# FERTILIZATION AND EMBRYOGENESIS

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# Fertilization

- **Human fertilization** is the union of a human egg and sperm, usually occurring in the ampulla of the fallopian tube. The result of this union is the production of a zygote cell, or fertilized egg, initiating prenatal development. Scientists discovered the dynamics of human fertilization in the nineteenth century.
- The process of fertilization involves a sperm fusing with an ovum. The most common sequence begins with ejaculation during copulation, follows with ovulation, and finishes with fertilization. Various exceptions to this sequence are possible, including artificial insemination, *in vitro* fertilization, external ejaculation without copulation, or copulation shortly after ovulation. Upon encountering the secondary oocyte, the acrosome of the sperm produces enzymes which allow it to burrow through the outer jelly coat of the egg. The sperm plasma, then fuses with the egg's plasma membrane, the sperm head disconnects from its flagellum and the egg travels down the Fallopian tube to reach the uterus.
- In vitro fertilization (IVF) is a process by which egg cells are fertilized by sperm outside the womb, *in vitro*.

# Steps in Fertilization

- **Corona radiata**
- The sperm binds through the corona radiata, a layer of follicle cells on the outside of the secondary oocyte. Fertilization occurs when the nucleus of both a sperm and an egg fuse to form a diploid cell, known as zygote. The successful fusion of gametes forms a new organism.
- **Cone of attraction and perivitelline membrane**
- Where the spermatozoan is about to pierce, the yolk (ooplasm) is drawn out into a conical elevation, termed the cone of attraction or reception cone. Once the spermatozoon has entered, the peripheral portion of the yolk changes into a membrane, the perivitelline membrane, which prevents the passage of additional spermatozoans.

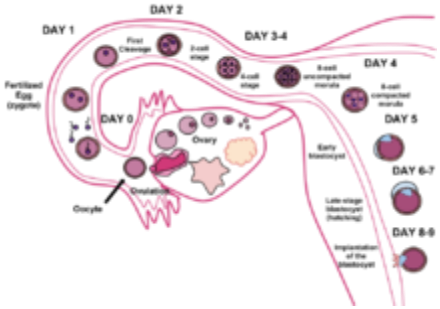
# Steps in Fertilisation

- **Sperm preparation**
- *Acrosome reaction*
- At the beginning of the process, the sperm undergoes a series of changes, as freshly ejaculated sperm is unable or poorly able to fertilize. The sperm must undergo capacitation in the female's reproductive tract over several hours, which increases its motility and destabilizes its membrane, preparing it for the acrosome reaction, the enzymatic penetration of the egg's tough membrane, the zona pellucida, which surrounds the oocyte.
- **Zona pellucida**
- After binding to the corona radiata the sperm reaches the zona pellucida, which is an extra-cellular matrix of glycoproteins. A special complementary molecule on the surface of the sperm head binds to a ZP3 glycoprotein in the zona pellucida. This binding triggers the acrosome to burst, releasing enzymes that help the sperm get through the zona pellucida.
- Some sperm cells consume their acrosome prematurely on the surface of the egg cell, facilitating the penetration by other sperm cells. As a population, sperm cells have on average 50% genome similarity so the premature acrosomal reactions aid fertilization by a member of the same cohort. It may be regarded as a mechanism of kin selection.

# Steps in Fertilisation

- **Cortical reaction**
- Once the sperm cells find their way past the zona pellucida, the cortical reaction occurs. Cortical granules inside the secondary oocyte fuse with the plasma membrane of the cell, causing enzymes inside these granules to be expelled by exocytosis to the zona pellucida. This in turn causes the glyco-proteins in the zona pellucida to cross-link with each other — i.e. the enzymes cause the ZP2 to hydrolyse into ZP2f — making the whole matrix hard and impermeable to sperm. This prevents fertilization of an egg by more than one sperm. The cortical reaction and acrosome reaction are both essential to ensure that only one sperm will fertilize an egg.

# Fusion



# Implantation

- Fertilization and implantation in humans.
- After the sperm enters the cytoplasm of the oocyte (also called ovocyte), the tail and the outer coating of the sperm disintegrate and the cortical reaction takes place, preventing other sperm from fertilizing the same egg. The oocyte now undergoes its second meiotic division producing the haploid ovum and releasing a polar body. The sperm nucleus then fuses with the ovum, enabling fusion of their genetic material.
- **Cell membranes**
- The fusion of cell membranes of the secondary oocyte and sperm takes place.

