

Evolution of Sex, Part 2.

1

1

Reading Assignments (Online Syllabus):

1. [Why Sex - The advantages of sex \(PBS series\)](#)
2. [The Trouble With Sex](#)
3. [Battle of the Sexes Pgs 13 - 18](#)
4. [Why the Y?](#)
5. [Male Sex Chromosome to Stick Around](#)
6. [Bowerbirds](#)
7. [Understanding Evolution](#)
8. [Rediscovering Biology: Sex & Gender Pgs 1 - 4](#)

2

2

• Two Main Types of Reproduction

1. **Sexual Reproduction** = reproduction

through combination of gametes

- Usually (not always!) requires separate male and female.

2. **Asexual reproduction** = reproduction

without combination of eggs & sperm

- Ex. Bacteria, fungi, plants!

3

• Two Main Types of Reproduction

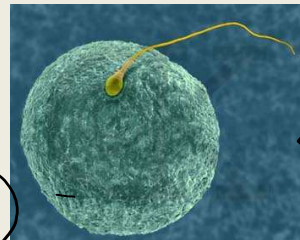
1. **Sexual Reproduction**

- refers to union (**syngamy**) – a review term.
- occurs through exchange of **gametes** = eggs & sperm
 - human sperm carries 23 chromosomes (22 autosomes plus an X or Y)
 - human egg carries 23 chromosomes (22 autosomes and an X)

Gametes defined by size:

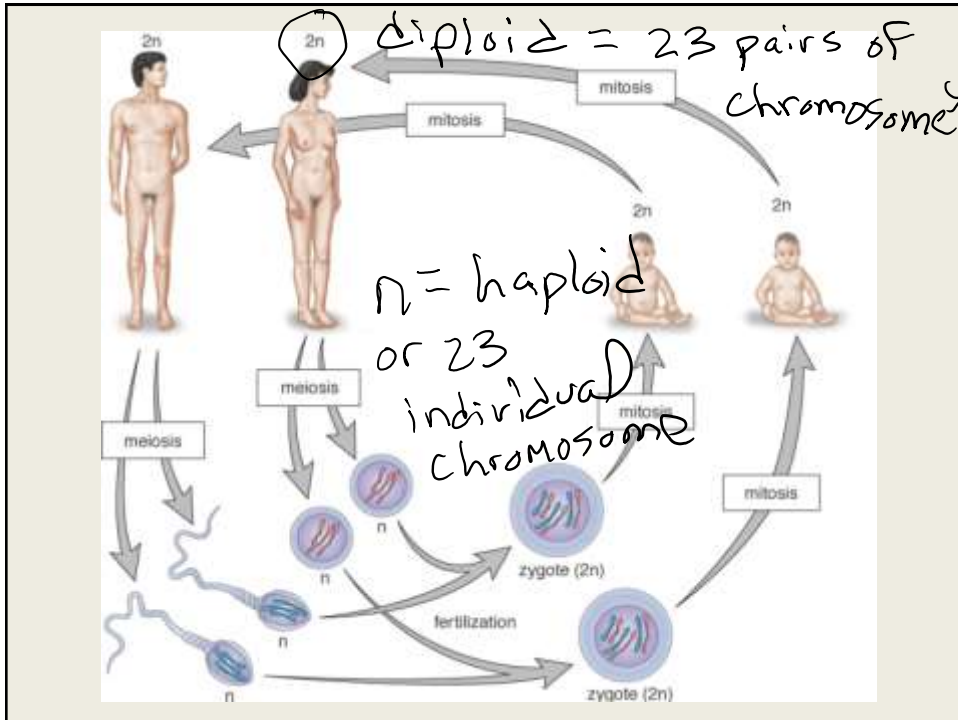
- **isogamy** = eggs & sperm
are same size

- **anisogamy** = eggs & sperm
are diff. size
(egg usually larger)



Anisogamy in human egg and sperm

4



5

• Two Main Types of Reproduction

1. Sexual Reproduction

- refers to union (syngamy)
- occurs through exchange of gametes = eggs & sperm
 - human sperm carries 23 chromosomes (22 autosomes plus an X or Y)
 - human egg carries 23 chromosomes (22 autosomes and an X)
- **Gametes defined by size:**
 - isogamy =
 - anisogamy =
- Does not always require separate sexes (male & female) but different gametes!

A) gonochoristic = individual can be only male or female in lifetime. Ex. humans

B) hermaphroditic = individual can be both male & female in lifetime.

6

A) gonochoristic = individual can be *only* male OR female (not both) in lifetime. Ex. Humans and most vertebrates

B) hermaphroditic = individual can be BOTH male & female in lifetime.

Ex. Earthworms, some lizards, some fish, etc...

- i. simultaneous hermaphrodite** = both male & female at same time during lifetime. (earthworms, snails)
- ii. Sequential hermaphrodite** = starts life as one sex & then changes to other (because of environment cue)

7

“Accidental” Simultaneous Hermaphrodites

When genetic or hormonal abnormality causes an animal to have both an ovary & testis.



Hermaphrodite bullfrog

Hermaphrodite cardinal

8

Natural Hermaphrodites

Simultaneous Hermaphrodites = banana slugs & snails





Banana slugs

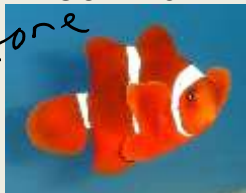
Snails

Sequential hermaphrodites

Grouper



Clown fish



Androgens = testosterone

Gyno = gynocology = female

"protogynous hermaphrodite" = starts life as female then turns into male.

"protandrous hermaphrodite" = starts life as male then turns to female.

