Chapter 20

Is There Something in the Water? Reproductive and Developmental Biology

20.1 Principles of Animal Reproduction

- Environmental factors – including a class of chemicals called **endocrine disruptors** – can affect reproductive cells
- Declines in reproduction can signal the presence of pollutants

Principles of Animal Reproduction

- Reproduction is the process whereby organisms produce offspring, allowing for the continuation of their species
- There are two basic strategies for producing offspring
  - Asexual reproduction
  - Sexual reproduction

Asexual Reproduction

- **Asexual reproduction** is when one parent produces a genetically identical offspring
  - This is cloning
- Prokaryotic organisms like bacteria reproduce by **binary fission**
- They copy their single circular chromosome and then split into two identical cells

Asexual Reproduction

- Some single celled eukaryotic cells, such as amoebas, reproduce by mitosis
- Sponges reproduce by **binary fission**, where one individual fragments into many individual cells that later develop into adults
- Yeast cells and hydra reproduce by **budding**
  - This is when a daughter cell is produced and remains attached to the parent

Asexual Reproduction

- **Vegetative reproduction** (a variation of budding) occurs in some plants and aquatic animals, like sea squirts
- This occurs when the parent sends out runners, on which buds form and develop into separate individuals

Asexual Reproduction

- Advantages
  - No need for a partner
  - Can produce large numbers of offspring
- Disadvantages
  - Since all offspring are identical, low ability to adapt to environmental change

Sexual Reproduction

- **Sexual reproduction** is the creation of offspring from two parents
  - Fusion of sex cells from parents
- **Gametes** – sex cells (egg or sperm)
- **Gonads** – gamete-producing structures (ovaries or testes)
- Gametes are haploid (*n*)
  - Contains one of each type of chromosome
- Fusion of two haploid gametes results in a diploid (2*n*) **zygote** (fertilized egg)

Sexual Reproduction

- A zygote is a mixture of parental genetic information
- Sexual reproduction produces genetically unique individuals
- Most organisms produce either male gametes (sperm) or female gametes (egg) but not both
- There are exceptions
  - **Hermaphrodites** are animals that have both female and male reproductive systems
    - ✓Can produce and receive sperm
    - ✓Earthworms are an example

Sexual Reproduction

- Fertilization has different forms
  - **Copulation** – sexual intercourse (depositing sperm in or near the female reproductive tract) allows **internal fertilization** (sharks, reptiles, birds, mammals)
  - **External fertilization** – female lays eggs in water, male releases sperm over the eggs (aquatic invertebrates, fish, amphibians)

Environmental Contaminants and Sexual Reproduction

- Environmental contaminants can affect frog reproduction
- Chemicals in water are absorbed by eggs and affect developing embryo
  - May cause deformities

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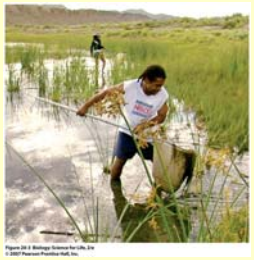
Environmental Contaminants and Sexual Reproduction

- Scientists are researching whether deformities like these are from man-made chemicals
- Frogs can be used as an early warning sign of environmental contamination

Environmental Contaminants and Sexual Reproduction

- Tyrone Hayes researched effects of atrazine, a pesticide which has been shown to travel from farmers' fields to groundwater

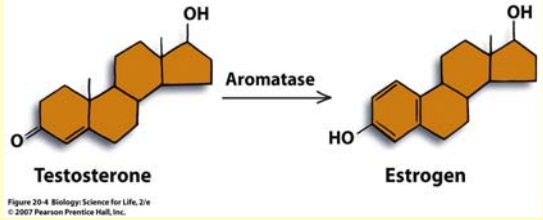


Environmental Contaminants and Sexual Reproduction

- Male frogs were found with eggs growing inside their testes
  - These 'feminized' frogs were found in ponds contaminated by atrazine
- Hayes hypothesized that atrazine might be an endocrine disruptor that affects the development of frog gonads

