Reproduction
Why sex???
Why Sex???

- Asexual reproduction is quicker, easier, and produces more offspring per individual.
  - Bacteria do it.
  - Dandelions do it.
  - Unisexual whiptail lizards do it.
  - With sexual reproduction there is a dilution of one’s own inheritance.
Why Sex???

- Advantages:
  - It limits harmful mutations
    - Asexual: all offspring get all mutations.
    - Sexual: There is a random distribution of mutations. Those with the most harmful ones tend not to reproduce.
  - It generates beneficial gene combinations.
    - Adaptation to a changing environment
    - Adaptation to all aspects of constant environment
Reproduction limits harmful mutations

Asexual

Parents

Offspring

Sexual

Parents

Offspring

O  Normal gene
X  Gene with harmful mutation
Steroid hormones influence gene expression
Sex Hormones

- **Androgens** include testosterone (T). They are referred to as “male hormones” because men have higher levels.
- **Estrogens** (E) include estradiol and others. They are referred to as “female hormones” because women have higher levels.
- **Progesterone** (P) prepares the uterus for the implantation of a fertilized ovum and promotes the maintenance of pregnancy.
Hormones have 2 kinds of effects

1. **Organizing effects** - occur at sensitive stages of development.
   - Determine whether the brain and body will develop male or female characteristics

2. **Activating effects** - occur at any time of life and temporarily activate a particular response.
Sex determination: SRY gene on Y chromosome → testes → testosterone → masculinization (SRY: Sex-determining Region on Y chromosome)
• During early prenatal development, both males and females have both Müllarian ducts and Wolffian ducts, as well as primitive gonads.
• Wolffian ducts become the vas deferens and seminal vesicles.
• Müllarian ducts become the oviducts, uterus, and upper vagina.
Primitive gonads can develop as either testes or ovaries.
Hormones mediate most (not all) genetic differences.
Descent of the testes

(A)

- Testis
- Kidney
- Epididymis
- Testicular artery
- Aorta
- Ureter
- Bladder
- Vas deferens
- Gubernaculum
- Scrotal swelling
- Penis
Descent of the testes
Sex and Hormones

• **Sensitive periods:** early periods when hormones have long-lasting effects.
• Sexual differentiation depends mostly on the level of testosterone during a sensitive period.
• The human sensitive period for genital formation is about the 3\textsuperscript{rd} and 4\textsuperscript{th} month of pregnancy.
Sex and Hormones

- Female rats exposed to testosterone shortly before or after birth are partly masculinized in anatomy and behavior.
  - Clitoris grows larger than normal
  - At maturity, pituitary and ovaries produce steady levels of hormones instead of cycles
  - Parts of the hypothalamus appear more male
  - Sexual behavior becomes masculinized
Sex and Hormones

• Sex hormones early in life bind to receptors in specific areas of the hypothalamus, amygdala, and other brain areas to produce anatomical and physiological differences.

• The sexually dimorphic nucleus in the medial preoptic area is larger in males and contributes to control of male sexual behavior.

• Parts of the female hypothalamus generate a cyclical pattern of hormone release; the hypothalamus of a male cannot.
Sexual differentiation in the hypothalamus of rats

(A) Male
- A normal male rat shows a testosterone peak perinatally (just before and around birth)...
- ...and a second rise at puberty.
- The male SDN-POA is large.

(B) Female
- A normal female rat lacks both the perinatal and pubertal rises in testosterone levels...
- ...and her SDN-POA is small.
Sexual differentiation in the hypothalamus

(C) Female

A female injected with testosterone at the time of the male perinatal surge...

Testosterone

...develops a large SDN-POA.

(D) Female

Injections at later times, such as at puberty...