9

Sex determination in humans

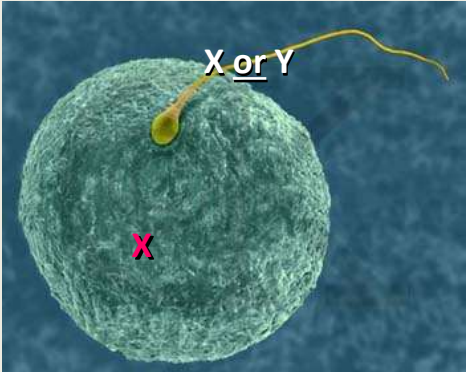

Men and women have **sexual dimorphism** (physical differences)

- numerous anatomical and physiological differences
- but at the chromosomal level there is just one:

— between sexes due to hormone exposure

Men have an X and Y chromosome (XY) = X from mother, Y from father

Women have two X chromosomes (XX) = X from mother, X from father

XX

XY

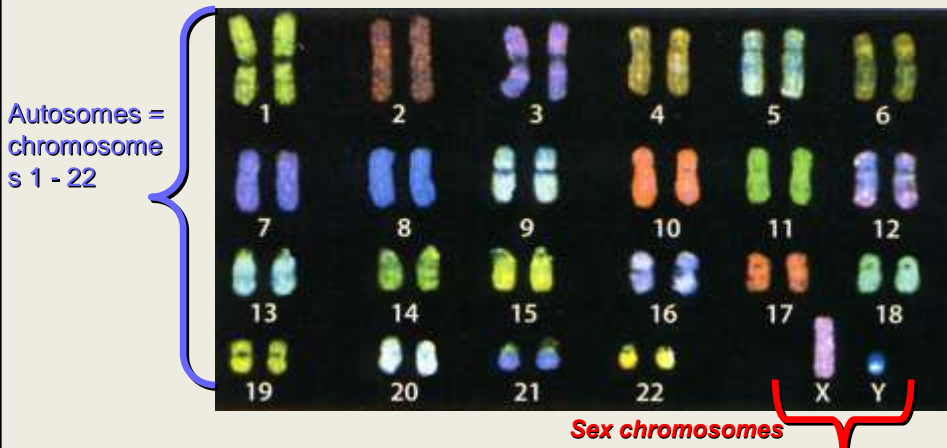
10

Sex determination in humans

Human somatic cells (all cells except egg or sperm) have **23 chromosome pairs** :

22 autosome pairs = carry genetic info for everything except sex.

1 pair sex chromosomes (XX or XY) - carry genetic info. for sex only



11

Sex determination in humans

Upon fertilization (union of gametes; egg & sperm) – get a **zygote**.



22 autosomes
1 sex chromosome
(either X or Y)

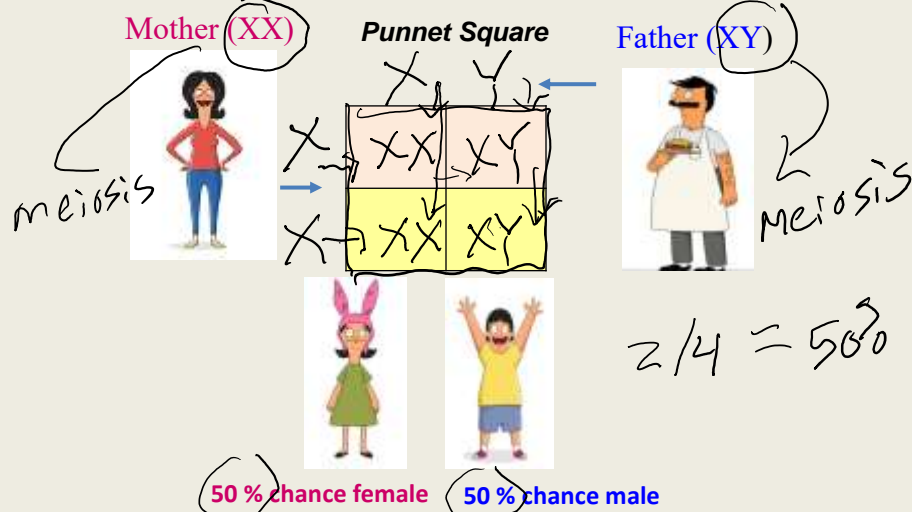
has 23 pairs chromosomes

12

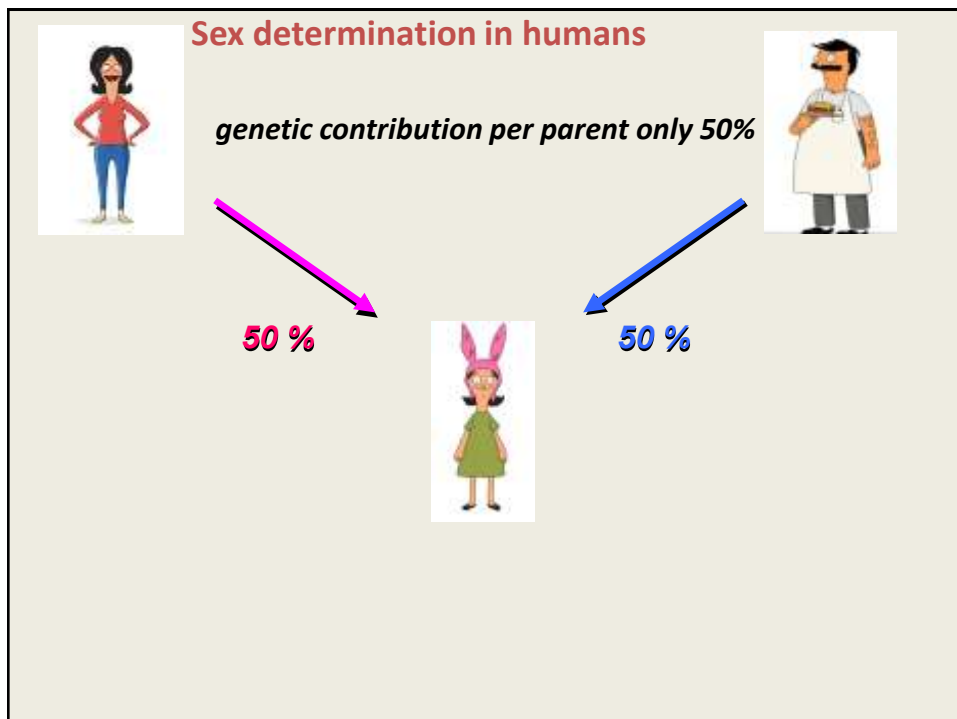
Sex determination in humans

All (normal) eggs of a human female contain one X chromosome
Sperm can contain either an X or a Y chromosome