Environmental Contaminants and Sexual Reproduction

- Hayes tested this in a laboratory by injecting normal male tadpoles with atrazine
  - Found that this did disrupt development of testicular tissue
  - This resulted in testes that could produce egg cells
- More research suggests atrazine activates **aromatase**, an enzyme that converts testosterone into estrogen
- This results in 'feminization' of male testicles



Environmental Contaminants and Sexual Reproduction

- Hayes found that the levels of atrazine in our drinking water is less than that which caused the deformities in frogs

Environmental Contaminants and Sexual Reproduction

- Exposure to endocrine disrupters causes changes in reproductive organs of other animals as well
- Canadian scientists put birth-control pills into an Ontario lake
- The lake was remote – to ensure that the only contamination was the estrogen
- Birth control pills were used because scientists think that estrogen is secreted by women using birth control pills and getting into waterways

Environmental Contaminants and Sexual Reproduction

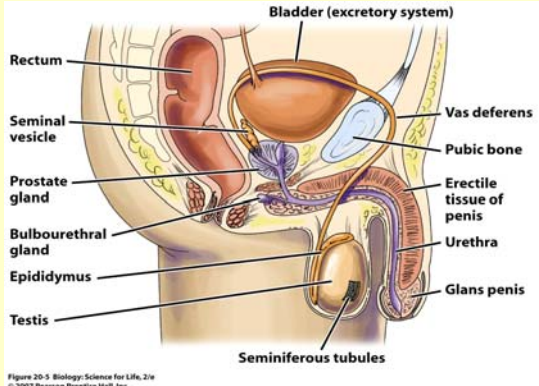
- The fish exposed to the estrogen had more 'feminization' in the males of several species
- Fish in nearby untreated lakes did not show the same increase in 'feminization' of males
- Even though humans don't live in contaminated water, sometimes the water we drink is contaminated

20.2 Human Reproduction: Human Reproductive Systems

- The reproductive systems of males and females consist of external and internal structures designed to
  - Allow the production and maturation of gametes, signal the synthesis and secretion of substances needed for reproduction, and provide a route to deliver the gametes through ducts

Male Reproductive Anatomy

- **Penis** – delivers sperm
- **Urethra** – tube inside penis that carries both sperm and urine
- **Glans penis** – head of penis
- **Scrotum** – pouch that contains testes
- **Testes** (or **testicles**) – produce sperm and male hormones (**androgens**)



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Male Reproductive Anatomy

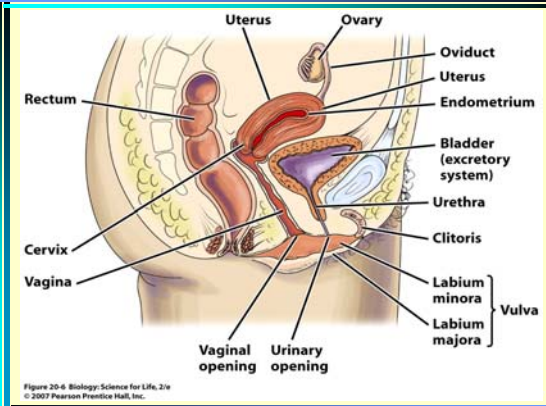
- Testes contain **seminiferous tubules** – site of sperm formation – which are held in place by **Leydig cells** (produce hormones)
- Sperm formation takes about 60 days
- As sperm develop, the cells travel from the seminiferous tubules through the coiled **epididymis** on top of each testis
- This is where sperm gain the ability to move and capability to fertilize an egg cell

Male Reproductive Anatomy

- During ejaculation, sperm are sent from the epididymis through the **vas deferens** ducts
- The vas deferens move the sperm out of the body in waves, due to the smooth muscle covering
- Secretions are added to developing sperm to make up **semen**
  - **Seminal vesicles** secrete mucus and sugar that sperm cells use as energy
  - **Prostate gland** secretes nutrients for sperm
  - **Bulbourethral glands** secrete mucus that neutralizes any acidic urine in urethra

