unite, and re-form into a fertilized egg takes about 24 hours. This new cell nucleus contains 46 elongated thread-like bodies (chromosomes), each of which consists of thousands of genes, the basic units of heredity. According to the Genome Projects published in *Science* and *Nature* (see below) there are some 40,000 genes which, they estimate, can make 250,000 proteins available to the estimated 100 million million cells in any adult human.

As the zygote (one-twentieth the size of a pinhead) sets out on its 3 to 4 day journey through the Fallopian tube toward its prenatal home in the uterus it begins to reproduce itself. There are two forms of cell division, as described below.

1. Somatic cell division (mitosis)

All somatic cells in humans and in most other species are diploid. They possess matching (homologous) chromosomes arranged in pairs and they

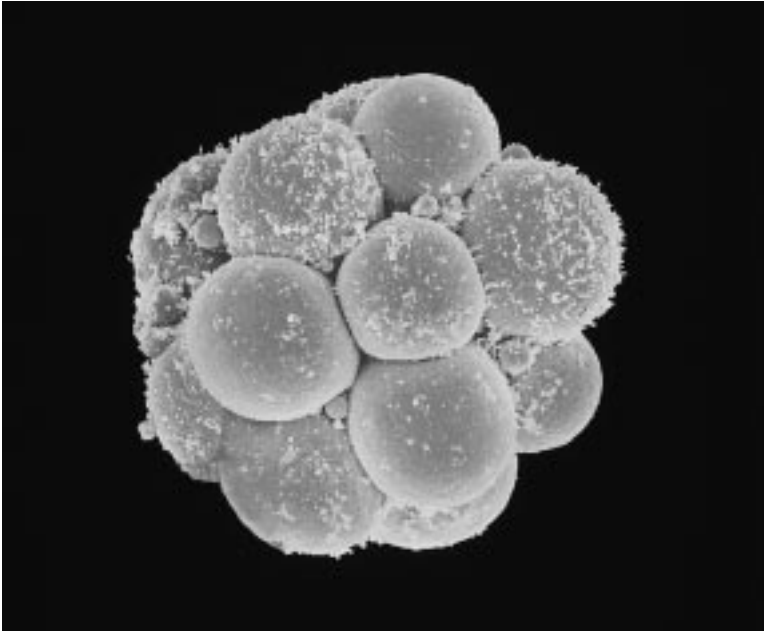


Figure 2 The human embryo at the 16-cell stage, some 3 days after fertilization: known as a morula, this cluster of large rounded cells, called blastomeres, is in the process of subdividing to form a hollow ball of cells (the blastocyst) on its journey to implantation in the wall of the uterus (Dr Yorgas Nikas/Science Photo Library)

proliferate through mitotic division. Mitosis occurs during tissue growth and now proceeds apace for the new being. At first the zygote, which contains 46 chromosomes, divides to form two new cells. Before it does this each of its 46 chromosomes doubles; then each doubled chromosome divides in half by separating lengthwise down its centre. The chromosomes next go to the opposite side of the cell. Thus when the cell itself divides down the centre, the new cells will each contain 46 chromosomes, as did the original cell. This process is repeated again and again: the two cells become four, four become eight, eight become sixteen, and so on and on.

By the time the infant is born s/he consists of billions of cells that make up bones, muscle, organs and other body structures. The human baby-to-be will undergo the equivalent of 42 successive divisions in progressing from a fertilized ovum to a full-term neonate. Gradually, as this process continues, the resulting cells begin to assume special functions, as part of the nervous, skeletal, muscular and circulatory systems. Not only do cells differentiate, many of them move from one place in the embryo to another along very specific pathways, by mechanisms that are poorly understood.

2. Germ cell division (meiosis)

In addition to body cells, human beings possess germ cells that have the specialized function of producing gametes: the sperms in males and ova in females. The germ cells are haploid. They possess half the number of chromosomes (one of each homologous pair). When the male germ cells in the testes and female germ cells in the ovaries produce sperm and ova respectively, they do so through the process referred to as meiosis. Meiotic cell division produces ova and spermatozoa by reducing the number of chromosomes from the diploid 46 (22 pairs of chromosomes plus the sex chromosomes) to the haploid number 23 chromosomes. When fertilization takes place the set of 23 chromosomes from each parent combines to make up the 46 chromosome-carrying zygote.

Genetic Variation and Influence

Genetic determinants

Variation in the genetic makeup of the chromosomes takes place during meiotic cell division by means of a process termed crossing over or recombination. This occurs before the stage of cell division, when the chromosome pairs are pulled apart to the poles of the cell. It leads to genetic material from one chromosome exchanging with the other member of the pair, and results in a completely independent assortment of genes. Each member of a pair corresponds to the other in size, shape and the hereditary functions it serves. The genes on each chromosome also function as pairs, the two members of each gene pair being located at the same sites on their corresponding chromosomes. From the moment of conception the child-to-be, an entirely novel combination of the parental genes, carries forward in her or his cells the blueprint that determines the genetic aspects of growth and development through life.

Male and female heredity

Twenty-three pairs of the elongated thread-like chromosomes are present within the nucleus of every cell, except the egg and sperm cells, which consist of 22 matched pairs: the non-sex autosomes and one pair of sex chromosomes. In the male, the sex chromosomes consist of an X and Y chromosome; in the female there are two X chromosomes. The genes on the chromosomes in the sex cells are the ones that are transmitted to successive generations. As we saw, they also work in pairs, each gene being paired with a gene on the corresponding chromosome, one member of the gene pair

coming from the father, the other from the mother. Each child thus inherits half of each parent's genes.

A major aspect of genetic determination is the child's sex (his or her gender identity is a matter we shall return to). It is the father (one half of whose sperm contains a Y chromosome, the other half an X chromosome) who determines, by fertilizing the ovum of the mother (who has two X chromosomes), the sex of their offspring. A child's sex is 'decided' by whether an X-bearing or Y-bearing sperm fertilizes the ovum. And the awful irony is that throughout history, as Shaffer (1999) points out, mothers have been belittled, tortured, divorced and even beheaded for failing to bear their husbands a male heir!