Upon fertilization zygote's genetic sex chromosomes could be:



13



14

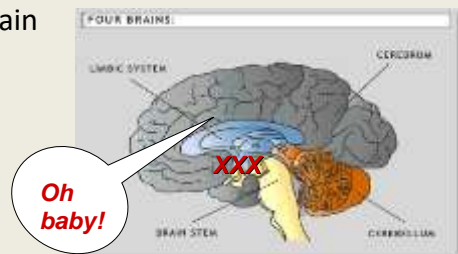
Sexual Reproduction

- bacterial sex started 4 billion yrs ago; **increases genetic variation** and for making more bacteria.
- now adopted by most (not all) forms of life.
- evolution of positive feedback to encourage sex.
- in higher mammals – evolved intense stimulation of pleasure centers in limbic system of brain.



limbic system = part of emotional brain that is associated with the 4 F's

4 F's = 1. Feeding
2. Fight
3. Fright
4. Fornicate



15

Types of Asexual Reproduction – contin...

Faked orgasms don't fool brain scans
CNN Monday, June 20, 2005



COPENHAGEN, Denmark (Reuters) -- Women may be able to fool their partners by faking an orgasm but a brain scanner will catch them every time, a conference heard on Monday.

- **Location of male/female orgasm = Limbic system** (includes hypothalamus and amygdala)
- In females **amygdala** shuts off during true orgasm, remains active if fake orgasm!

http://people.fmarion.edu/tbarbeau/CNN_Faking_Orgasms_Brain.pdf

16

REVIEW:

Vocabulary:

- Sexual vs asexual reproduction
- Gametes
 - Isogamy vs Anisogamy
- Gonochoristic vs Hermaphroditic
 - > Simultaneous hermaphrodite vs sequential hermaphrodite (and examples).
- Sexual dimorphism
- Autosomes vs sex chromosomes
- Sex determination in humans.
- 4 F's of the limbic system (and role of amygdala in orgasm in women).

17

Asexual Reproduction - Disadvantages

1. No genetic variation in the population (all are clones)
2. Cannot evolve (adapt) to new environments.
3. **Mutational meltdown** = Buildup of mutations can lead to problems.
4. "Bad" mutations don't get diluted by a mate's contribution.

18

Asexual Reproduction - Advantages

1. Don't need to find a mate!
2. No separate male or female needed.
3. Guaranteed chance to reproduce.
4. Offspring are 100% your genes (not diluted by mate's contribution).
5. Being asexual **avoids** the **2-fold cost of sex**: (John Maynard Smith, 1971)

AS
Asexual

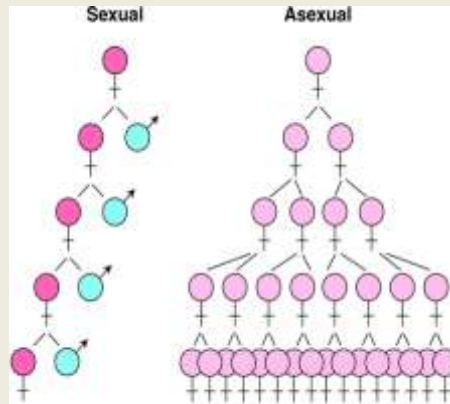
① you can produce more offspring faster than sexual reproducers

② Avoid cost of males (males can't carry offspring)

19

Asexual Reproduction - Advantages

1. Don't need to find a mate!
2. No separate male or female needed.
3. Guaranteed chance to reproduce.
4. Offspring are 100% your genes (not diluted by mate's contribution).
5. Being asexual **avoids** the **2-fold cost of sex**: (John Maynard Smith, 1971)



Milinski M. 2006. Annu. Rev. Ecol. Evol. Syst. 37:159-86

1) Asexual reproduction
More offspring
faster

2) "cost of males" = no males who cannot carry children.

20

Asexual Reproduction - Advantages

Darwin's Question??

- WHY don't more organisms have asexual reproduction?

Answer

many organisms do just that!

21

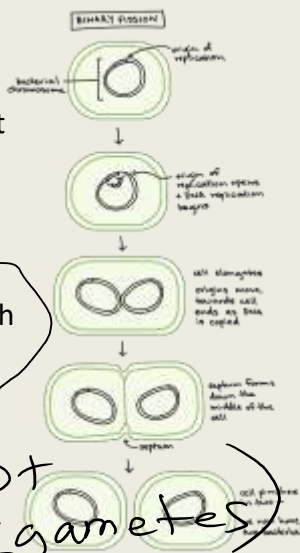
Types of Asexual Reproduction

1. Cloning = An individual reproduces offspring that are genetically and phenotypically identical to themselves.

Ex. A) Bacterial fission = bacterial cells divide by fission to produce cloned cells identical to parent cell.

Ex. B) The majority of our cells (somatic cells) clone themselves to produce new cells for growth & repair of body tissues. This process is called

Mitosis All cells in
our body except
for sex cell (gametes)



22

Types of Asexual Reproduction

More Cloning -

Ex. C) Parthenogenesis

= female produces cloned offspring without contribution of a male.
Population is all females. (Ex. 15 species of Whiptail lizards in New Mexico)



Click [HERE](#) for natural occurrence of parthenogenesis in: Insects, Crustaceans, Spiders, Rotifers, Flatworms, Snails, Squamata (snakes & lizards), Amphibians (frogs, toads, salamanders), & Sharks.