...have no effect on the size of a female’s SDN-POA.
In rats, AVPV is larger in females than in males. It controls menstrual cycles (or estrous cycles in rats). Note that T increases the size of the SDN and decreases the size of the AVPV.
Sex differences in the cerebral cortex:

• Men tend to have more white matter.
• Women tend to have a more neurons in language areas of the temporal lobe.
• The language areas are larger in the left than the right hemisphere for both sexes, but the difference is greater in women.
Hormones influence intellectual performance:

- Females typically do better in most school subjects than men, except for math and science.
- Boys perform better at mental rotation tasks and line orientation tasks.
- These differences are probably organizational effects.
Can the set of blocks on the left be rotated to match the set at the right?

On average, men perform better than women on these tasks, but women are better at verbal fluency & manual dexterity than men.

Which of the lines at the left has the same angle as the one at the right?
Sex differences in solving spatial problems

- Men are more likely to use directional (north, south, etc.) orientations to navigate.
- Women are more likely to use landmarks.
- Evolutionary explanation: males of many species travel over greater geographical areas than do females.
Route learning: men are better than women if route requires reference to compass direction or distant landmarks.

Women are better if they navigate by nearby landmarks and street names (or ask directions!!)
Activational effects

• In adulthood, sex hormones can activate behavior.
• Behavior can also influence hormone secretion.
• Hormones do not cause behavior but change the way the brain responds to certain stimuli.
• Hormones also change sensitivity in the penis, vagina, and cervix.
Hormones & sexual arousal

• Humans are less dependent on current sex hormones than other species, but changes can increase or decrease sexual arousal.

• For men, sexual excitement is usually highest when testosterone (T) levels are highest.
  – T affects the genitals, spinal cord and brain.

• The hormone oxytocin contributes to sexual pleasure. A huge amount is released from the pituitary into the general circulation and is also released in the brain during orgasm.
Hormones & sexual arousal

- Decreases in T levels generally decrease male sexual interest, but the effects are variable.
- Erection partially depends on T increasing the release of nitric oxide.
  - It increases dopamine release in the brain and increases blood flow to the penis.
Mechanism of penile (or clitoral) erection

(A)

Corpora cavernosa  Corpus spongiosum  Sinusoids
In the non-erect state the sympathetic nervous system reduces blood flow into the penis.
Penile (or clitoral) erection

During erection the parasympathetic system increases blood inflow so much that the veins that remove the blood are blocked & blood is trapped in the penis. Nitric oxide is the main dilator, and Viagra prolongs its effect. T increases nitric oxide production.
Hormones & sexual arousal

- Although most sex offenders have normal T levels, T reduction has sometimes been tried as a means of controlling sex offenders.
- **Cyproterone** blocks the binding of T to androgen receptors.
- **Medroxyprogesterone** inhibits the pituitary hormone that stimulates testosterone production.
Female reproductive tract

(B) Frontal view

- Oviducts
- Isthmus
- Ampulla
- Infundibulum
- Ovaries
- Fimbriae
- Ovarian ligament
- Endometrium
- Myometrium
- Cervix
- Os
- Vagina
Women’s internal genitalia

• Ovaries
  – Egg-shaped, ~1.5” long (~ man’s testicles)
  – Large number of follicles at various stages
• Oocytes: ~1 million at birth; 200,000 at puberty; ~400 are ovulated in woman’s lifetime.
Sexual arousal

• The **periovulatory period**: the time of maximum fertility and increased E levels, when ovulation occurs.
• Women become more sexually responsive during this time
  – Show increased attention to sex-related stimuli.
  – Show increased mate preference towards men who act and look more masculine.
The face that changes sex
Women find more masculine faces more attractive around the time of ovulation, but prefer slightly more feminized faces at other times.
Parental behavior

• Hormones released around the time of giving birth facilitate maternal behavior in females.
• Late in pregnancy, the female secretes large amounts of E, prolactin, and oxytocin.
  • Prolactin → milk production, contributes to parental behavior.
  • Oxytocin → maternal behavior and social attachment.
• The hormonal changes increase the attention of the mother to the young after birth.
• Mothers are also stimulated by the odors of their babies.
A male & female prairie vole

A male prairie vole retrieves a pup
Mother rats retrieving & licking pups
Variations in Sexual Behavior

• A wide degree of variation exists between people in terms of frequency of sexual behavior, preferred types of sexual activity, and sexual orientation.