Even before the female baby is born she will have the ova which, when fertilized at the time of her sexual maturity, will constitute her contribution of genetic material to the next generation. The processes by which spermatozoa and ova are formed are named spermatogenesis and oogenesis respectively. One of the distinctions between spermatogenesis and oogenesis relates to the timing of meiosis in the life of the individual. Oogenesis begins in late fetal life or at about the time of the female's birth. The process is arrested, however, before the first meiotic division is completed. By, or before the end of the female's life as a fetus, all the ova she is ever going to have are already produced and have reached the so-called dictyotene stage of meiosis. They remain in this state until puberty, and from puberty onwards will ripen at the rate of one a month (or more, since some pregnancies are multiple) until the menopause.

The ovum fertilized in a woman of 40 is 20 years older than one fertilized in a woman of 20. Sperms, on the other hand, are produced throughout male adult life from puberty onwards. As a result, the spermatozoon of a man of 40 that fertilizes an ovum is of recent production, no older in that sense than that of a man of 20.

Development, which is about the increasing complexity, differentiation and specialization of the cells, is under the direction of genes that function like minute chemical factories from their home base on the chromosomes. They modify the activity and development of entire cells in keeping with the environment in which they are located. From conception onwards, the child's environment and inherited capacities (the genes in that original cell turn up in all the millions of cells that eventually constitute the adult) interact to produce a complete individual, the emphasis being on that word 'individual'. More than a million genetic differences between humans have been found so far. The observable result of the highly complex nature-nurture interaction is referred to as the phenotype.

Developmental psychology is essentially about the emergence of individual differences. This individualism begins with the 'lottery' described earlier, whereby we receive our genetic makeup. It continues as such by being shaped by the child's personal life-events, and her/his idiosyncratic construction

of their world (Kelly, 1955). Even siblings, given the figurative personal 'goggles' through which they view life do not, in a sense, inhabit the same environment, despite living in the same home.

Multiple births

MONOZYGOTIC (MZ) TWINS

Perhaps to a somewhat lesser extent the same applies to monozygotic (identical) twins despite the fact that they share the same set of genes (genotype). This comes about because they have developed from a single zygote. In the



Figure 3 Monozygotic (identical) twins: these children share identical genes (PhotoDisc)



Figure 4 Monozygotic (identical) quadruplets: they too share identical genes, unlike dizygotic (fraternal) twins. Triplets, quads etc. are commonly born to parents who have had fertility treatment (© Associated Press)

zygote stage of cell division, the cells split off into two (or more) separate organisms. A majority of MZ twins result from division of the inner mass at the blastocyst stage, when the organism is implanting into the uterine wall and the embryonic membranes are beginning to develop. These twins share one placenta and chorion but generally have two umbilical cords and amniotic sacs. In some 20–30 per cent of cases the split takes place before the zygote stage, during so-called cleavage divisions. The two organisms implant separately, and have two placentas and chorions (O'Brien and Hay, 1987). Identical twins occur in approximately one in every 250 births around the world. They are always of the same sex.

The splitting of an embryo into two sections fails, in rare circumstances, to result in complete separation. Such twins were widely exhibited in sideshows in the nineteenth century. Their origins in Siam gave the name Siamese Twins to this atypical form of twinning, a title best replaced by the words 'conjoined twins'.

FRATERNAL (DIZYGOTIC, DZ) TWINS

The statistics for the birth of fraternal (dizygotic) twins are one in every 125 births. They share no more of their genotype than any other pair of siblings, as they result from the fertilization of two different ova by two different sperms. The twins may be of different sexes. The sharing of genetic make-up makes MZ twins ideal for investigating the contribution of heredity and environment in disorders like autism and schizophrenia. Fraternal twins and non-twins provide excellent contrast and control groups in such studies. There appear to be advantages for first-born and heavier twins in terms of their well-being and development.

The Genotype

The genetic constitution of the child, referred to as the genotype, is the total set of genes. The genes are present in every cell of the body, but not all of them are active. It is the site and functions of the cell that determine which of them are active. Particular sets of genes, for example, are active in bone cells. Genes influence and direct the development and functioning of all of the organs and body systems, and account, inter alia, for variations in height, hair and eye colour, body shape and intelligence.

The Human Genome Project

This is a monumental global effort to read the entire human genome – the master blueprint that gives instructions to the person's many billions of cells. The deciphering of the human genetic code, an awesome number of letters making up the linear sequence of DNA (deoxyribose nucleic acid), reached a watershed with the publication of two decades of painstaking research in the February 2001 editions of *Nature* and *Science*. The two research groups have virtually managed to 'map' the many thousands of genes stored on these DNA threads. These have been referred to rather dramatically as the first clear words from the 'book of life'. The use of the word 'first' is apt, as this most promising and exciting journey of discovery has barely begun.

To the surprise of many researchers the number of genes is fewer than the fifty to one hundred thousand expected. There are, in fact, around forty thousand genes, some two times as many as the fruit fly and only three hundred more than a mouse. Although the number seems limited compared with expectations, there is a vast number yet to explore and understand. Much of the complexity arises from the combining of these genes. They work together (along with interacting environmental influences) to create or influence complex patterns of human behaviour.

Our genomes come packaged in tightly coiled threads of DNA which if unwound and tied together, would probably stretch more than one-and-a-half metres. A DNA molecule is a long chain of 'building blocks' called nucleotides. Genes are made up of two chains of DNA, the sides of which are sugar-phosphate molecules. This edifice spirals upon itself and is referred to as the double helix (Watson and Crick, 1953).