Parthenogenesis

23

Ex. D) Human clones?



24

Ex. D) Human clones?

Identical
twins

Fertilized
egg

We already have them! They're called:

from
"one" zygote

Monozygotic twins = babies that arise when a fertilized egg (zygote) splits evenly early in development. Result is two offspring with same genetic make-up.

(Although they might end up looking and acting very differently.)



Mary Kate and Ashley Olsen

25

Ex. E) Artificial Cloning 1st cloned mammal = Dolly the sheep

TECHNOLOGY

A Noah's Ark of Cloned Animals

◀ PREVIOUS

3 of 7

NEXT ▶

Dolly, first cloned mammal—and the sheep that started it all. The basic method used to clone Dolly and other animals including Snuppy, an Afghan hound, involves placing an adult animal's DNA, extracted from, say, a skin cell, into an egg cell from the same species whose DNA has been removed. The reengineered ovum is then implanted in a surrogate mother to begin gestation as the genetic twin of the adult DNA donor.

Dolly was also the first animal to prove that clones can breed normally and produce healthy offspring. She conceived naturally and gave birth to Bonnie in 1998, and then triplets in 1999. Dolly died in February 2003 and is on display at a Scottish museum. The animal was put to sleep at the age of six after being diagnosed with progressive lung disease.

◀ PREVIOUS

3 of 7

NEXT ▶



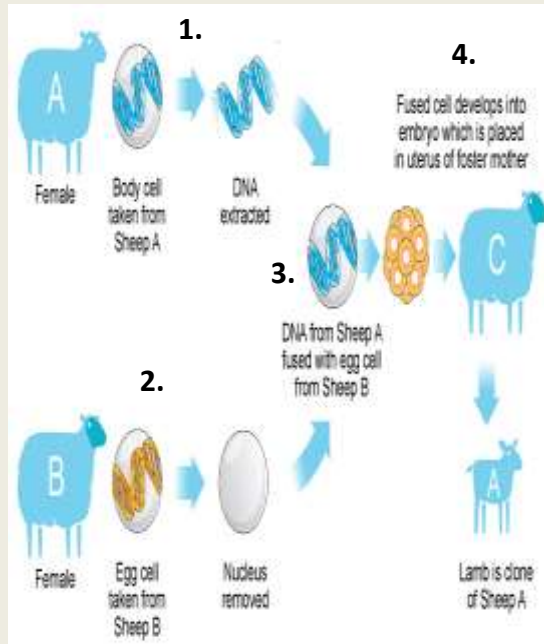
Dolly and friend at the Roslin Institute in Scotland.
(Photo: Roslin Institute)

August 8, 2005

26

Artificial Cloning

1. Take body (somatic) cell from one animal & extract DNA.
2. Add DNA to egg without DNA (cell nucleus) from donor animal.
3. Fuse these to produce an embryo in petri dish.
4. Implant embryo into uterus of surrogate animal.



27

Other cloned animals



2nd cloned mammal = Noto and Kaga the cows



3rd cloned mammal = Rhesus monkey



4th cloned mammal = "CC" the cat

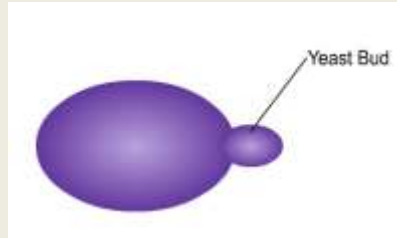
28

Types of Asexual Reproduction – contin...

1. *Cloning*

2. **Budding** = Asexual reproduction where new cell buds off of parent cell.

Ex. Yeast



29

Types of Asexual Reproduction – contin...

3. **Viral replication** = Virus (not a cell) hijacks host cell forcing them to produce new copies (virions) of virus. Cell eventually bursts and virus invades new cells.

Ex. AIDS, HIV, Shingles, HPV, Herpes *COVID*

WHAT IS HIV?

Human Immunodeficiency Virus (HIV) is a virus that attacks cells that help the body fight infection.

There's no cure, but it is **treatable** with medicine.

HIV.gov

30

Types of Asexual Reproduction – contin...

4. Fragmentation = when part of organism breaks off, the broken piece can become a whole new organism.

Ex: *Sea sponges and Flatworms*

Sea sponge



Planaria (a flatworm)



Ex: *The Thing* (Sci-fi movie)



31

REVIEW:

Asexual Reproduction

Advantages

- no male & female gametes to combine (no searching for mate)
- offspring is genetic clone to parent (100% genetic contribution)
- avoids the **two-fold cost of sex** (produce more offspring faster, no males)
- desirable traits not diluted (50%) by a mate's contribution
- guaranteed chance to reproduce!

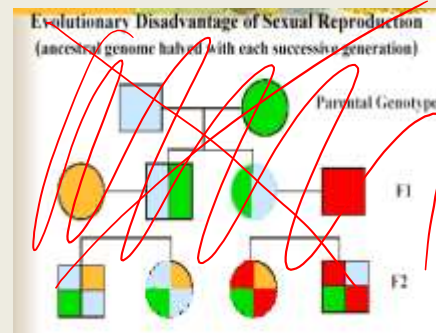
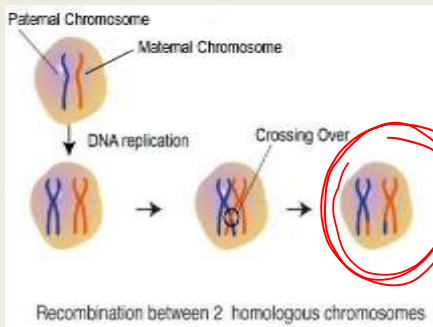
Disadvantages