# Transformation and Replication

- **Transformations**
- In preparation for the fusion of their genetic material both the oocyte and the sperm undergo transformations as a reaction to the fusion of cell membranes.
- The oocyte completes its second meiotic division. This results in a mature ovum. The nucleus of the oocyte is called a pronucleus in this process, to distinguish it from the nuclei that are the result of fertilization.
- The sperm's tail and mitochondria degenerate with the formation of the male pronucleus. This is why all mitochondria in humans are of maternal origin. Still, a considerable amount of RNA from the sperm is delivered to the resulting embryo and likely influences embryo development and the phenotype of the offspring.
- **Replication**
- The pronuclei migrate toward the center of the oocyte, rapidly replicating their DNA as they do so to prepare the zygote for its first mitotic division.

# Mitotic Division

- **Mitosis**
- Usually 23 chromosomes from spermatozoon and 23 chromosomes from egg cell fuse (half of spermatozoons carry X chromosome and the other half Y chromosome[14]). Their membranes dissolve, leaving no barriers between the male and female chromosomes. During this dissolution, a mitotic spindle forms between them. The spindle captures the chromosomes before they disperse in the egg cytoplasm. Upon subsequently undergoing mitosis (which includes pulling of chromatids towards centrioles in anaphase) the cell gathers genetic material from the male and female together. Thus, the first mitosis of the union of sperm and oocyte is the actual fusion of their chromosomes.
- Each of the two daughter cells resulting from that mitosis has one replica of each chromatid that was replicated in the previous stage. Thus, they are genetically identical.
- Fertilization age

# Fertilization Age

- Fertilization age
- Fertilization is the event most commonly used to mark the zero point in descriptions of prenatal development of the embryo or fetus. The resultant age is known as *fertilization age*, *fertilizational age*, *conceptional age*, *embryonic age*, *fetal age* or *(intrauterine) developmental (IUD)[ age*.
- Gestational age, in contrast, takes the beginning of the last menstrual period (LMP) as the zero point. By convention, gestational age is calculated by adding 14 days to fertilization age and vice versa. In fact, however, fertilization usually occurs within a day of ovulation, which, in turn, occurs on average 14.6 days after the beginning of the preceding menstruation (LMP). There is also considerable variability in this interval, with a 95% prediction interval of the ovulation of 9 to 20 days after menstruation even for an average woman who has a mean LMP-to-ovulation time of 14.6. In a reference group representing all women, the 95% prediction interval of the LMP-to-ovulation is 8.2 to 20.5 days.
- The average time to birth has been estimated to be 268 days (38 weeks and two days) from ovulation, with a standard deviation of 10 days or coefficient of variation of 3.7%.
- Fertilization age is sometimes used postnatally (after birth) as well to estimate various risk factors. For example, it is a better predictor than postnatal age for risk of intraventricular hemorrhage in premature babies treated with extracorporeal membrane oxygenation.