The regular structure of DNA enables the genes to be accurately interpreted and reproduced. The nucleotide building blocks come in only four different kinds: adenine, thymine, cytosine and guanine (shortened to A, T, C, and G). These are the same in all animals and plants; what is different is the order in which they are strung together. They are arranged in different combinations on different parts of the chromosome. The sequence of building blocks in a human being is not only different from insects and animals, but it also differs, although less so, from the sequence in every other human individual. The DNA is distributed among the multitude of cells making up the human body. It represents a set of instructions on how to make a body, written in the A, T, C, G alphabet of the nucleotides.

The coded message of the DNA is translated into another alphabet. This is the alphabet of amino acids that spell out the vital protein molecules. Genes only specify the sequence of amino acids that are linked together in the manufacture of a molecule called a polypeptide, which folds up in many different ways to make different proteins. These proteins not only constitute much of the physical fabric of the body, they also exert sensitive control over all the chemical processes inside the cell, selectively turning them on and off at precise times and in precise places.

The genome map sets out to find out where different pieces of information are on the chromosome. The exploration of the map is far from complete and the sorting out of what is, and what is not relevant to function, will take many years of research. The reason why geneticists refer to a genetic 'map' is that information is arranged in a line along each of the chromosomes. As we have seen, each chromosome is a very long string of letters that contains a defined, ordered sequence of information. Each combination of bases provides coded instructions that regulate the various activities of the body, and indeed its development. Only 3 per cent of the three billion letters in our DNA code (the As, Ts, Cs and Gs) that actually encode the genes that make up the human genome, and thus make us what we are, appear in the genes. This 3 per cent is very similar in other mammals, and even in insects.

Plomin (2001b) states that mutations are quickly weeded out from these bits of DNA because these are so crucial for development. When they are not weeded out, they often cause the severe single-gene disorders. The remaining 97 per cent has been described as 'junk', 'litter' or 'rubbish'. He does not believe that this large remainder is 'just along for the ride'. There is increasing evidence that most genetic influence on complex traits involves this 97 per cent of the genome, not the 3 per cent that codes for classic genes. Variations

in this 97 per cent have a regulatory activity that is responsible for the widespread influence of genes on complex medical disorders such as heart disease and psychiatric disorders such as schizophrenia.

Plomin (ibid.) makes the point that such conditions are genetically *influenced* but not genetically *determined*, unlike single-gene disorders such as phenylketonuria (PKU). As he describes it, genes work like risk factors, slightly increasing or decreasing risk for a disorder. They do not work like a 'master puppeteer pulling our strings'. A large proportion of the disorders dealt with later in the book are influenced by many as opposed to single genes, and therefore it is the discovery of human gene sequences that will be particularly important. By sequencing the genome for many people's DNA, we are rapidly finding all the bits of DNA that differ between them.

Among the many interesting findings to fuel the genetic modification debate, has been the discovery of bacterial genes in our genomes, a phenomenon referred to as 'horizontal transfer'. The implications are that it is possible for 'intrusive' DNA from other outside organisms, to get into our genomes.

Similarities and Differences in Individuals and Groups

As every ovum and sperm contains a different assortment of genes, every child inherits a mix of genetic information that differs from the siblings. The exceptions are, as we saw earlier, monozygotic twins who inherit the same selection of genes. Ashley Montagu (1964) estimated that in a single mating the possible combinations between the 23 male and 23 female chromosomes amount to 8,388,608 and the chance of any such combination being precisely repeated more than once, approximately one in 70 million.

Although there can be wide variations within a family group, a child is still somewhat more similar to his or her blood relations than to anyone else. After all, their genes are drawn from a gene pool provided by the same two parents. Although each sibling inherits half of each parent's genes, they never inherit the same half owing to the random distribution of chromosomes (and genes) into the sperm and ovum gametes that unite to generate new life.

Researchers on the Genome Project have so far collected almost a million tiny variations in the genetic code – single nucleotide polymorphisms or SNPs – that might explain why humans differ from one another. The variation between any two individuals in the same population could be greater than that between two different groups. Craig Venter, head of one of the genome research groups (quoted by Tim Redford, science editor, *The Guardian*, 12 February 2001) found no way of telling which of some African-American, Asian-American and Hispanic-American individuals, was which. He stated that no serious scholar in this field considers race to be a scientific

concept. We all evolved out of the same three or four groups in Africa. Different populations were fixed with immigrations. Venter considers that there is more diversity within Africans than there is between Africans and Caucasians; we are part of a continuum because we evolved from the same set of people over a relatively short period of time.

Inherited characteristics

Genes are sometimes identical in a pair (homozygous), sometimes different (heterozygous). Those that are dominant (e.g. brown eyes) determine which characteristics will emerge when paired with recessive genes (e.g. blue eyes). The implications of this for the inheritance of abnormal physical or mental disorders are highly significant, and are discussed later. Genes may show their effects early in life (e.g. gender differences or a condition such as Down's syndrome); they may appear later in life (e.g. schizophrenia), or they may be delayed until late in life (e.g. the dementias). Genetic influences contribute to cognitive abilities, an issue that has given rise to heated debates within psychology and sociology (Plomin, 1990, 2001b). Plomin (2001b), in a review of the behavioural genetic literature, states that many studies, adding up to more than 8000 parent-offspring pairs, 25,000 pairs of siblings, 10,000 twin pairs, and hundreds of adoptive families, converge in concluding that genetic factors contribute substantially to general intelligence ('*g*'). Estimates of the effect size (heritability) vary from 40 to 80 per cent. Estimates based on the entire body of data are about 50 per cent, indicating that genes account for about half of the variance in *g*.

The term heritability is sometimes misunderstood. It is not a synonym for 'inherited'. Heritability estimates, which may vary widely across populations and environments, are not informative about the development of individuals. Although heritability estimates are useful in determining whether there is any hereditary basis for the *differences* people display on one or another attribute, they tell us nothing about children's capacity for change. They should therefore not be used to formulate public policy of the kind that could put constraints on children's development, or in some other way adversely affect their welfare.

Genetic material inherited at conception normally remains unaltered throughout life, and is transmitted to the offspring in the same form. It may change (mutate) in exceptional circumstances, but the mechanism of heredity is remarkably reliable, and the vast majority of infants is born within the normal range of variation. The basic chemical structure of the chromosomes appears to be very stable. Genetic errors do sometimes occur and they take different forms, the subject matter of part IV.