- less genetic variation in offspring (poorer quality offspring)
- slow rate of evolutionary change
- vulnerable to environmental changes (all offspring equally vulnerable)
- undesirable traits not diluted by a mate's contribution
- mutations build up in population – "**mutational meltdown**"

32

Sexual Reproduction - Disadvantages

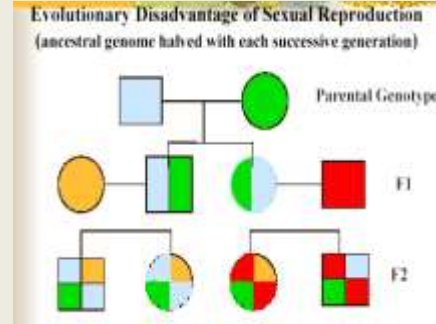
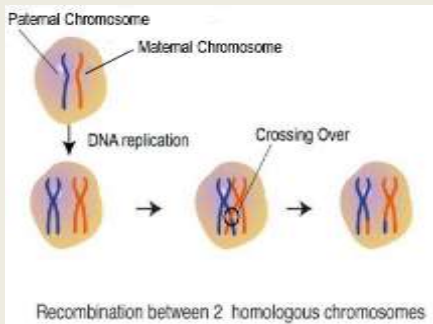
1) **Recombination**, during meiosis when eggs & sperm are made, **could destroys adaptive combinations of genes in parents**. So less and less of parental genes are reflected in later generations.



33

Sexual Reproduction - Disadvantages

1) **Recombination**, during meiosis when eggs & sperm are made, **could destroys adaptive combinations of genes in parents**. So less and less of parental genes are reflected in later generations.



34

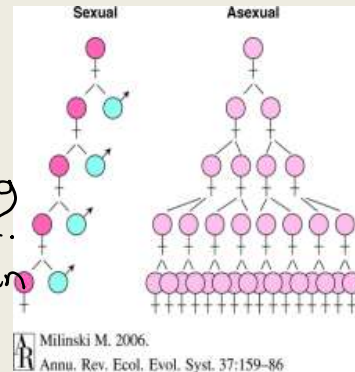
Sexual Reproduction - Disadvantages

1) **Recombination**, during meiosis when eggs & sperm are made, **could destroys adaptive combinations of genes in parents**. So less and less of parental genes are reflected in later generations.

2) Sexual Reproduction HAS the "**Two-fold Cost of Sex**"

(sexual reproduction = slower process w/fewer offspring)

- ① They produce less offspring over longer period of time.
② males can't bear children



3) Only 50% genes inherited from each parent (good genes could be diluted)

35

Sexual Reproduction - Disadvantages

4) males & females **must find each other** to reproduce. This isn't always easy!

Ex. Deep sea fish, in vast ocean, have hard time finding each other!



5) Egg usually stays put (in female) while sperm must move, find, and compete for egg entrance.

6) involves "*being at right place, right time*" - evolution of reproductive cycles.

36

Sexual Reproduction - Disadvantages

4) males & females **must find each other** to reproduce. This isn't always easy!

5) Egg usually stays put (in female) while sperm must move, find, and compete for egg entrance.

6) involves "*being at right place, right time*" - evolution of reproductive cycles.

7) brings in complication of **competition** for access to mates.

8) **Female choice** means not all males get a chance to mate.

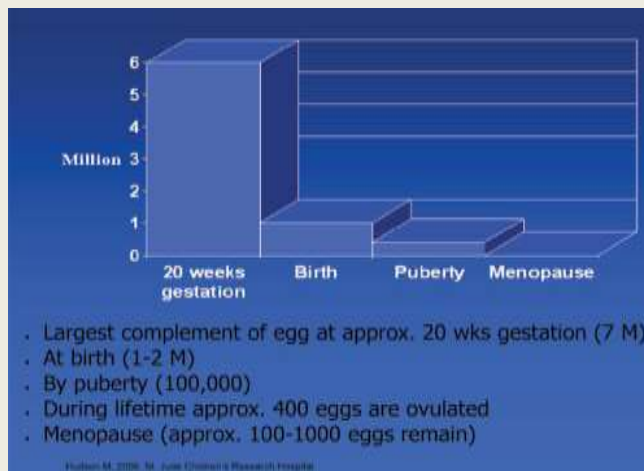


37

Sexual Reproduction - Disadvantages

9) **Imbalance in cost of cost of sex between males & females**

- Females produce fewer eggs than males produce sperm
- Human females lose eggs as they go from fetus, birth, puberty (this is called "**atresia**")
- Sexually producing females don't have same reproductive capacity as males.



38

Sexual Reproduction - Disadvantages

10. This imbalance in cost of sex between males and females leads to **“different agendas for females and males”**. [often these strategies conflict w/each other]

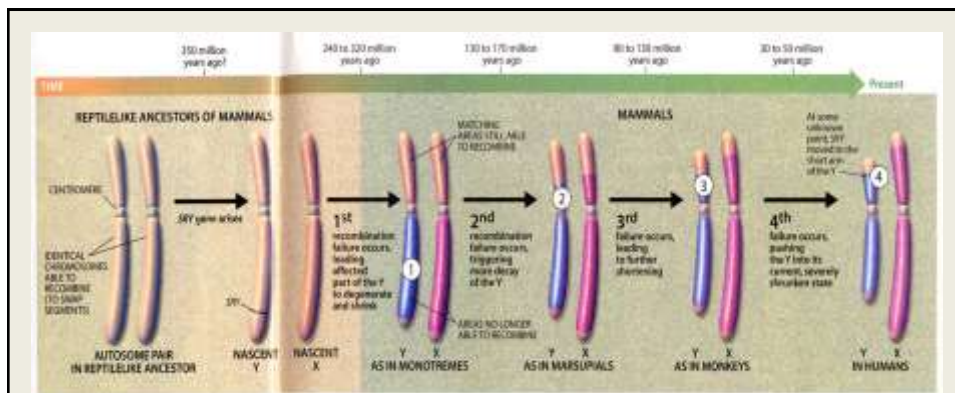
11) the Y-chromosome is shrinking!

