

Human Embryonic Development

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1. The journey from an egg and sperm brought together by fertilization to a squirming infant emerging from the uterus is one of the most wondrous stories that science has ever told.
 - There are those, a few scientists and some philosophers (often Creationists) who feel that the evolutionary emergence of the human mind over a few million years is nothing short of a miracle.
 - However, during gestation, something similar happens *in thirty-eight weeks*. That is much more of a miracle. Admittedly, a newborn infant has only rudimentary mental skills but consider the difference in mental prowess between the infant and the fertilized cell.
2. What we are talking of here is *development*. We will start with a few general remarks about animal development before we focus on humans.
 - In sexually reproducing organisms, development is the construction of an adult form from a fertilized cell. Here adulthood consists of the onset of reproductive capacity.
 - A developmental *cycle* consists of all processes from the onset of adulthood in one generation to the next. Thus, development includes reproduction.
 - Embryonic development is thus one part of the developmental cycle.
 - It is through development that animals get the wondrous spatial forms that they in all their beauty and complexity. We do not have even a rudimentary biological theory of the genesis of forms. (Statements to the effect that the genes determine or specify these forms are just a way of hiding our profound ignorance.)
3. The process of reproduction starts with the maturation of eggs and sperm for fertilization.
 - Eggs:
 - In females, *oocytes* which will eventually complete meiosis are formed during fetal development and are found in the ovary with each one surrounded by follicle cells.
 - During the menstrual cycle one of or two of these oocytes are released into the fallopian tubes.
 - This process of *ovulation* is under hormonal control.
 - Disrupting these hormones is the basis for chemical contraception using female birth control pills.
 - The egg erupts from the outer surface of the ovary and moves to the fallopian tube where it secretes chemicals that attract sperm.
 - There is a 24-hour period (roughly) during which the egg can be fertilized,
 - Morning after pills *prevent ovulation*. They do nothing to prevent pregnancy if ovulation has already occurred.
 - Sperm:
 - Sperm are made in the testes in small tubes called seminiferous tubules.
 - They are formed from stem cells that migrate to and lodge in the testes during embryonic development.
 - The testes are housed in the scrotum sac which maintains the temperature of the developing sperm at just below the normal body temperature,
 - Human males produce sperm continually starting with puberty at a rate of about 1500/sec.
 - In natural reproduction, sperm are ejaculated into the vagina using the penis as part of semen.
 - Each ejaculation consists of about two hundred million (2×10^8) sperm.

- At the base of the uterus, the cervix regulates entry of the sperm by the amount and stickiness of mucus.
- Sperm swim into the oviduct (fallopian tubes) helped by tail movement and are activated by chemicals from the oviduct cells. This is sperm *capacitation*. Capacitated sperm have enhanced tail movements helping them swim.
- In humans there is virtually no evidence of sperm competition.
- Fertilization and implantation:
 - Less than a dozen capacitated sperm make it to the area around the egg guided by the the slightly excess heat in this area.
 - These sperm make it through a layer of weakly bound cells surrounding the egg.
 - Then the sperm encounters the *zona pelluda* which consists of a protein coat surrounding the egg.
 - The zona pelluda proteins recognize sperm and facilitate their contact with the cell membrane of the egg. (They also have the function of preventing the egg from implanting in the oviduct.)
 - The membranes of the sperm and egg fuse together and the nucleus of the sperm is surrounded by the enormous cytoplasm of the egg. This is *fertilization*.
 - The egg immediately releases enzymes that prevent entry of any more sperm.
 - The egg completes meiosis and soon begins mitotic cell division to form the embryo
 - The fertilized egg travels to the uterus. It breaks out of its protein shell and burrows into the uterus.
 - It attaches itself into blood cells and begins to grow.

4. Stages of human embryonic development:

- The entire period from fertilization to birth is called *gestation*. This is typically 38 -42 weeks.
- Gestation is divided into two periods: an *embryonic period* (weeks 1 -8) followed by a *fetal period* (weeks 9 -38).
- The embryonic period is that of body construction: rudimentary organs get formed during it.
- In contrast, the fetal period is largely one of growth. The fetus is generally regarded as viable after week 26.

5. Embryonic development:

- The fertilized cell is called a *zygote*.
- While traveling towards the uterus, the zygote undergoes multiple cell divisions, once every 12 -18 hours, becoming a ball of cells. This process is called *cleavage*. The first eight cells are *totipotent*, capable of being anything.
- Cells on the outside eventually become part of the placenta.
- Cells in the inside are the *embryonic stem cells* that comprise the *inner cell mass* which eventually become the embryo. They also give rise to the associated yolk sac, allantois (or waste sac), and amnion (or water sac). Inner mass cells are *pluripotent*, capable of being all other cells than the placenta. They are called embryonic stem cells, especially when they are grown in the laboratory. They have the ability to multiply indefinitely and give rise to more stem cells or differentiates specialized cells.
- The cells produce a fluid that swells the embryo so that the outer cells touch the zona pellucida and push against it. At this stage the embryo is a fluid-filled ring of cells called the *blastocyst*.
- When the fluid forces the embryo out of the zona pellucida, it is said to have *hatched*.
- By this stage the embryo is in the uterus and, having burst through the zona pellucida, can attach to the wall of the uterus.
- Once the embryo has started burrowing into the uterus, the female is said to be *pregnant*.

- After implantation, the process of *gastrulation* begins, consisting of cell differentiation leading to organ formation. At the beginning of gastrulation, some cells are sequestered as future *germ cells*, precursors of egg cells and sperm. The rest of the cells form three major lineages: (i) the *ectoderm* or outermost layer of the embryo which generates the layer of skin and also forms the nervous system (including the brain); the *endoderm* or innermost layer which gives rise to the lining of the alimentary canal (or digestive tube) and associated organs including the lung; and (iii) the *mesoderm* in between which gives rise to the blood, heart, kidneys, gonads, bones, muscles, and connective tissue.
- The placenta forms in week 2; the rudimentary heart in week 3; the eye and limbs in week 4; teeth in week 6; the palate, ear, and external genitalia in week 7; and, finally, the brain and spinal cord in week 8.
- Identical (or *monozygotic*) twins can form until gastrulation begins.

References:

- Gilbert, S. F. and Pinto-Correia, C. 2017. Fear, Wonder, and Science in the New Age of Reproductive Biotechnology. New York: Columbia University Press.