Many characteristics in which there is quantitative variation, notably complex ones like intelligence, temperament, stature, longevity and athletic

ability, depend on the action, called polygenic inheritance, of many genes. Polygenic mechanisms are thought to produce attributes that are approximately normally distributed (e.g. height, weight, blood pressure and IQ). The physical capabilities, social and psychological skills, and strategies acquired by the individual, plus all the developmental changes that occur as the child grows up, result from an interaction of maturational and learning processes.

Maturation and learning

Maturation is the term applied to those developments in the child such as beginning to walk and talk, becoming pubescent, and others which are canalized, which is to say that they occur in a predictable sequence, as a function of time or age. It is an orderly process that progresses in fetal development from the simple to the complex. The direction is cephalocordal (i.e. from top to bottom – brain forming before legs) and proximodistal (i.e. from the centre to the periphery – the spinal cord forming before the arms). Maturation also refers to the various neurophysiological and biochemical changes that take place from conception to death. Among these will be the hormonal changes of puberty which contribute to the shaping (via bodily changes) of male and female identity (see chapter 7). The environmental influences, which are so critical, depend in large part – as with so many other human attributes – on learning (i.e. instruction and/or experience).

Progress from Conception to Birth

The germinal stage: the first 14 days

The baby-to-be's first journey following the fertilization, which took place in one of the mother's two Fallopian tubes, is as a cluster of dividing cells moving down her oviduct and uterine lumen. Cell division begins 24 to 36 hours following conception. During the process of so-called cleavage division, from 0 to 40 hours, all cells are identical. By the time the zygote has reached the uterus – a journey taking 3 to 4 days – cleavage has proceeded to the point where the zygote has 12 to 16 cells. By 4 days of age (the number of days counted from conception) the egg mass at around 16 cells is called a morula. After approximately 4 days the multiplying cells separate into two distinct masses: the outer cells of the bilaminar disk forming a protective cocoon around the embryo, a cocoon that will create the rudiments of the all-important placenta – the embryo's life support system, and the shelter within which it will grow.

The inner layers of cells called the embryonic disk will form a nucleus of cells to become the embryo. Further differentiation takes place in the Fallopian