- millions of yrs ago sex chromosomes were identical.
- over time X & Y chromosomes in organisms diverged
- The X chromosome is 4 times the size of the Y and has ~3000 genes
- The Y chromosome has shrunk and has ~ few dozen genes (mostly for maleness & fertility)

> **Shrinking due to buildup of mutations from failure to “cross-over” during meiosis** in formation of sperm in testes.

See reading assignments: **“Why Sex?”**, **“Why the Y?”**, **“The Trouble With Sex”**, & **“Rediscovering Biology” Pgs 1 - 4**

39



Sex chromosomes common ancestry
(From reading assign. **“Why the Y?”** and **Rediscovering Bioogy Pgs 1 - 4**)

X has ~3000 genes



Y has only few dozen genes

40

Sexual Reproduction – Disadvantages Review

- 1) Recombination destroys adaptive combinations of genes
- 2) Has the “**Two-fold Cost of Sex**” (slow process w/fewer offspring)
- 3) Only 50% genes inherited from each parent
- 4) males & females must find each other to reproduce.
- 5) Egg usually stays put (in female) while sperm must move, find, and compete for egg entrance.
- 6) involves “*being at right place, right time*” - evolution of reproductive cycles.
- 7) brings in complication of **competition** for access to mates.
- 8) brings in complication of “**female choice**” into mating (females are choosy when selecting mate)
- 9) imbalance in cost of sex between males & females
 - females produce fewer eggs than males produce sperm
 - human females lose eggs as they go from fetus, birth, puberty (“**atresia**”)
10. This imbalance in cost of sex between males and females leads to “**different agendas for females and males**”. [often these strategies conflict w/each other]
- 11) the Y-chromosome is shrinking!

41

Sexual Reproduction

If sex has so many disadvantages, the question then becomes:

WHY SEX?

See reading assign. “[Why Sex?](#)”, “[The Trouble With Sex](#)”

42

Sexual Reproduction - Advantages

3 Hypotheses for why sex exists and persists

43

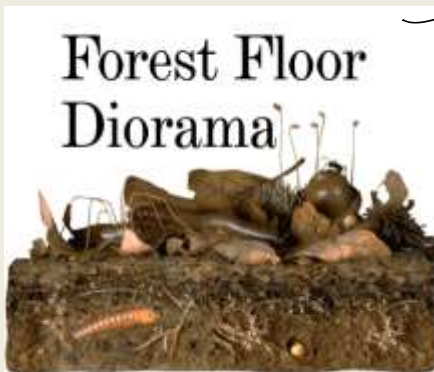
Sexual Reproduction - Advantages

3 Hypotheses:

1. Tangled Bank Hypothesis

~~2~~ (Williams & Ghiselin) = Sex creates offspring diff. enough from parents so that they can exploit more ecological niches in environment without competing with parents.

(So won't outstrip resources in environment)



This hypothesis, however, is not well supported by fact that:

> sexually reproducers more likely found in highly variable environments

> sexual reproduction yields fewer offspring to compete w/parents.

44

Sexual Reproduction - Advantages

2. Red Queen Hypothesis (Hamilton and VanValen) = Sexual reproduction ↑ genetic variation of offspring keeping parasites and pathogens from penetrating defenses.

"As parasites evolve a better attack, we evolve better defenses"

Based on Alice in Wonderland where Alice met the Red Queen who told her they must run, run, run as fast as they can just to stay in one place.

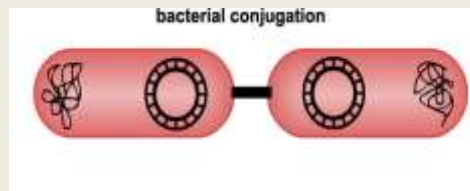


We are running to stay one step ahead of parasites & pathogens. We do this through sexual reproduction, which ↑ genetic variation in offspring to help do this.

45

Sexual Reproduction - Advantages

Sex first evolved in bacteria - 4 billion years ago! "Bacterial conjugation"



If bacteria can "clone" themselves WHY mix genes with other bacteria?

ANSWER:

To create **genetic variation** to penetrate host organism's immune defenses.

Viruses do the SAME THING! Ex. Influenza (flu) & COVID viruses.

46

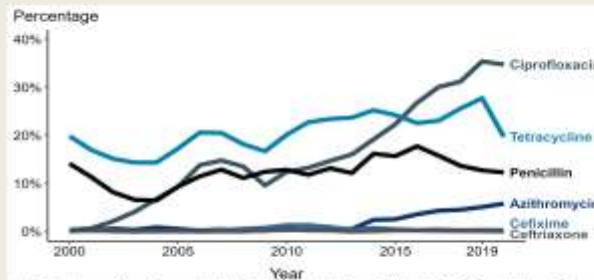
Sexual Reproduction - Advantages

The Red Queen Hypothesis: (Van Valen)

Parasites & pathogens are evolving (mutating) as fast as they can to evade our immune system.

Gonorrhea bacteria is becoming resistant to most of the antibiotics used to treat it.

