Animal Reproduction

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1. Asexual vs Sexual Reproduction
Both asexual and sexual reproduction occur in the animal kingdom

- **Sexual reproduction** is the creation of an offspring by fusion of a male gamete (sperm) and female gamete (egg) to form a zygote

- **Asexual reproduction** is creation of offspring without the fusion of egg and sperm
Mechanisms of Asexual Reproduction

- Budding is a simple form of asexual reproduction found only among invertebrates
  - New individuals arise from outgrowths of existing ones
- Many invertebrates reproduce asexually by fission, separation of a parent into two or more individuals of about the same size
**Fragmentation** is breaking of the body into pieces, some or all of which develop into adults

- Fragmentation must be accompanied by *regeneration*, regrowth of lost body parts

**Parthenogenesis** is the development of a new individual from an unfertilized egg

- Parthenogenesis is mainly observed in invertebrates, but is observed rarely in some vertebrates
Sexual Reproduction: An Evolutionary Enigma

- Sexual females have half as many daughters as asexual females; this is the “twofold cost” of sexual reproduction.
- Despite this, almost all eukaryotic species reproduce sexually.

![Diagram showing asexual and sexual reproduction processes.](diagram.png)
Advantages of Each

- By producing offspring of varied phenotypes, sexual reproduction may enhance reproductive success of parents when environmental factors change relatively rapidly.

- Asexual reproduction is expected to be most advantageous in stable, favorable environments.
Variation in Patterns of Sexual Reproduction

- For many animals, finding a partner for sexual reproduction may be challenging.

- One solution is hermaphroditism, in which each individual has male and female reproductive systems.

- Two hermaphrodites can mate, and some hermaphrodites can self-fertilize.
Fertilization depends on mechanisms that bring together sperm and eggs of the same species

- The mechanisms of **fertilization**, the union of egg and sperm, play an important part in sexual reproduction.

- In external fertilization, eggs shed by the female are fertilized by sperm in the external environment.

- A moist habitat is always required for external fertilization to allow sperm to swim to the egg and to prevent the gametes from drying out.
Gamete Production and Delivery

- To reproduce sexually, animals must produce gametes
- In most species individuals have **gonads**, organs that produce gametes
- Some simple systems do not have gonads, but gametes form from undifferentiated tissue
- More elaborate systems include sets of accessory tubes and glands that carry, nourish, and protect gametes and developing embryos
Most insects have separate sexes with complex reproductive systems.

In many insects, the female has a **spermatheca** in which sperm is stored during copulation.
A **cloaca** is a common opening between the external environment and the digestive, excretory, and reproductive systems.

A cloaca is common in nonmammalian vertebrates; mammals usually have a separate opening to the digestive tract.
2. Human Reproductive Systems
Human Male Reproductive Anatomy

- The male’s external reproductive organs are the scrotum and penis
- Internal organs are the gonads, which produce sperm and hormones, accessory glands that secrete products needed for sperm movement, and ducts that carry sperm and glandular secretions
Testes

- The male gonads, or testes, consist of highly coiled tubes surrounded by connective tissue.

- Sperm form in these seminiferous tubules.

- Leydig cells produce hormones and are scattered between the tubules.

- Production of normal sperm cannot occur at the body temperatures of most mammals.

- The testes of many mammals are held outside the abdominal cavity in the scrotum, where the temperature is lower than in the abdominal cavity.
Ducts

- From the seminiferous tubules of a testis, sperm pass into the coiled duct of the **epididymis**

- During **ejaculation**, sperm are propelled through the muscular **vas deferens** and the **ejaculatory duct**, and then exit the penis through the **urethra**
Accessory Glands

- **Semen** is composed of sperm plus secretions from three sets of accessory glands.

- The two *seminal vesicles* contribute about 60% of the total volume of semen.

- The *prostate gland* secretes its products directly into the urethra through several small ducts.