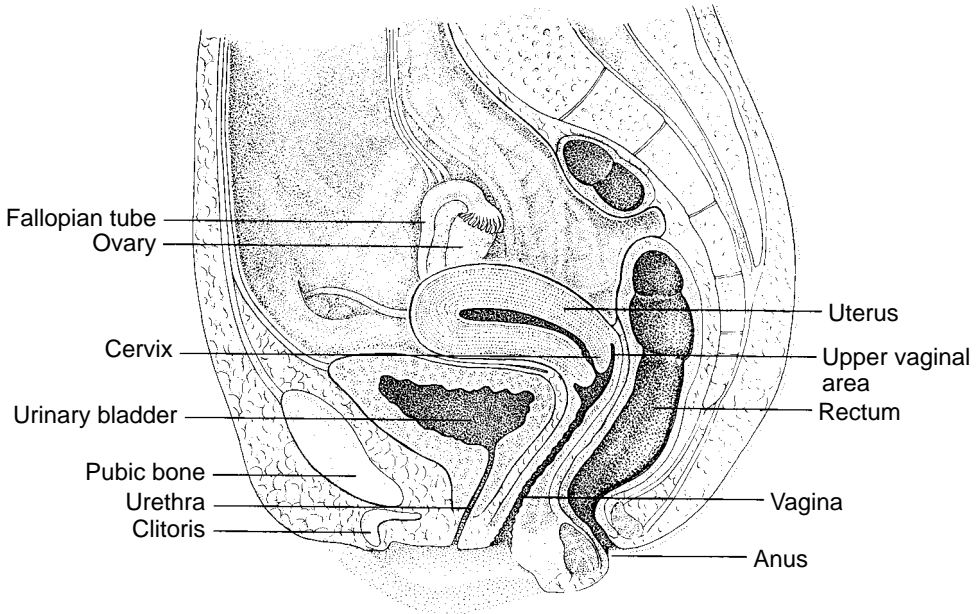


Figure 5 The female reproductive system

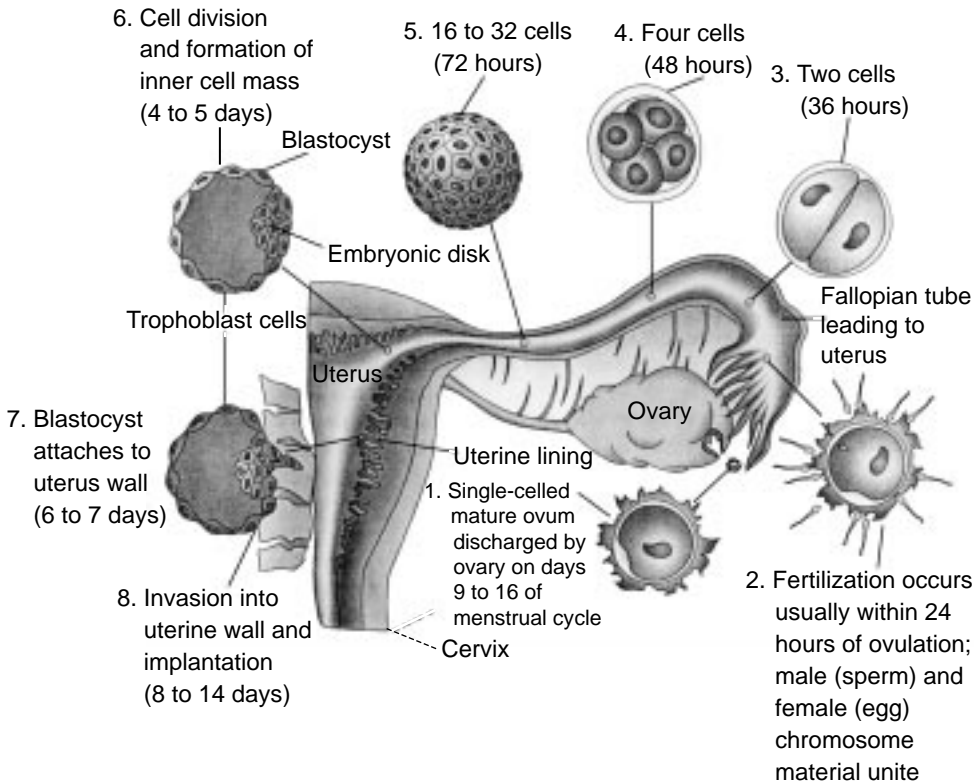


Figure 6 Germinal period: the 14 days after fertilization

tube resulting in the so-called blastocyst. As it approaches the uterus small burr-like tendrils (villi) emerge from its outer surface, and after entry into the womb they burrow into its lining (the endometrium). This process is known as implantation and, at around 10 to 14 days, marks the end of the germinal period and the beginning of the embryonic stage of development.

Comment: Close to 60 per cent of all developing blastocysts fail to implant properly and therefore do not survive the germinal period. Most of them were grossly abnormal.

The embryonic stage: the third to the eighth week

The first stage of development of the conceptus (the product of conception) itself, is the embryonic stage. The embryo, as one of its major tasks, secretes chemicals that suppress the mother's immune system so that the embryo will not be rejected as an alien intruder, but allowed to grow. They have a second task of producing the chorionic gonadotrophin which stops the embryo being carried away by a menstrual period. The ovulation cycle now ceases. Pregnancy induces a higher metabolic rate (10–25 per cent higher than normal) in the expectant mother, and results in her body accelerating all of its functions. Cardiac output rises steeply and is maintained almost to the maximum level throughout the rest of the pregnancy. Breathing becomes more rapid as the mother sends more oxygen to the baby and exhales more carbon dioxide.

From the third week following conception, the embryo enters a highly sensitive period of growth. The first trimester of human development is a period of morphogenesis in which a differentiated fetus will eventually emerge from a homogenous embryo. The major organs and basic tissues are laid down. Development proceeds in an orderly manner and at a regular rate, with specific changes occurring at specific times. Every organ and every tissue – in fact, every cell – has its own timetable for coming into existence, for developing, for taking its place in the machinery of the body, and for beginning to carry out its function. And every small timetable is meshed with every other timetable. At no time in the future will this baby-to-be change as much as during these early prenatal months. Montagu (1964) makes the point that during this so-called *critical period* the development of the human body exhibits the most perfect timing and the most elaborate correlation that we display in our entire lives. He uses as an analogy the building and launching of a satellite, involving thousands of people and hundreds of electronic devices which, he says, is not nearly so complex an operation as the building and launching of a human being.

During the first phase of embryonic differentiation there are a number of spontaneous abortions, often of embryos with major chromosomal defects. They are not absorbed earlier because this is the first stage of development that is governed by the genetic material (DNA) of the embryonic cell nucleus. Earlier cleavage division is governed by the ribonucleic acid (RNA) that still survives from the original (i.e. the unfertilized) ovum.

Disturbances in the uterus can also produce calamitous effects on their growth and development. Only one out of every six embryos gets beyond 8 weeks in the womb. It is during periods of rapid change that an organism is most vulnerable to deleterious influences; so it is no wonder that mothers have to be careful about their health, which in essence means their baby's health and well-being. After this phase of development it is difficult, if not impossible, to affect the morphology of the organism in any fundamental manner. At 3 weeks, the embryo is already 10,000 times the size of the zygote from which it developed. However, this is not the time of maximal growth velocity. In the case of body weight that achievement occurs at approximately 20 weeks. The rate of growth thereafter slows down until term. Maternal factors such as uterine volume now confine the fetus.

From roughly the beginning of the third week after conception the hitherto formless mass of cells becomes a distinct being. A perceptible sign of body formation is the development of a three-layered (trilaminar) disk. A portion of the outer layer of cells folds into a neural tube that soon becomes the brain and spinal cord. The disk becomes attached to the uterine wall by the short, thick umbilical cord, and the placenta develops rapidly. The organism is now made up of three layers:

- The ectoderm (to become the nervous system, skin, hair and teeth)
- The mesoderm (to develop into the circulatory system, muscle and bone tissue)
- The endoderm (which will become the digestive system, and various internal organs).

There is a rudimentary heart that begins to beat by the end of the fourth week, and the eyes begin to form. The neural tube closes; if not the result is a hare lip or spina bifida. Growth rate is about 1 mm per day. The support systems for the embryo develop, namely:

- The amniotic sac and fluid in which the embryo will float. This is a water-tight membrane that develops from the trophoblast and surrounds the developing embryo, regulating its temperature and cushioning it against injuries.
- The chorion, which is a membrane that develops from the trophoblast and becomes attached to the uterine tissues to gather nourishment for the embryo. It acts as a safety cushion around the amniotic sac.
- The yolk sac, which manufactures blood.

The placenta, which is formed from the lining of the uterus and the chorion, provides for respiration and nourishment for the unborn baby, also for the elimination of its metabolic wastes. It pumps out hormones such as chorionic gonadotrophin, which help to support a healthy pregnancy. The umbilical cord, a soft tube containing blood vessels, connects the embryo to the placenta. The villi of the growing placenta intermingle with maternal blood vessels of the uterine wall so that they eventually constitute spaces surrounded by 'pools' of blood. The mother's blood flows in and around these spaces and an exchange of materials can take place within them. Small blood vessels from both mother and embryo intertwine, but they do not join. Although she and her baby do not share blood-streams, there is an interchange of certain substances – nutrients and waste – between their circulatory systems by way of the placental barrier; they include vitamins, antigens, antibodies, blood proteins, amino acids, drugs and viruses. Small molecules (oxygen, food, salts from maternal blood and carbon dioxide plus digestive wastes from infant blood) can pass to and from the mother's and the embryonic blood vessels. Large molecules such as red blood cells, most bacteria and various toxins, hormones and maternal wastes that could harm the developing conceptus cannot do so.