• One perspective of explaining differences in behavior is from an evolutionary perspective.
Gender differences in sexual behavior

• Men are more likely to seek multiple sex partners, especially for short-term encounters.
• Women are more likely to be concerned about a mate’s earning potential: men are more likely to be concerned about a mate’s youth.
• Men usually show greater jealousy at indications of sexual infidelity.
Gender differences in sexual behavior

• Gender differences may reflect past evolutionary pressures.
• Men are interested in brief sexual relationships with multiple partners because that strategy increases the likelihood of their genes being passed along to the next generation.
Gender differences in sexual behavior

- Women may also gain from having multiple sexual partners.
  - Increases resources available to her child and herself.
  - May get better genes for her offspring.
- No direct evidence for specific genes that may influence people’s preference for single or multiple mates.
Gender differences in sexual behavior

• Both men and women prefer a mate that is healthy, intelligent, honest, and physically attractive.
• In almost all cultures, women prefer mates who are likely to be good providers.
• Evolutionary explanation: choosing a father who is a good provider aids the woman while she is pregnant or caring for a small child.
Gender differences in sexual behavior

• Men tend to prefer a young partner.
• Evolutionary explanation: younger women are more likely to be fertile than older women.
• Men remain fertile well into old age, so preference for a young mate for women is not as pronounced.
  – Also older men may be better providers.
Variations in Sexual Behavior

• Most people have a gender identity that matches their external appearance.
• Some people have a gender identity that is opposite their biological sex.
• Psychologists and researchers once believed that gender identity was learned and more a product of rearing and experience.
• Current evidence strongly suggests that biological factors, especially prenatal hormones, play a large role in gender identity.
Variations in Sexual Behavior

- **Intersex** people are people are intermediate between being male or female.
- Some XY males with a mutation of the SRY gene have poorly developed genitals.
- Some are born with an XX chromosome pattern but an SRY gene that translocates from the father’s Y chromosome causes ambiguous genitalia.
- Can also occur because of an atypical hormone pattern or mutation of testosterone receptors before birth.
Sex determination: SRY gene on Y chromosome $\rightarrow$ testes $\rightarrow$ testosterone $\rightarrow$ masculinization
• A number of genetic males born without a penis, or who had the penis accidentally removed, and who were raised as a girl, ask to be reassigned as males.

• Many who remain female feel discontent with being female.

• Although hormones do not determine gender identity, they do play an important role.
Variations in Sexual Behavior

- **Congenital adrenal hyperplasia (CAH):** due to overdevelopment of the adrenal glands from birth.
- Genetic defect $\rightarrow$ lack of cortisol $\rightarrow$ no negative feedback to anterior pituitary (AP) $\rightarrow$ lots of ACTH from AP $\rightarrow$ overstimulation of the adrenal gland, which produces a lot of adrenal androgens.
  - The female fetus becomes partly masculinized.
  - Can also occur in boys $\rightarrow$ mature too early
Congenital Adrenal Hyperplasia (CAH)
Toy preferences by CAH girls were between those of other girls and of boys.

In another study, daughters of women who had higher T levels during pregnancy also showed increased play with boys’ toys.
CAH

• During adolescence and early adulthood, CAH girls read more sports magazines & fewer teen & glamour magazines than other girls.