- The bulbourethral glands secrete a clear mucus before ejaculation that neutralizes acidic urine remaining in the urethra.
Penis

- The human **penis** is composed of three cylinders of spongy erectile tissue
- During sexual arousal, the erectile tissue fills with blood from the arteries, causing an erection
- The head of the penis, or **glans**, has a thinner skin covering than the shaft and is more sensitive to stimulation
- The glans is surrounded by a fold of skin called the **prepuce**, or foreskin
Gametogenesis is the production of gametes

Spermatogenesis, the formation of sperm, is continuous and prolific

Hundreds of millions of sperm are produced per day; each sperm takes about 7 weeks to develop
Figure 46.11ab

Primordial germ cell in embryo

Mitotic divisions

Key
- Diploid (2n)
- Haploid (n)

Spermatogonial stem cell

Mitotic divisions

Spermatogonium

Mitotic divisions

Primary spermatocyte

Meiosis I

Secondary spermatocyte

Meiosis II

Early spermatid

Differentiation

Sperm cell
1) **Spermatogonial stem cells** divide by mitosis to give rise to spermatogonia and to replace themselves

2) spermatogonia divide by mitosis give rise to **primary (1°)** spermatocytes

3) **1° spermatocytes** undergo meiosis I to produce **secondary spermatocytes**

4) **2° spermatocytes** undergo meiosis II to produce spermatids

5) spermatids **differentiate** into mature sperm

***begins at puberty, continues throughout adulthood***
Human Female Reproductive Anatomy

- The female external reproductive structures include the clitoris and two sets of labia.
- The internal organs are a pair of gonads and a system of ducts and chambers that carry gametes and house the embryo and fetus.
Ovaries

- The female gonads, the **ovaries**, lie in the abdominal cavity.

- Each ovary contains many **follicles**, which consist of a partially developed egg, called an **oocyte**, surrounded by support cells.
Oviducts and Uterus

- The egg cell travels from the ovary to the uterus via an **oviduct**, or fallopian tube.
- Cilia in the oviduct convey the egg to the **uterus**, also called the womb.
- The uterus lining, the **endometrium**, has many blood vessels.
- The uterus narrows at the **cervix**, then opens into the vagina.
Vagina and Vulva

- The **vagina** is a muscular but elastic chamber that is the repository for sperm during copulation and serves as the birth canal.

- The vagina opens to the outside at the **vulva**, which consists of the **labia majora**, **labia minora**, hymen, and **clitoris**.
Oogenesis

- **Oogenesis**, the development of a mature egg, is a prolonged process

- Immature eggs form in the female embryo but do not complete their development until years or decades later
Primordial germ cell

- Mitotic divisions
  - Oogonium

IN EMBRYO

- Primordial germ cell (present at birth), arrested in prophase of meiosis I

STARTING AT PUBERTY

- Completion of meiosis I and onset of meiosis II
  - Primary oocyte within follicle
  - Growing follicle

- First polar body
  - Secondary oocyte, arrested at metaphase of meiosis II

- Ovulation, sperm entry
  - Mature follicle
  - Ruptured follicle

- Completion of meiosis II
  - Ovulated secondary oocyte
  - Corpus luteum

- Fertilized egg
  - Degenerating corpus luteum
Oogenesis (within ovarian follicles)...

1) **Oogonia** give rise to **primary (1°) oocytes**
   - occurs during fetal development (done by 3rd month)

2) 1° oocytes begin meiosis only to halt the process in prophase I
   - also occurs during fetal development

Beginning at puberty, once per month…

3) Several 1° oocytes finish meiosis I, begin meiosis II producing a **secondary (2°) oocyte** (& polar body)
   - the 2° oocyte is arrested in metaphase II

4) A 2° oocyte (“egg”) is released at ovulation
   - meiosis II is completed only after fertilization
Spermatogenesis differs from oogenesis in three ways

- All four products of meiosis develop into sperm while only one of the four becomes an egg
- Spermatogenesis occurs throughout adolescence and adulthood
- Sperm are produced continuously without the prolonged interruptions in oogenesis
3. Regulation of Mammalian Reproduction
The interplay of tropic and sex hormones regulates mammalian reproduction

- Human reproduction is coordinated by hormones from the hypothalamus, anterior pituitary, and gonads.