Neisseria gonorrhoeae — Prevalence of Tetracycline, Penicillin, or Ciprofloxacin Resistance* or Elevated Cefixime, Ceftriaxone, or Azithromycin Minimum Inhibitory Concentrations (MICs)†, by Year — Gonococcal Isolate Surveillance Project (GISP), 2000–2020



* Resistance: Ciprofloxacin: MIC \geq 1.0 $\mu\text{g}/\text{mL}$; Penicillin: MIC \geq 2.0 $\mu\text{g}/\text{mL}$ or Beta-lactamase positive; Tetracycline: MIC \geq 2.0 $\mu\text{g}/\text{mL}$

† Elevated MICs: Azithromycin: MIC \geq 1.0 $\mu\text{g}/\text{mL}$ 29 (2000–2004); \geq 2.0 $\mu\text{g}/\text{mL}$ (2005–2020); Ceftriaxone: MIC \geq 0.125 $\mu\text{g}/\text{mL}$; Cefixime: MIC \geq 0.25 $\mu\text{g}/\text{mL}$

47

Sexual Reproduction - Advantages

The Red Queen Hypothesis: (Van Valen)

Parasites & pathogens are evolving (mutating) as fast as they can to evade our immune system.

HIV = Human Immunodeficiency Virus

HIV invades human cells & avoids detection/defense by host immune system (for years).

Eventually immune system suppressed and develop

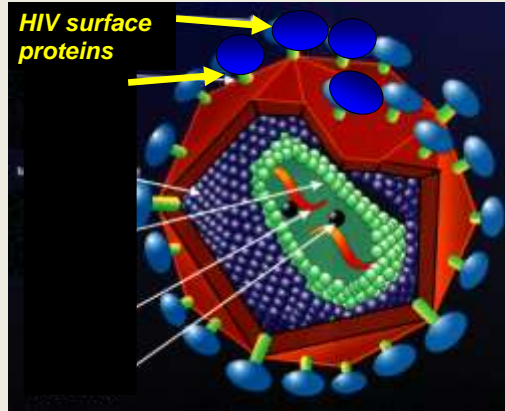
AIDS = Acquired immunodeficiency Syndrome

48

Sexual Reproduction - Advantages

2. The Red Queen Hypothesis: (Van Valen)

Parasites & pathogens are evolving (mutating) as fast as they can to evade our immune system.



HIV evading human immune system defenses

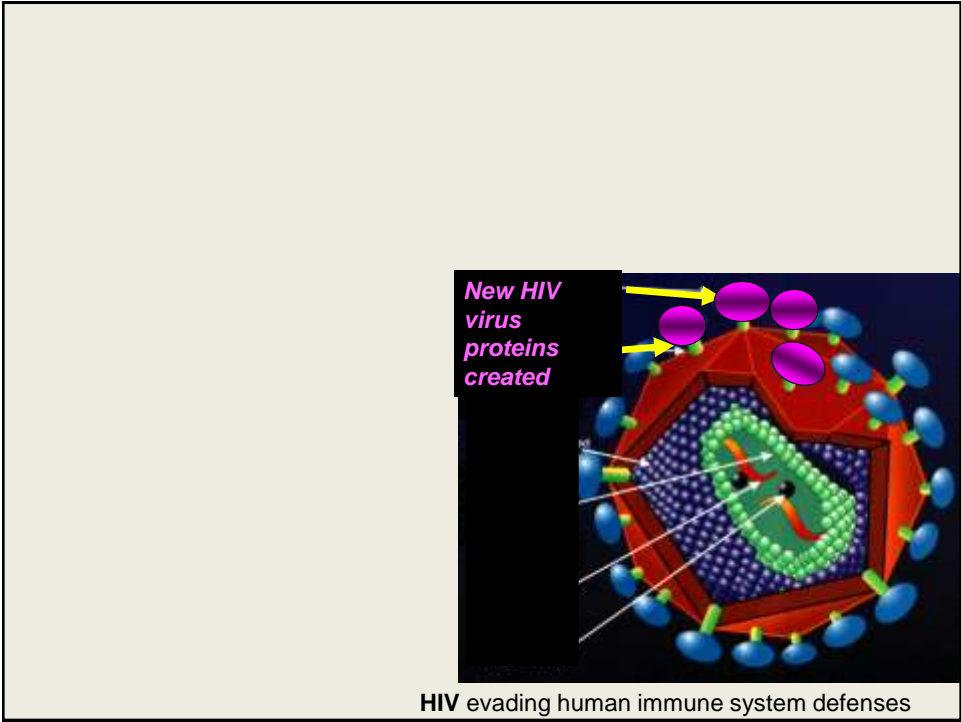
49

Immune Cell

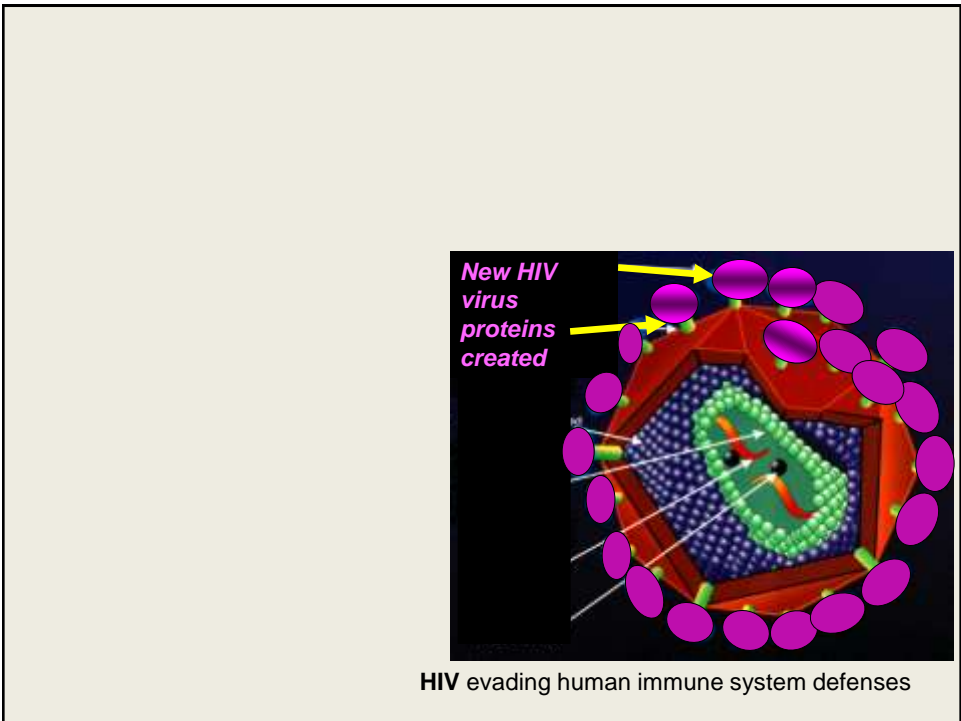
Pathogen (HIV virus)