Female Reproductive Anatomy

- External genitalia
  - **Vulva** consists of two lips, the **labia majora** and the **labia minora**
  - **Clitoris** is an important organ for female sexual arousal



Female Reproductive Anatomy

- Urethra – opening for urine from bladder
  - Short compared to male urethra, which contributes to greater female susceptibility to bladder infections
- Vaginal opening – from uterus
- Internal genitalia
  - Ovaries
  - Vagina
  - Oviducts

Female Reproductive Anatomy

- **Ovaries** are **female gonads**
  - Produce gametes and sex hormones
  - Contain about 2 million eggs at birth
  - Release one or more eggs each month from **follicle**, a fluid-filled sac containing the developing egg, which secretes estrogen
- **Ovulation** – release of egg cell
  - Follicle ruptures
- The remnants of the ruptured follicle are called the **corpus luteum** – secretes estrogen and progesterone

Female Reproductive Anatomy

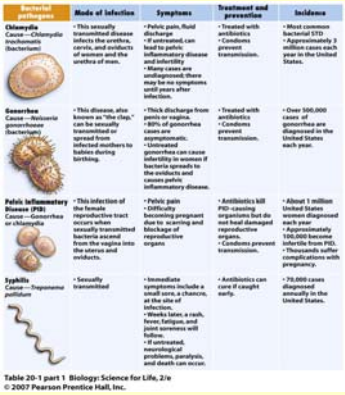
- **Vagina** –muscular organ that connects uterus to outside (acts primarily as a passageway into and out of the uterus)
- **Uterus** – thick walled, extremely muscular organ about the size of a fist
- Uterus walls contract during labor and childbirth, as well as during orgasm
  - Internal lining is called the **endometrium**
  - Narrow lower part is called the **cervix**

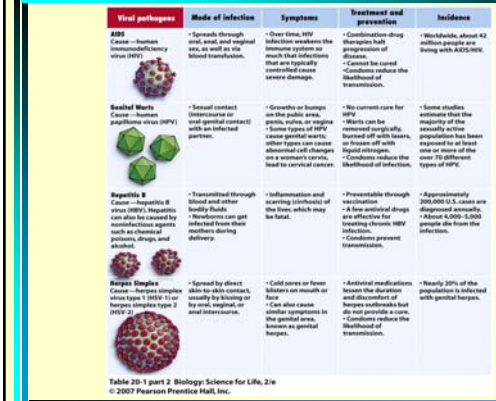
Female Reproductive Anatomy

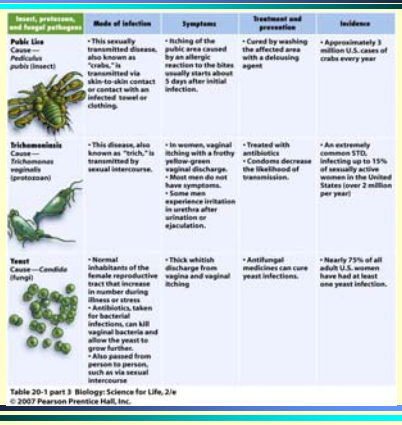
- **Oviducts** – extensions of top surface of uterus
  - Extend from uterus to ovaries, but are not connected to the ovaries
- Oviducts end at ovaries in brushy structures that wave over the ovaries
  - This motion draws released eggs into the oviducts

Female Reproductive Anatomy

- Since this pathway leads from the outside to the inside, infections can happen – especially sexually transmitted diseases (STDs)
- Numerous STDs affect both men and women
- Sexually transmitted diseases can cause permanent **infertility** – the failure to achieve pregnancy after 1 year of unprotected intercourse
  - Infertility can result from physical blockages of ductal sturctures caused by scarring in response to infection