The late embryonic stage

Ultrasound can detect the presence of the embryo. By 5 weeks after conception arm and leg buds form. Until now female and male embryos look alike. At the fifth to sixth week of gestation the rudimentary testes and ovaries can be distinguished by microscopic examination. The first primordial structure to differentiate sexually is the bipotential gonad; and it is the male who manifests the first sexual difference. The male derives from the more basic female form, contrary to ancient received wisdom. If fetal androgen (a male hormone similar to the testosterone produced by adult male testes) is not present, or removed from an embryo with XY chromosomes (carrying the male genes that were imposed from the moment of fertilization), it will develop internal female sexual structures. If male hormones are present, the embryo develops male internal sexual characteristics. At 5 to 6 weeks of life part of the genital gland (the medulla) begins to proliferate and the surface portion (the cortex) regresses. When the genital gland differentiates into the primitive testes, these organs secrete fetal androgen. Low levels of androgen in a female embryo (conceived with XX chromosomes and female genes) allow the normal development of female sex organs.

Although a rare event, an imbalance in this system of hormone secretion can occur during fetal development. If there is insufficient androgen in a male embryo or an excess of androgen in a female embryo, the result is an individual with both male and female sex organs – an intersex

phenomenon or hermaphrodite. (See Calapinto, 2000 and Money, 1993 on these atypical developments.)

It is hypothesized that sexual differentiation does not end with the completion of the formation of the physical sexual structures (at 12 weeks for the female ovaries; 16 weeks for male organs). Appropriate sexual behaviours (for example, controversially: aggression, spatial reasoning, rough and tumble play) are thought to become encoded physiologically in the brain. One can hear the cries of protest and sceptical requests for proof at this suggestion.

By 7 weeks, facial structures fuse (otherwise facial defects such as cleft palate occur). By 8 weeks, crown–rump length is 3 cm (slightly over 1 in) and weight is 1 g (about 0.03 oz). The major development of body organs and most structures is now complete.

Nerve cells that will form the brain will travel along pathways that are being laid down by glial cells which enable the neurons to move towards each other, connect and become active. The all-important nerve cells, as Pinker (1997) observes, are born in appropriate numbers at the right times, migrate to their resting places, send out connections to their targets and hook up to the appropriate cell types in the right general regions. All this is achieved under the guidance of chemical trails and molecular locks and keys. What is missing, as he points out, is an answer to the mystery as to how precisely this happens.

The fetal stage: the ninth week up to birth

Despite a mother's responsibility as host in protecting her baby-to-be, and the intimate emotional bond she may feel toward her unborn child (see the following chapter), courts of law have given recognition to the fact that the fetus is only a temporary lodger, always a distinct individual. The fetus has its own unique pattern of genes, and possesses its own nervous system and blood stream. As we have seen, there is no more direct blood tie between a mother and child than between a father and child. Despite its tenancy of the womb the fetus has rights of its own. There are passionate debates about the extent and balance of the rights of the mother and her unborn baby, arguments that are too complex for a brief and adequate discussion, and therefore not pursued in this text.

By the second trimester that begins on week 13, the pregnancy is well established and 'shows'. Many women report a surge of energy and a sense of well-being, earning the trimester (which lasts until the end of week 27) the soubriquet 'golden period of pregnancy'. Most of the baby's external features that are observed at birth are now apparent. The body begins to straighten and elongate. The head is large in comparison to the body. The heart beats at 140–150 per minute. All of the structures that will be present

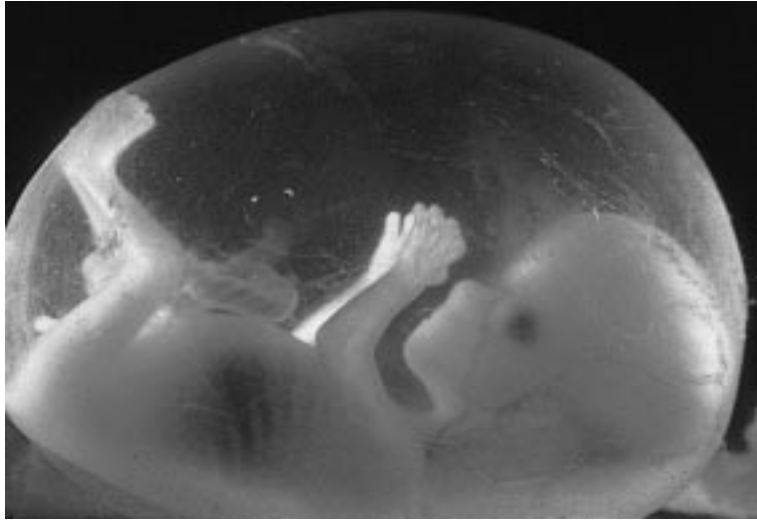


Figure 7 At 14 weeks, surrounded by its amniotic sac, the fetus is recognizably the infant it will become, with discernible facial features, limbs and sexual differentiation (Petit Format/Nestlé/Science Photo Library)

when the baby is born, in 7 more months, have already formed, at least in their beginning stages.

Apgar and Beck (1974) observe that medically, the unborn organism is no longer an embryo, but a fetus; not an it, but a he or she; not an indistinct cluster of cells, but an increasingly recognizable, unique human being in the making. It seems somehow miraculous after this highly sensitive period of development just how much (and how often) things go right despite the potential hazards. The vast majority of babies emerge into the world as reasonably intact beings.

The placenta now takes over the production of pregnancy hormones, the mother's hormone levels begin to resume a balance making for enhancements in appearance and in mood (sometimes a sense of elation) for many. The fetus not only looks more human; it is possible by 12 weeks to discern its gender. It now contains nearly the same number of neurons as an adult, and the nerves from the brain begin to be coated in myelin, a layer of protective fat. This is a crucial stage in their maturation as it facilitates the passage of messages to and from the brain.