- Gonadotropin-releasing hormone (GnRH) is secreted by the hypothalamus and directs the release of FSH (follicle-stimulating hormone) and LH (luteinizing hormone) from the anterior pituitary.
- FSH and LH regulate processes in the gonads and the production of sex hormones

- The main sex hormones are steroid hormones

- **Testosterone** is the main androgen

- Estrogens consist of mainly **estradiol** and **progesterone**

- Sex hormones serve many functions in addition to gamete production, including sexual behavior and the development of primary and secondary sex characteristics
Hormonal Control of the Male Reproductive System

- FSH promotes the activity of Sertoli cells, which nourish developing sperm
- LH regulates Leydig cells, which secrete testosterone and other androgens, which in turn promote spermatogenesis
- Testosterone regulates the production of GnRH, FSH, and LH through negative feedback mechanisms
- Sertoli cells secrete the hormone inhibin, which reduces FSH secretion from the anterior pituitary
Figure 46.13

Hypothalamus

GnRH

Anterior pituitary

FSH

LH

Sertoli cells

Inhibin

Spermatogenesis

Leydig cells

Testosterone

Spermatogenesis

TESTIS

Negative feedback

Negative feedback

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Hormonal Control of the Female Reproductive Cycles

- In females, the secretion of hormones and the reproductive events they regulate are cyclic.
- Prior to ovulation, the endometrium thickens with blood vessels in preparation for embryo implantation.
- If an embryo does not implant in the endometrium, the endometrium is shed in a process called menstruation.
- Hormones closely link the two cycles of female reproduction:
  - Changes in the uterus define the menstrual cycle (also called the uterine cycle).
  - Changes in the ovaries define the ovarian cycle.
The Ovarian Cycle

- The sequential release of GnRH then FSH and LH stimulates follicle growth
- Follicle growth and an increase in the hormone estradiol characterize the follicular phase of the ovarian cycle
- The follicular phase ends at ovulation, and the secondary oocyte is released
(a) Control by hypothalamus

Hypothalamus

Anterior pituitary

FSH

LH

Inhibited by combination of estradiol and progesterone
Stimulated by high levels of estradiol
Inhibited by low levels of estradiol

(b) Pituitary gonadotropins in blood

FSH and LH stimulate follicle to grow

LH surge triggers ovulation

GnRH

Day 0 5 10 14 15 20 25 28
In the luteal phase, following ovulation, the follicular tissue left behind is stimulated to transform into a corpus luteum.

The corpus luteum secretes progesterone and estradiol, which exert negative feedback on the hypothalamus and pituitary.
FSH and LH stimulate follicle to grow

LH surge triggers ovulation

Ovarian cycle:
- Growing follicle
- Maturing follicle
- Corpus luteum
- Degenerating corpus luteum

Estradiol secreted by growing follicle in increasing amounts

Progesterone and estradiol secreted by corpus luteum

Days:
- 0
- 5
- 10
- 14
- 15
- 20
- 25
- 28
The Uterine (Menstrual) Cycle

- Hormones coordinate the uterine cycle with the ovarian cycle
  - Thickening of the endometrium during the proliferative phase coordinates with the follicular phase
  - Secretion of nutrients during the secretory phase coordinates with the luteal phase
  - Shedding of the endometrium during the menstrual flow phase coordinates with the growth of new ovarian follicles
Figure 46.14d

(d) Ovarian hormones in blood

- Estradiol level very low
- Peak causes LH surge (see 6)
- Progesterone and estradiol promote thickening of endometrium

(e) Uterine (menstrual) cycle

- Endometrium
- Menstrual flow phase
- Proliferative phase
- Secretory phase

Day
0 5 10 14 15 20 25 28

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A new cycle begins if no embryo implants in the endometrium.

Cells of the uterine lining can sometimes migrate to an abnormal, or **ectopic**, location.