Endocrine Disruptors, Reproductive Anatomy, and Infertility

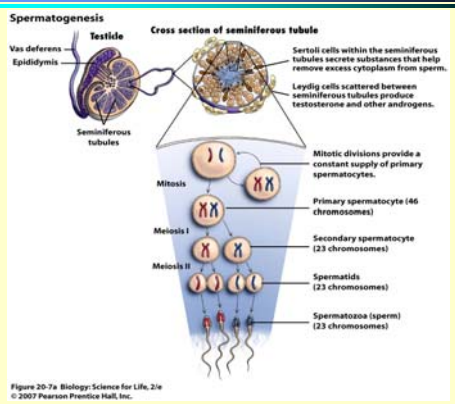
- Endocrine disruptors can cause misshapen uterus in women
- They may be causing low sperm counts in men
  - Scientists are trying to determine why sperm counts in men are declining in many developed countries

Gametogenesis

- **Gametogenesis** is the production of gametes
  - Involves process of meiosis
- From 46 chromosomes to 23; from diploid to haploid

Spermatogenesis

- In **spermatogenesis** a cell in wall of seminiferous tubule lining divides by mitosis
  - One cell remains function
  - Other cell carries out meiosis
- These cells are never used up – males can always make sperm

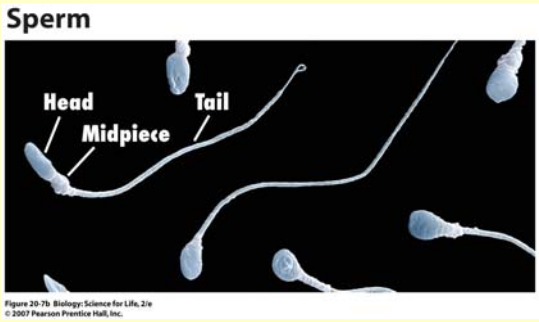


Spermatogenesis

- The **primary spermatocyte** divides by meiosis I, separating the homologs
- The **secondary spermatocytes** are haploid and undergo meiosis II
- The final products of meiosis are **spermatids**

Spermatogenesis

- **Sertoli cells** in the seminiferous tubules secrete substances to help spermatids develop into **spermatozoa** (cytoplasm is removed)
- Mature sperm – head with DNA, midpiece with mitochondria, and tail
- **Acrosome** – area at tip of sperm head containing digestive enzymes to penetrate the coating of the egg during fertilization



Oogenesis

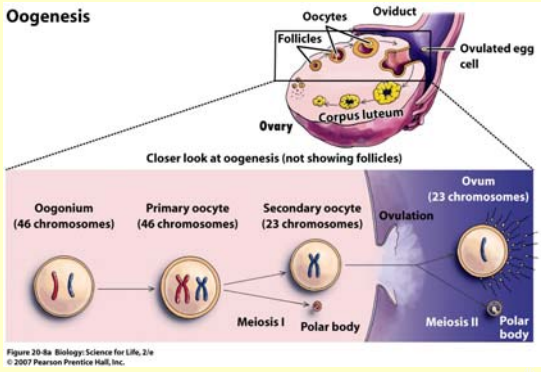
- A small percentage of eggs are released during lifetime – and very few will be fertilized
- **Oogenesis** begins in the female fetus and pauses until puberty
- At puberty, egg cells develop each month until **menopause** (cessation of menstruation)
  - About 2 million potential eggs
  - Only 700,000 at birth
  - Only 350,000 at puberty
  - Due to degeneration

Oogenesis

- **Oogonia** – developing egg cells
- Pause at prophase I
- Cells called **primary oocytes**
- Surrounded by single flat layer of **follicle cells**
- **Primary follicle** – the primary oocyte surrounded by follicle cells

Oogenesis

- At puberty, an egg cell matures
- Follicle cells divide and secrete estrogen
- Primary oocyte divides into secondary oocyte and **polar body** (small cell that doesn't leave the ovary)
- The **secondary oocyte** is released from the ovary about 12 hours after it is formed
- This is **ovulation**
  - Occurs on the 14th day of the menstrual cycle