THE FINAL MONTHS

These months find the baby growing bigger in her mother's abdomen; it is during this final period that the body parts and organ systems are enlarged and refined. Some of the milestones of fetal development are the announcing of his or her presence by kicking (by 16 weeks), sucking their thumbs and



Figure 8 A 19-week-old male fetus sucking his thumb: at this time, the crown–rump length is around 18 cm and the fingers and toes have formed; the mother will have noticed the fetus’s movement (Neil Bromhall/Science Photo Library)

displaying the beginning of hair growth (by 20 weeks). By the seventh month the fetus is able to breathe, cry, digest, and excrete, and is in a good position to survive premature birth. The final months of fetal development are primarily concerned with length and weight-gain. At the end of the fifth month the fetus is around 20–30 cm (8–12 in) long and weighs about 225–450 g (0.5–1 lb); at the sixth month it is 28–35 cm (11–14 in) in length and its weight is 680 g (1.5 lb).

During the final 3 months *in utero* the fetus is reported to be capable of learning from the events in its environment. Despite the protective roles of amniotic fluid, embryonic membranes, uterus, and maternal abdomen, it is not entirely cut off from what is going on in the world outside. The uterine environment is a stimulating, interactive home for a now ceaselessly active – kicking, hiccuping, face-pulling, crying, hitting out – inhabitant. Certainly, the fetus with the use of its rudimentary access to the fundamentals of experience and communication – touch, taste, smell, hearing, and vision – is preparing for life outside the womb.

Several experiments have revealed the following about the fetus:

- Listening begins at 16 weeks.
- It actively processes and responds to sounds that are filtered through the amniotic fluid that surrounds it, distinguishing, it is claimed, between music, language, intonation, rhythm, and other auditory stimuli. Researchers state that prior to any *ex utero* experience, newborns show that they have already extracted information about some of the important abstract features of mother's voice during their period in the womb. It is claimed that congenital deafness may be diagnosed during the prenatal period because of possible access to the fetus while it is in the womb (see Shahidullah and Hepper, 1993, and chapter 2).
- It shows sensitivity to light, responding to it with accelerated heart rate.
- It shows skin sensitivity to a hair stroke to a growing number of areas of the embryonic/fetal body.

Eventually, at around 266 days after conception, the baby usually rotates into a downward position with its head settling into the bony part of the mother's pelvis, relieving the pressure on her abdomen. This so-called engagement (the 'drop') is one of the first signs that labour is approaching. There may be different intervals of time before its actual onset. In the weeks preceding delivery the uterus may have 'practice' contractions (first described in 1872) which are usually brief and relatively painless. They tone up the delivery system for the 'real thing', while helping adjust the baby's position. By the time true labour begins, the cervix will probably have already started to dilate and thin (efface), initiated often by the pre-labour contractions.

No one can predict what will happen during labour; fortunately most births go without a hitch. The typical birth and the exceptions are described in chapters 2 and 9 respectively.

Comment: About 5 per cent of all fetuses are aborted spontaneously before possible viability at 22 weeks, or are stillborn after 22 weeks.

The chronology of events in the child's first journey is summarized below.

Summary of Prenatal Events: Times After Conception

The germinal stage

Week 1

- A single-cell mature ovum is discharged by an ovary between days 9 and 16 of the mother-to-be's menstrual cycle.
- Fertilization takes place in one of the woman's Fallopian tubes: a male sperm cell penetrates the wall of the ovum.
- 0–24 hours: ovum and sperm (gametes) unite to form a fertilized egg (zygote) with 46 chromosomes (23 + 23).
- The one-cell zygote begins to float down the Fallopian tube toward the uterus, a journey that will take about a week.
- Cell division (mitosis) begins 24–36 hours after conception. Each of the cells is identical during the cleavage divisions, until the third doubling.
- At 36 hours there are two cells; at 48 hours four cells, 16 to 32 cells at 72 hours, and so on and on.
- 3–4 days the egg mass is called a morula and is made up of 12 to 16 cells.
- At about 4 days following conception, the mass of cells, now called a blastocyst, is a ball-shaped group of cells consisting of 16 to 64 cells. It is now about the size of a pinhead. Each cell is about the size of a normal cell, much reduced from the original zygote.
- At the eight-cell division stage, cell differentiation begins. The cells take on, for the first time, distinct characteristics, and they gravitate towards particular locations that foreshadow the types of cells they will become.
- Around the end of the first week or the beginning of the second week a hollow sphere forms, as the blastocyst undergoes further differentiation. It has an inner layer (the embryonic disc) that forms a nucleus – the future embryo; and also an outer layer of tissues to protect and nourish the embryo – the future placenta.

Week 2

- After 6–10 days following conception the blastocyst approaches the uterus and enters it. The blastocyst now has some 150 cells.
- Implantation is completed usually 12–14 days after conception. The blastocyst has some 250 cells. Tendrils on the cell mass burrow into the wall of the uterus thus attaching itself. Its outer layer forms four major support structures: placenta, amnion, chorion and umbilical cord.
- At about 14 days a mature placenta begins to develop.

The embryonic period: the third to the eighth week

Week 3

- The mother-to-be misses her menstrual period. A pregnancy test is now positive. The embryo secretes chemicals that suppress the mother's immune system so that it will not be rejected; also gonadotrophin which stops its evacuation by a menstrual period. During the first weeks the mother's body produces oestrogen and progesterone which make the uterus enlarge, and cause the muscle fibres to thicken.
- The neural tube begins to form 20–22 days approximately after conception. This will become the brain and spinal cord.
- The embryonic (trilaminar) disk is rapidly differentiating into 3 cell layers: ectoderm, mesoderm and endoderm.
- 21–28 days: the eyes begin to form.