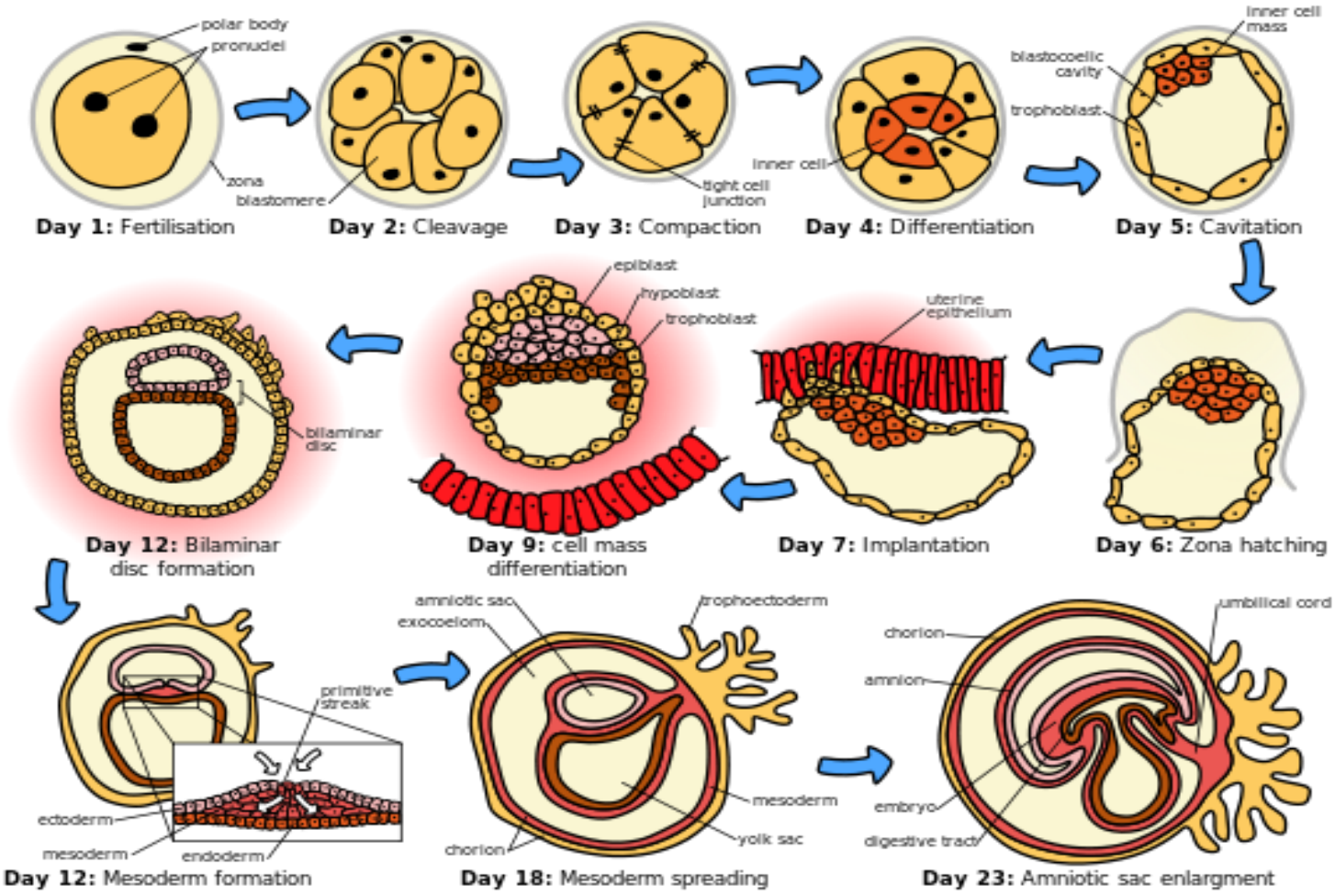
# Embryogenesis

- **Embryogenesis**
- Zygote undergoes repeated cell division called cleavage. Cleavage starts as the zygote moves down from oviduct to uterus 3-5 days after fertilization, zygote develop into ball like structure of cell with central cavity; **blastocyst (Blastula stage).**
- Outer cell of blastocyst is known as **trophoblastic cell** while inner cell is known as **embryonic cell.** Trophoblastic cell secrete **HCG (human chorionic gonadotropin) hormone; similar in function as LH.** It Prevent degredation of corpus luteum, therefore corpus luteum continue to secrete progesterone and oestrogen, which help continuous growth of endometrium wall causing **menstruation cycle to stop.**
- As blastocyst reaches to uterus, trophoblast cell invade endometrium wall and utilize nutrients for its growth and multiplication. This invasion establishes the embryo within 6-9 days in the uterus called **Implantation.** With successful implantation, trophoblast form chorion membrane, which later become part of **placenta.**
- Chorion membrane develop small villi like projection on its outer layer called **Chorion villi** that begins to grow in the endometrium and help in exchange of nutrition between embryo and uterus. Embryonic cell grow to become embryo. It also form other embryonic membrane covering the embryo.

# Embryogenesis

- Within 20 days, embryonic membrane become clearly distinguished from embryo. The **amnion** is a thin membrane filled with amniotic fluids that eventually surrounds the embryo and act as shock absorbent. Later allantoin membrane develop, which develop toward the chorion and get fused to form Allanto-chorion which later form Placenta. **Yolk sac** has no significant function in human. **Embryonic disc** present between yolk sac and amnion give rise to embryo. Embryonic disc differentiate into **3 germ layer** (Ectoderm, mesoderm and endoderm) known as **Gastulation.** Embryo shows distinct from at about 4-5 weeks. Only after 6 week, embryo can be distinguished as human embryo .

# Stages of Embryonic Development



# Summary

- **Week 1:** fertilization, blastocyst formation, Implantataion
- **Week2**: 3 germ layer differentiate
- **Week3**: beginning of back bone and neural plate (first organ), embryo 2mm size long
- **Week 4**: heart, blood vessel, blood, gut start forming, umbilical cord develop, embryo 5mm size
- **Week5**: brain developing, **limb buds,** heart beats starts **(seen on USG),** embryo 8 mm long
- **Week 6**: eyes and ear form, embryo known as f**etus**
- **Week 7:** internal organs, face form, limbs, mouth and tongue, fetus 17mm size.
- **By Week 12:** fetus fully form, sex organ develop, fetus starts moving, 56mm long,
- **By week 20:** Hair and nails begins to grow, fingerprint develop, firm hand grip, movement of fetus can be felt, 160m long,
- **By Week 24:** eyelid opens, legal limit for abortion,
- **By week 26:** good chance of survival if prematurely born
- **By week 28:** respond to touch and sound, swallowing amniotic fluid, urinating
- **By week 30:** head lying down, 240 mm long
- **Week 40:** birth

- THANK YOU