Oogenesis

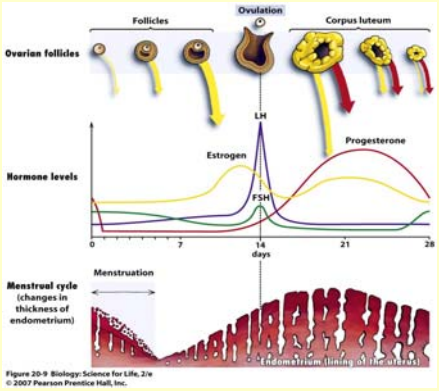
- It takes about 3 days for the released egg to travel down the oviduct through the uterus and out via the vagina
- If sperm are present and the egg is fertilized, then meiosis II occurs from metaphase II to produce the ovum and a second polar body
- Women are fertile for a few days each month between puberty and menopause
- Men are fertile throughout their lifetimes, but sperm count does decline as they age

Endocrine Disruptors, Gametogenesis, and Infertility

- Male infertility usually is due to low sperm count or malfunctioning sperm cells
- Likelihood increases with age, alcohol and drug use, and smoking
- Endocrine disruptors can play a role as well

The Menstrual Cycle

- The **menstrual cycle** refers to the cyclical changes that occur in the uterus
- Preparation of egg cell for potential fertilization and preparation of uterus for potential pregnancy
- If pregnancy does not occur the uterine lining is discarded during menstruation



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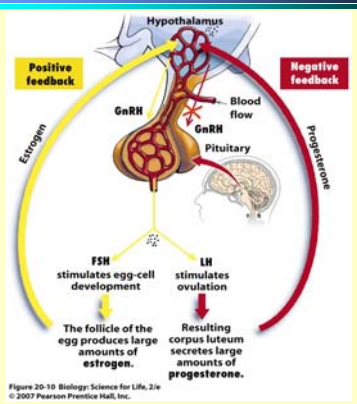
The Menstrual Cycle

- High levels of estrogen provide positive feedback to the hypothalamus
- High levels of the hormone **progesterone** have a negative feedback on the hypothalamus



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The Menstrual Cycle

- If fertilization has occurred, the endometrium does not break down
- The **placenta** develops
- Get secretion of HCG – human chorionic gonadotropin hormone
  - Over the counter tests for pregnancy test for this

The Menstrual Cycle

- During pregnancy, hormone levels remain high
- Birth control pills emit a low dose of synthetic progesterone and estrogen
  - This mimics pregnancy and prevents follicle development and uterine lining development
- Various other methods of birth control exist as well

	Method	Mode of action	Risks
Abstinence	Abstinence 	• Sperm and egg never have contact.	• No associated risks. • 100% effective*

*Percent effectiveness assumes correct usage. Pregnancy rate without birth control is 85%.

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	Method	Mode of action	Risks
Hormonal methods	Combination birth control pill 	• Synthetic estrogen and progesterone given at continuous doses (versus the cyclic fluctuations of a menstrual cycle) prevent ovulation.	• Increased risk of heart disease and fatal blood clots for women over age 35 who smoke. May have slightly increased risk of breast cancer. Decreased risk of uterine and ovarian cancers. • Does not protect against STDs • 99% effective
	Minipill 	• The minipill contains progesterone only. Since there is no estrogen to combat the effects of progesterone, cervical mucus is thickened, sperm ascent is impeded, and the uterine lining is not prepared to support a pregnancy.	• Increased risk of ovarian cysts. • Does not protect against STDs • 95% effective
	Depo-Provera 	• This method requires the user to have progesterone injections every 3 months. Same mode of action as the minipill.	• Irregular vaginal bleeding • Does not protect against STDs • 99% effective
	Implantables 	• Norplant, recently taken off the market, delivered progesterone to thicken cervical mucus. Another implant, Implanon, may be available soon.	• Under investigation • Does not protect against STDs • Effectiveness unknown