Swelling of these cells in response to hormone stimulation results in a disorder called **endometriosis**.
Menopause

- After about 500 cycles, human females undergo **menopause**, the cessation of ovulation and menstruation
- Menopause is very unusual among animals
- Menopause might have evolved to allow a mother to provide better care for her children and grandchildren
Menstrual Versus Estrous Cycles

- Menstrual cycles are characteristic only of humans and some other primates
  - The endometrium is shed from the uterus in a bleeding called menstruation
  - Sexual receptivity is not limited to a time frame
- Estrous cycles are characteristic of most mammals
  - The endometrium is reabsorbed by the uterus
  - Sexual receptivity is limited to a “heat” period called estrus
  - The length and frequency of estrous cycles vary from species to species
4. Human Development
Conception, Embryonic Development, and Birth

- **Conception**, fertilization of an egg by a sperm, occurs in the oviduct.
- The resulting zygote begins to divide by mitosis in a process called cleavage.
- Division of cells gives rise to a **blastocyst**, a ball of cells with a central cavity.
1. Ovulation
2. Fertilization
3. Cleavage
4. Cleavage continues
5. Implantation
After blastocyst formation, the embryo implants into the endometrium

Pregnancy, or gestation, is the condition of carrying one or more embryos in the uterus

Duration of pregnancy in other species correlates with body size and maturity of the young at birth

The roughly nine months of human gestation are divided into three trimesters of equal length
First Trimester

- The first trimester is the time of most radical change for both the mother and the embryo
- The implanted embryo secretes hormones that regulate the mother’s reproductive system
- One such hormone, human chorionic gonadotropin (hCG) maintains secretion of progesterone and estrogens during early pregnancy
During its first 2 to 4 weeks, the embryo obtains nutrients directly from the endometrium.

The outer layer of the blastocyst, called the trophoblast, mingle with the endometrium and eventually forms the placenta.

Blood from the embryo travels to the placenta through arteries of the umbilical cord and returns via the umbilical vein.

The first trimester is the main period of organogenesis, development of the body organs.

All the major structures are present by 8 weeks, and the embryo is called a fetus.
Figure 46.16

Placenta

Uterus

Umbilical cord

Maternal arteries

Maternal veins

Maternal portion of placenta

Fetal portion of placenta (chorion)

Umbilical vein

Maternal blood pool

Chorionic villus, containing fetal capillaries

Fetal arteriole

Fetal venule

Umbilical cord

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Twins

- Splitting of the embryo during the first month of development results in genetically identical (monozygotic) twins.
- Release and fertilization of two eggs result in fraternal and genetically distinct (dizygotic) twins.
Changes in the Mother

- Mucus plug to protect against infection
- Growth of the placenta and uterus
- Cessation of ovulation and the menstrual cycle
- Breast enlargement
- Nausea is also very common
Figure 46.17

(a) 5 weeks

(b) 14 weeks

(c) 20 weeks
Second and Third Trimesters

- During the third trimester, the fetus grows and fills the space within the embryonic membranes.
- Childbirth begins with labor, a series of strong, rhythmic uterine contractions that push the fetus and placenta out of the body.
- Labor is regulated by prostaglandins and hormone such as estradiol and oxytocin.
Figure 46.18

Estradiol from ovaries

Activates oxytocin receptors on uterus

Oxytocin from fetus and mother’s posterior pituitary

Stimulates uterus to contract

Stimulates placenta to make Prostaglandins

Stimulate more contractions of uterus

Positive feedback
Labor

- Labor typically has three stages
  - Thinning and opening of the cervix, or dilation
  - Expulsion or delivery of the baby
  - Delivery of the placenta

- Postnatal care in mammals includes lactation, the production of mother’s milk
Figure 46.19

1. Dilation of the cervix
2. Expulsion: delivery of the infant
3. Delivery of the placenta
Contraception

- **Contraception**, the deliberate prevention of pregnancy, can be achieved in a number of ways.

- Contraceptive methods fall into three categories:
  - Preventing release of eggs and sperm
  - Keeping sperm and egg apart
  - Preventing implantation of an embryo
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Infertility and In Vitro Fertilization

- Causes of infertility are quite varied, with men and women equally affected.

- Among preventable causes of infertility, STDs are most significant.

- *In vitro fertilization (IVF)* mixes eggs with sperm in culture dishes and returns the embryo to the uterus at the eight-cell stage.

- Sperm or sperm nuclei can also be injected directly into an oocyte.