• They also reported fewer sexual experiences with men. Some studies have shown an increase in homosexual experiences, compared to non-CAH women, but still only a minority were lesbian.
Variations in Sexual Behavior

- Hermaphrodites are individuals whose genitals do not match the usual development for their genetic sex.
- An estimated 1 out of 100 children is born with some degree of genital ambiguity.
- 1 in 2000 has enough genital ambiguity to make the sex uncertain.
Gonadal Intersexuality ("True Hermaphroditism")

(A) 

(B) 

- Testes tissue
- Ovarian tissue
Gonadal Intersexuality (Hermaphrodites)

- Either 2 ovotestes or 1 ovary and 1 testis
- Very rare, appear more feminine than masculine.
- Usually, XX with an Sry gene located on one X. Tissue in which that X is expressed is masculinized.
- Sometimes, an XX and XY embryo fuse.
- Several hermaphrodites have become pregnant and delivered children; one fathered a child.
Intersexes: sexual development is intermediate or ambiguous

- Physicians have traditionally recommended that intersex people be reared as girls.
  - Surgery was often conducted to make them look more feminine.
  - It was assumed that children consistently raised as female would accept that identity.
- Many intersex people protest against such surgery and suggest that an informed consent would have been preferred.
Androgen Insensitivity Syndrome

- XY, normal testes in abdomen secrete T
- But mutation in gene for androgen receptor → lack of effect of T
  - Sometimes only partial insensitivity to androgens
- Testosterone is converted to estrogen to produce breast development.
- They do not menstruate or have pubic or underarm hair
- Woffian ducts degenerate, due to lack of androgen receptors; no sperm production for same reason.
- Mullerian ducts degenerate because of Mullerian inhibiting hormone from testes.
Androgen Insensitivity Syndrome: XY genetic male, but a female appearance due to lack of androgen receptors
5-alpha-reductase deficiency

- T is normally converted to dihydrotestosterone (DHT) by cells in the genitals (and brain).
  - DHT is more potent than T.
- Some XY babies lack the enzyme that makes DHT.
- Normal internal genitalia: testes secrete T.
- Lack of DHT leads to little masculinization of external genitals at birth
  - Testes in labia or abdomen.
- At puberty, lots of T → testes descend, scrotum darkens, penis enlarges, muscular, deep voice.
- Most then accept a male gender identity.
  - Brain is exposed to testosterone during early development.
Boy with 5alpha-Reductase Deficiency

T is present during gestation, but is not as effective as DHT at masculinizing the genitals (A). At puberty, lots of T masculinizes the genitals (B).
Variations in Sexual Behavior

- There have been genetic males born without a penis or who had the penis accidentally removed and who were raised as a girl. Most asked to be reassigned as males.
- Many who remain female feel discontent or in conflict with being female.
- Such cases show that, although hormones do not determine gender identity, they do play an important role.
Sexual Orientation

- Studies of twins suggest sexual orientation is influenced by genetic factors.
- Identical (monozygotic) twins have higher concordance (similarity) than fraternal (dizygotic) twins regarding homosexuality. Concordance is even lower in siblings and adopted brothers or sisters.
- Because monozygotic twins can have opposite sexual orientations, genes are not the only factor.
Variations in Sexual Behavior

• Studies also suggest a higher incidence of male homosexuality among the maternal relatives of homosexual men.
• These results suggest a gene on the X chromosome that a man receives from his mother may play a role in some cases.
• Other studies have not replicated this result and thus the findings are inconclusive.
• There may be numerous genes that predispose one to homosexuality.
Variations in Sexual Behavior

• Possible explanations for the survival of “gay genes”
  – They increase the fertility of women relatives
  – They may be beneficial to a man if present on a single chromosome (i.e., heterozygous for the trait)
    • They could make him more emotionally responsive, and thus, attractive to women.
    • Only the homozygous condition would produce homosexuality.
Variations in Sexual Behavior

• Sexual orientation may be influenced by testosterone levels during sensitive periods of brain development.
• Male animals deprived of testosterone early in life show sexual interest in other males as adults.
• Studies of female animals exposed to testosterone during early development show an increased likelihood of mounting behavior.
Variations in Sexual Behavior