Table 20-2 part 2 Biology: Science for Life, 2/e
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	Method	Mode of action	Risks
Sterilization	Female sterilization 	• Permanently blocking oviducts with a tightly coiled tube.	• Does not protect against STDs • 99.8% effective
	Male sterilization (vasectomy) 	• Cutting each vas deferens prevents sperm from being ejaculated in the semen.	• Does not protect against STDs • 99.9% effective

Table 20-2 part 3 Biology: Science for Life, 2/e
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	Method	Mode of action	Risks
Barrier methods	Cervical cap 	• When inserted against cervix before intercourse, prevents sperm and egg contact.	• No known risks • Does not protect against STDs.
	Diaphragm 	• When inserted into vagina before intercourse, prevents sperm and egg contact.	• No known risks • Does not protect against STDs.
	Female condom 	• Held against cervix by a flexible ring, the female condom prevents sperm and egg contact.	• No known risks
	Male condom 	• Prevents sperm and egg contact.	• No known risks

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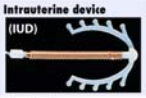
	Method	Mode of action	Risks
Other methods	Spermicides 	• When inserted into vagina 1 hour before intercourse, kills sperm.	• No known risks • Does not protect against STDs.
	Fertility awareness 	• Abstinence for the 4 days before and 4 days after predicted time of ovulation.	• None • Does not protect against STDs.
	Intrauterine device (IUD) 	• When this small plastic device is inserted into the uterus by a physician, it prevents fertilization and prevents the uterus from supporting a pregnancy.	• May increase risk of pelvic inflammatory disease.

*Percent effectiveness assumes correct usage. Pregnancy rate without birth control is 85%.

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	Method	Mode of action	Risks
Hormonal methods	Patch 	• When applied to skin, delivers progesterone and estrogen to prevent ovulation and thicken cervical mucus.	• Same as combination pill • Does not protect against STDs • 99% effective
	Vaginal ring 	• When inserted in vagina, delivers progesterone and estrogen to prevent ovulation and thicken cervical mucus.	• Same as combination pill • Does not protect against STDs • 99% effective
	Emergency birth control pills 	• High doses of progesterone and or estrogen prevent sperm from reaching egg or prevent fertilized egg from attaching to wall of uterus. Can also prevent ovulation for one cycle if it has not occurred. These so-called "morning after pills" are not the same as the mifepristone abortion pill. Emergency birth control pills prevent pregnancy, and mifepristone terminates an established pregnancy.	• Nausea, vomiting, abdominal pain, fatigue, headache • Does not protect against STDs • 80% effective

*Percent effectiveness assumes correct usage. Pregnancy rate without birth control is 85%.

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Endocrine Disruptors, Menstruation, and Infertility

- Female infertility may be caused by **endometriosis** – when uterine tissue grows in other areas leading to scarring and disruption of ovulation
- Endocrine disruptors may also cause infertility

20.3 Human Development

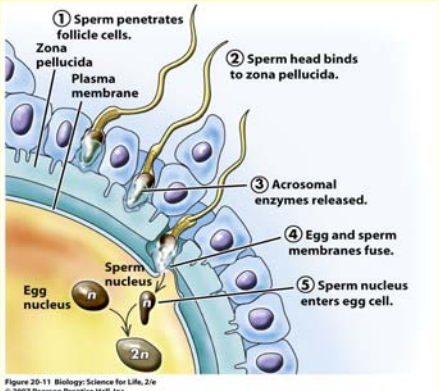
- **Development** is a series of events that takes place after fertilization
  - It leads to the formation of new multicellular organisms
  - Fertilization sets the stage for development

Fertilization

- 300 million sperm are ejaculated
- 200 million reach the oviduct
- Sperm need to survive the acidic vaginal conditions
- Some sperm get stuck in folds of cervix and uterine wall

How Fertilization Takes Place

- Sperm must penetrate follicle cells surrounding the egg then pass through the **zona pellucida** – translucent covering on the egg
- The zona pellucida is species specific – only enzymes on sperm from same species will dissolve it
- Once past the zona pellucida, the sperm plasma membrane fuses with the egg plasma membrane
- The egg cell draws in the sperm cell nucleus