HIV evading human immune system defenses

50



51

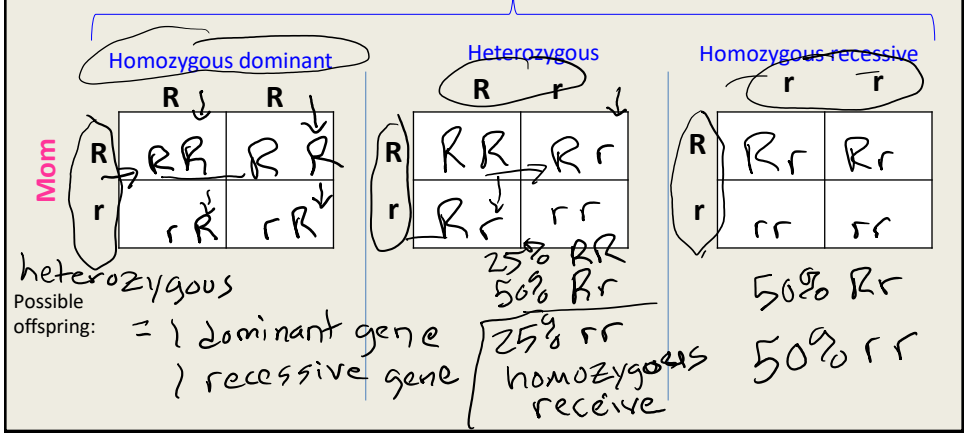


52

Autosomal recessive disorders = recessive trait for a disorder/disease where offspring must inherit 2 copies (one from mom & dad) in order for it to be expressed.

R = normal gene (dominant)
r = recessive gene (with mutation for a disease)

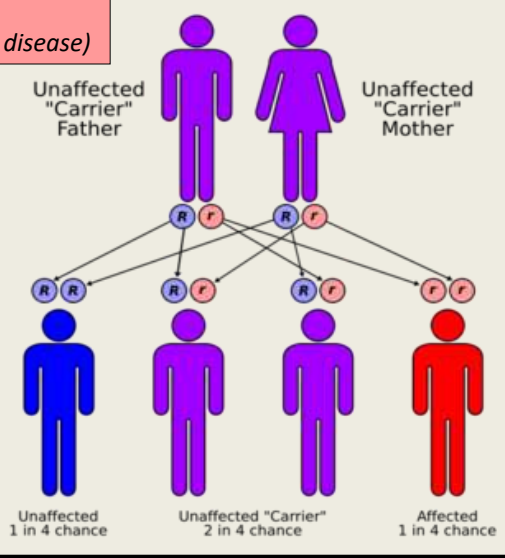
Possible Gene Contributions of Father:



55

Autosomal recessive disorders = recessive trait for a disorder/disease where offspring must inherit 2 copies (one from mom & dad) in order for it to be expressed.

R = normal gene (dominant)
r = recessive gene (with mutation for a disease)



56

Examples of autosomal recessive disorders:

Ellis-Van Creveld Syndrome - (ee)

extra fingers (polydactyly) in Amish community of Pennsylvania due to inbreeding depression (closed community ↓ mating diversity)



Cystic fibrosis – (cc) = defective cell walls leading to fluid buildup outside of cells – especially fluid & mucus in lungs



Tay-Sachs – (tt) = missing enzyme that breaks down lipids in brain. Causes buildup of brain lipids. Death by 2 – 3 yrs of age. Found in isolated Jewish Orthodox communities.

57



Heterosis (hybrid vigor) = being heterozygous carrier of a recessive gene (with mutation) has protection from expressing the disease / disorder because the dominant gene masks the recessive.

Take home message: Better to mate with those that are genetically very different from you. Offspring healthier.

58

REVIEW OF CONCEPTS

WHY SEX?

59

REVIEW OF CONCEPTS: WHY SEX?

Disadvantages:

- 1) Recombination destroys adaptive combinations of genes
- 2) Has the "**Two-fold Cost of Sex**" (slow process w/fewer offspring)
- 3) Only 50% genes inherited from each parent
- 4) males & females must find each other to reproduce.
- 5) Egg usually stays put (in female) while sperm must move, find, and compete for egg entrance.
- 6) involves "*being at right place, right time*" - evolution of reproductive cycles.
- 7) brings in complication of **competition** for access to mates.
- 8) brings in complication of "**female choice**" into mating (females are choosy when selecting mate)
- 9) imbalance in cost of sex between males & females
 - females produce fewer eggs than males produce sperm
 - human females lose eggs as they go from fetus, birth, puberty ("**atresia**")
10. This imbalance in cost of sex between males and females leads to "**different agendas for females and males**". [often these strategies conflict w/each other]
- 11) the Y-chromosome is shrinking!

60

REVIEW OF CONCEPTS: WHY SEX?

Advantages

- increased genetic variation
 - Offspring exploit new niches/adapt to environment – **Tangled Bank Hypothesis**
 - Resistance to parasites/pathogens - **Red Queen Hypothesis**
 - Reduced expression of recessive, possibly dangerous traits (**DNA Repair Hypothesis** and “**hybrid vigor**)

61

REVIEW OF CONCEPTS: WHY SEX?

**If not for changing environments, parasites
& disease, and dangerous mutations**

We might not have sex at all!

62