- Research also suggests that certain brain structures differ in size between heterosexual and homosexual men and women.
- On average, the male homosexual brain is shifted towards a female development in some (but not all) ways; the female is shifted in some ways towards male development.
- Studies emphasize the role of testosterone at certain times of development as certain areas of the brain have altered sensitivities to testosterone.
Variations in Sexual Behavior

- The probability of homosexual orientation is also higher among men with older brothers.
- Number of previous sisters has no effect and these effects do not apply to females.
- A mother’s immune system may react against the SRY protein in a son and attack that protein in later sons to alter their development.
Variations in Sexual Behavior

- Laboratory research has also shown that prenatal stress can alter sexual development.
- Male subjects subjected to either prenatal stress or alcohol developed male sexual behavior in addition to female sexual behaviors.
- Male subjects exposed to both stress and alcohol during prenatal development had decreased sexual behavior.
Variations in Sexual Behavior

• On average, differences in brain anatomy exist between heterosexual and homosexuals.
• Homosexual men tend to have:
  – Smaller neurons in a nucleus of the hypothalamus (INAH-3)
• Difficult to know why differences exist.
• AIDS cannot explain the difference, because some homosexual men did not have AIDS and some heterosexual men did have AIDS.
Third interstitial nucleus of the anterior hypothalamus (INAH3)
Summary

• Advantages of sexual reproduction include:
  – getting rid of bad mutations
  – producing diversity that can adapt to a changing environment or making full use of a constant environment.

• Steroid hormones are derived from cholesterol and are fat-soluble. Most effects of steroid hormones are mediated by activating genes that alter production of proteins.
Summary

• Organizing effects of hormones, during an early sensitive period, produce relatively permanent alterations in anatomy & physiology.

• In the absence of sex hormones, an infant mammal develops female-looking external genitals. The addition of testosterone (T) shifts development toward the male pattern.

• The sexually dimorphic nucleus of the preoptic area (SDN/POA) is larger in males (→ male sex behavior); the AVPV is larger in females (→ menstrual or estrous cycling).
Summary

• There are also sex differences in the cerebral cortex, with some areas being larger in men and others, in women.

• Men are better at spatial tasks and mathematical reasoning; women are better at verbal fluency and manual manipulation. There are also differences in the cues men & women use to navigate spatially, with men using compass directions and women using landmarks.

• In adulthood, sex hormones can activate sex behaviors, partly by facilitating activity in the hypothalamus. The hormones prime the cells to respond to sexual stimuli.
Summary

• Hormones released around the time of birth facilitate maternal behavior in females of many mammalian species. However, prolonged exposure to young is also sufficient to induce parental behavior.

• People can develop ambiguous genitals or genitals that do not match their chromosomal sex for several reasons.
  – Congenital adrenal hyperplasia (CAH) is due to a genetic defect in cortisol production, which leads to overstimulation of the adrenal gland, which produces excess adrenal androgens. Those androgens partially masculinize the genitals of girl babies. Girls with CAH show more interest in boys’ toys and as young adults also show partly masculinized interests.
Summary

• Androgen insensitivity results from a genetic lack (or decrease) in androgen receptors. The individual is an XY genetic male with abdominal testes that secrete testosterone. However, the lack of androgen receptors results in a female external appearance.

• People born with intermediate or ambiguous genitals are called intersexes. Traditionally, physicians have recommended surgery to make these people look more feminine. However, many intersexed people protest against imposed surgery and insist they should have made an informed decision themselves.

• Some children have a gene that decreases their early production of dihydrotestosterone (DHT). Such a child looks female at birth and is considered a girl, but develops a penis at adolescence. Most then develop a male gender identity.
Summary

• One genetic male was exposed to male hormones until infancy, when his penis was accidentally removed and then his testes intentionally removed. In spite of being reared as a girl, he insisted on a male gender identity.

• Possible biological explanations for homosexual orientation include genetics, prenatal hormones, and (in males) reactions by the mother’s immune system. Hormone levels in adulthood are within the normal range.