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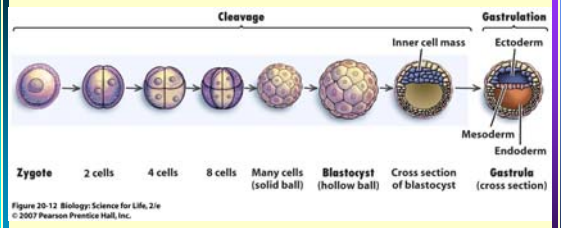
Endocrine Disruptors and Fertilization

- Studies suggest that endocrine disruptors can inhibit fertilization

Human Embryonic Development

- The fertilized egg is a zygote
- The zygote divides many times
- **Embryo** – stage of development from first divisions until 9th week
- **Fetus** – After 9th week, when body structures appear
- **Cleavage** – rapid cell divisions – begin in oviduct
- The embryo reaches the uterus a few days after fertilization and is a hollow ball of cells called a **blastocyst**



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Human Embryonic Development

- The **inner cell mass** of the blastocyst form the embryo
- The outer cells of the blastocyst form the placenta
- The inner cell mass rearranges into three layers of cells and is known as a **gastrula**
- The cells in these three layers specialize, or **differentiate** into different tissues

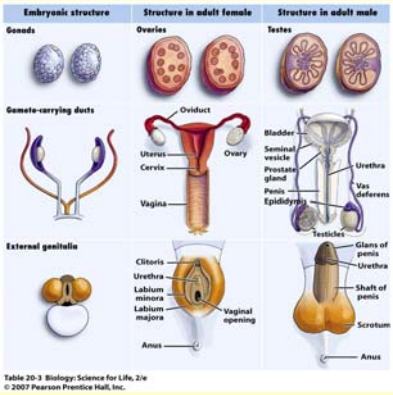
Human Embryonic Development

Gastrula layers:

- **Ectoderm** – forms skin, nervous system and sense organs
- **Mesoderm** – forms muscles, excretory organs, circulatory organs, gonads and skeleton
- **Endoderm** – forms organs of digestion and breathing

Development of Human Reproductive Organs

- Reproductive organs develop at about week 7
- Before that, human embryos are indistinguishable beyond DNA
- Gonadal tissue can form either ovaries or testes, depending on expression of sex-specific genes



Endocrine Disruptors and the Development of Reproductive Organs

- The development of female and male reproductive structures appears to be vulnerable to endocrine disruptors
  - **Cryptorchidism** (undescended testes) as well as other deformities in reproductive structures

Pregnancy

- Pregnancy, or gestation, is the time between fertilization and childbirth
  - It is about 38 weeks in humans
- The placenta forms inside the uterus
- The embryo reaches the uterus
  - Inner cell mass – becomes fetus
  - **Trophoblast** - outer cell mass – becomes part of placenta

Pregnancy

- Trophoblast cells secrete enzymes that help the embryo attach to the uterus lining
- Attachment begins at about day 7 (postfertilization) and trophoblast projections that can carry blood begin to grow into the uterus lining

Pregnancy

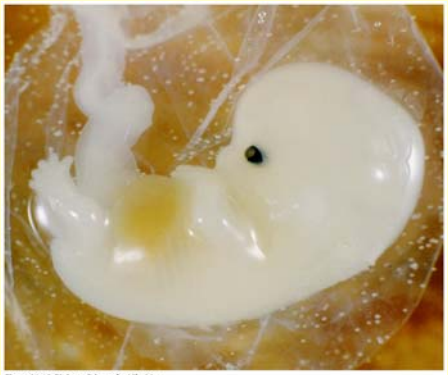
- Uterine blood vessels send blood into the area
- Nutrients and wastes can be exchanged between fetal and maternal blood
  - Oxygen, water, salt, hormones, viruses, many drugs
  - Blood cells and bacteria usually are not passed between mother and fetus