Week 4

- The neural tube closes. The head begins to take shape. A blood vessel that will become the heart begins to pulsate.
- The placenta is fully formed, and the maternal–placental circulation begins to function.
- The two bloodstreams are separated by a membrane that allows substances to be diffused from one bloodstream to the other; they never mix.

Week 5

- A tail-like appendage extends from the spine.
- Buds that will form arms and legs appear. Eyes, ears and nose and mouth are forming and by the middle of the week the eyes have corneas and lenses.
- The brain divides into three main sections: forebrain, midbrain and hindbrain.
- Peripheral nerves are appearing.

Week 6

- Primitive nose and ears develop. Facial structures fuse.
- A cluster of cells appears that will develop in male or female sex organs.
- Males and females are still virtually identical. Later, a gene on the Y chromosome sends a chemical signal that initiates the development of male sex organs. Indifferent gonad begins to develop on female sex organs (Koopman et al., 1991).

Week 7

- The ears are well formed. The embryo has a rudimentary skeleton. Limbs are developing from the body outwards. Sexual development begins on the seventh and eighth week.

Week 8

- The circulatory system functions on its own. The liver and spleen produce the blood cells.
- Ovaries and testes are distinguishable. The first muscular contractions take place, directed by the embryonic brain.
- The body begins to straighten and elongate. The head is more rounded. Features of the face are formed. All the basic organs and body parts of a human being (except sex organs) are present. The embryo is now more human in appearance. The tail is no longer visible having been incorporated into the lower spine.
- The mouth has 20 buds that will become baby teeth.
- The gross structure of the nervous system is established. The brain develops rapidly from this time.

The fetal period: ninth week until birth**12 weeks after conception**

- By the end of the third month the fetus can move every part of her/his body. It changes position, sucks its thumb, kicks, frowns, squints, swallows amniotic fluid and urinates.
- Startle and sucking reflexes, facial expressions, finger prints and lanugo, are all present.
- The external genital organs are fully formed.
- Simple abortion by curettage is no longer possible.
- The *first trimester* ends.

13 to 16 weeks

- The umbilical cord continues to grow and thicken in order to carry sufficient nourishment from mother to fetus.
- Skin and true hair have developed.
- The skeleton becomes bony.
- The fetal heart is growing stronger and can be heard with a stethoscope.
- Movements of the fetus become obvious to the mother ('quickening').

17 to 24 weeks

- Digestive and excretory systems develop more fully. Fingernails, teeth buds, toenails, hair and eyelashes grow.
- The most impressive growth is in the brain which begins to react to stimuli (Carlson, 1994).

22 to 25 weeks

- Viability begins around 25 weeks (Moore and Persaud, 1993); the baby has a good chance of survival if born prematurely.

- By the end of the second trimester, the fetus's visual and auditory senses are clearly functional.

25 to 27 weeks

- Weight-gain, particularly fat, accelerates and continues over the final 10 weeks.
- There is a leap forward in brain development. Brain wave patterns change.
- Terminals of lung and associated blood vessels develop.
- The *second trimester* ends.

28 to 32 weeks

- The heart rate is regulated by bodily movement.
- The nervous system is well organized for survival. The odds of premature survival after 28 weeks (previously thought of as the 'time of viability') are much improved. Currently, neonatologists generally put this threshold at 25 weeks. Babies born earlier than this are still in the second trimester zone; they have a daunting, unfinished developmental journey to complete outside an all-providing womb.
- A range of tests – such as ultrasound, fetal monitoring, fetal acoustical stimulation – is available to check on both normal and risky pregnancies, at this time.

35 to 38 weeks

- The final trimester sees the maturing of the respiratory system and cardiovascular system. All the organ systems mature rapidly.
- The lungs begin to expand and contract.
- The fetus takes in fluid through the mouth and nose and then exhales it.

38 weeks

- The baby weighs 3400 g (7.5 lb) on average.
- The *third trimester* ends

Unanswered Questions

A very small sample of such issues includes the following:

1. Is the fetus in any sense, a conscious being? And if so, at what stage of its prenatal existence did consciousness emerge?

If the baby is a conscious being surely its conscious awareness is not suddenly 'switched on' at birth. If not, how far back do we have to go to its onset? At birth four of the five senses are fairly well developed. Vision lags behind. The fetus possesses the following:

- Touch: from about 8 weeks into the pregnancy.
- Hearing: unfocused from 20–22 weeks; certainly focused enough by 24 weeks to startle and register an increased heart rate in response to a very loud sound.
- Vision: from 26–28 weeks.
- Smell and taste. These are both less capable of being pinpointed in time, but seem to emerge somewhere between 8 and 20 weeks.

In neurobiological terms, awareness requires a cortex capable of receiving and processing adequate stimuli from outside and within it, a condition that effectively rules out awareness before 20 weeks of prenatal life. It is not possible to go beyond this statement that there is a period when presumably consciousness cannot emerge.

2. Does the fetus experience pain?

Given the increasing ability to intervene surgically before birth, this becomes an important question. Pain is subjective and the fetus is in no position to tell us how he or she feels. What is undeniable is that they do show stress responses indicated by increases in noradrenaline levels.

3. Does the fetus have a memory?

This question relates, in part, to the mystery of consciousness. It is not possible to comment meaningfully about the concept of a conscious memory, although there are many anecdotal accounts, notably of personal prenatal experiences recovered as ‘memories’ in psychotherapeutic sessions. These amount to evidence on a par with data associated with a belief in UFOs. One either believes or disbelieves the ‘evidence’, or one adopts a cautious agnostic position.

With regard to memory as a product of conditioning, there is research on animals indicating that prenatal experimental conditions elicit conditioned physical responses (stress reactions) that are replicated in postnatal situations of a similar kind. We know that human mothers who suffer domestic violence experience an increased heart rate that is also registered in her fetus. After birth the baby responds to recordings of the mother’s increased (stressed) heart rate with an increase in its own heart rate.

Note: Chapters 8 and 9 continue the account of the child’s first journey in its atypical (abnormal) manifestations.