Pregnancy

- Later in pregnancy, the proteins **somatomammotropin** and **prolactin** are produced to stimulate development of the mother's mammary glands
- Prolactin is a hormone that stimulates production and secretion of breast milk for **lactation** (breastfeeding)

Pregnancy

- Embryonic development is remarkable and swift
  - At 4 weeks: 7mm long and beginning brain and spinal cord development
  - At 9 weeks: all organs and limbs



Pregnancy

- For the remainder of the pregnancy
  - Growth in size
  - Refining of features
  - Eyebrows, eyelashes, finger- and toenails
- At the end of pregnancy changes in fetal circulatory and respiratory systems
  - Enable fetus to breathe air

Endocrine Disruptors and Pregnancy

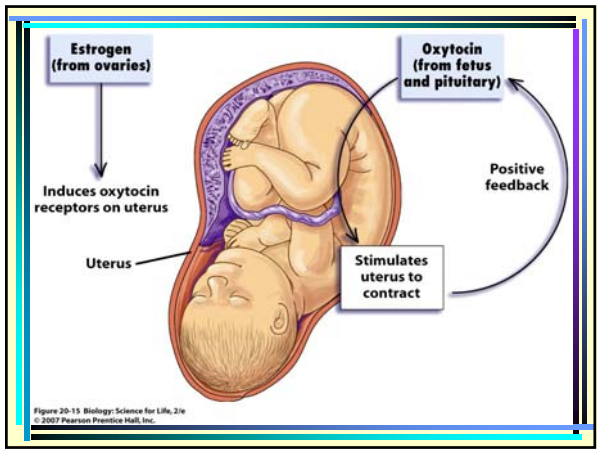
- Substances can cross into the fetus by blood, so the mother must be careful
  - Cigarette smoke leads to low birth weight
  - Mercury exposure affects brain development
  - Alcohol can cause severe developmental problems

Endocrine Disruptors and Pregnancy

- Endocrine disrupters can also negatively affect fetal development
  - PCBs – low birth weight and premature birth
- Premature birth – increased risk of respiratory and heart problems

Childbirth

- Childbirth involves both labor and delivery
- **Labor** – contractions of uterus resulting in birth of baby
  - Controlled by hormones
  - Estrogen increases, stimulates **oxytocin**
  - Oxytocin stimulates contractions
  - Produced by fetal cells and maternal pituitary gland

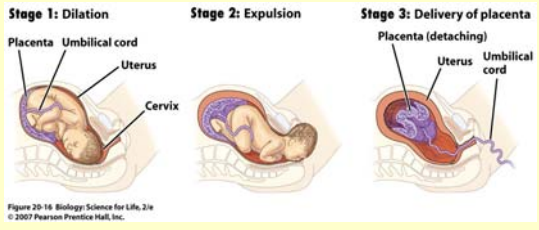


Childbirth

- As cervix begins to dilate at the beginning of labor, the mucus plug blocking the entrance to the uterus becomes loose and passes out of the body
- The **amnion** (fluid sac around fetus) ruptures – "water breaking"

Stages of Labor

- Dilation of cervix
  - Enlarges to 10 cm
- Delivery of baby
  - Contractions and pushing
- Delivery of placenta



Endocrine Disruptors and the Newborn

- There is concern over possible endocrine disruptors in plastics and newborns
- DEHP – found in soft vinyl products
- No definitive evidence it is harmful, but parents are advised to dispose of baby products with DEHP as a precaution
- Babies fed formula are exposed to tap water
- Are there endocrine disruptors in tap water?

20.4 Is the Water Safe to Drink?

- The U.S. Environmental Protection Agency (EPA) is the governmental organization charged with regulating the amount of various chemicals, including known endocrine disruptors, present in drinking water
- Water is tested every 3 months in city water supplies
- Are the EPA-allowed levels low enough to prevent reproductive problems in humans?
- This is uncertain, but there is evidence that endocrine disruptors negatively affect aquatic wildlife