

## Evolution of Sex, Part 2.

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## 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](#)

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• Two Main Types of Reproduction

1. **Sexual Reproduction** = \_\_\_\_\_

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

2. **Asexual reproduction** = \_\_\_\_\_

- \_\_\_\_\_
- Ex. Bacteria, fungi, plants!

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• Two Main Types of Reproduction

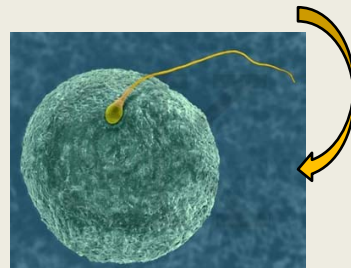
1. **Sexual Reproduction**

- refers to union (**syngamy**) – a review term.
- occurs through exchange of **gametes** = \_\_\_\_\_
  - 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:

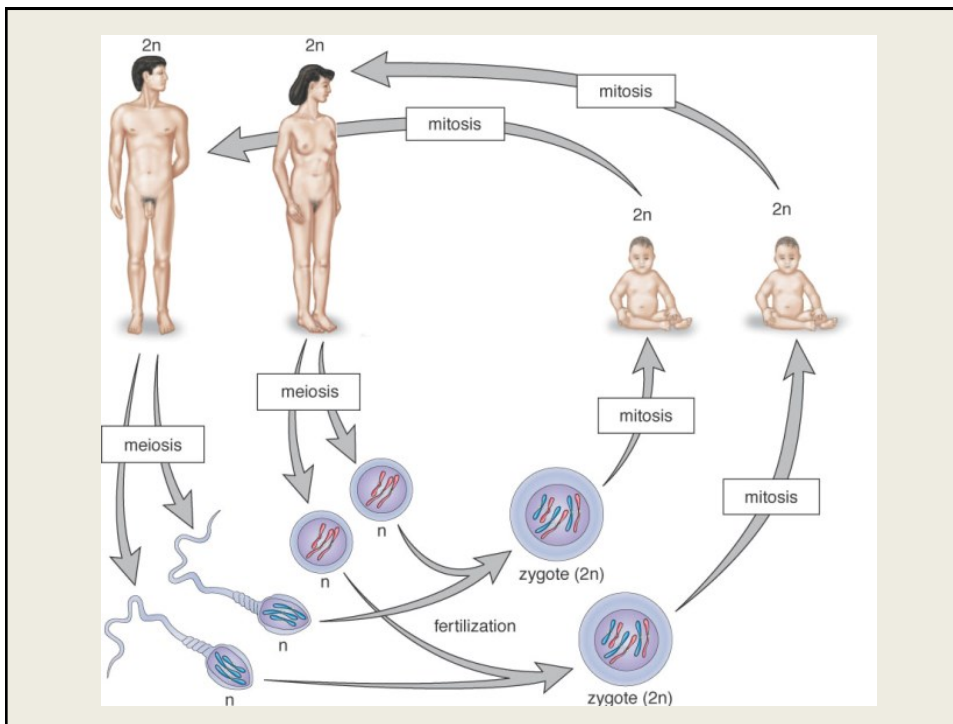
- - **isogamy** =

- - **anisogamy** =



*Anisogamy in human egg and sperm*

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## • 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** =
  
  - B) **hermaphroditic** =

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**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** =

**ii. Sequential hermaphrodite** =

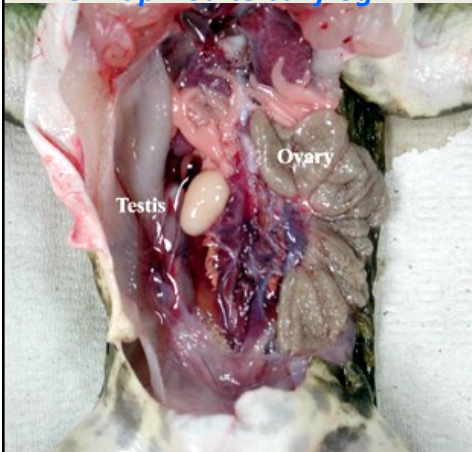
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### **Accidental Simultaneous Hermaphrodites**

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

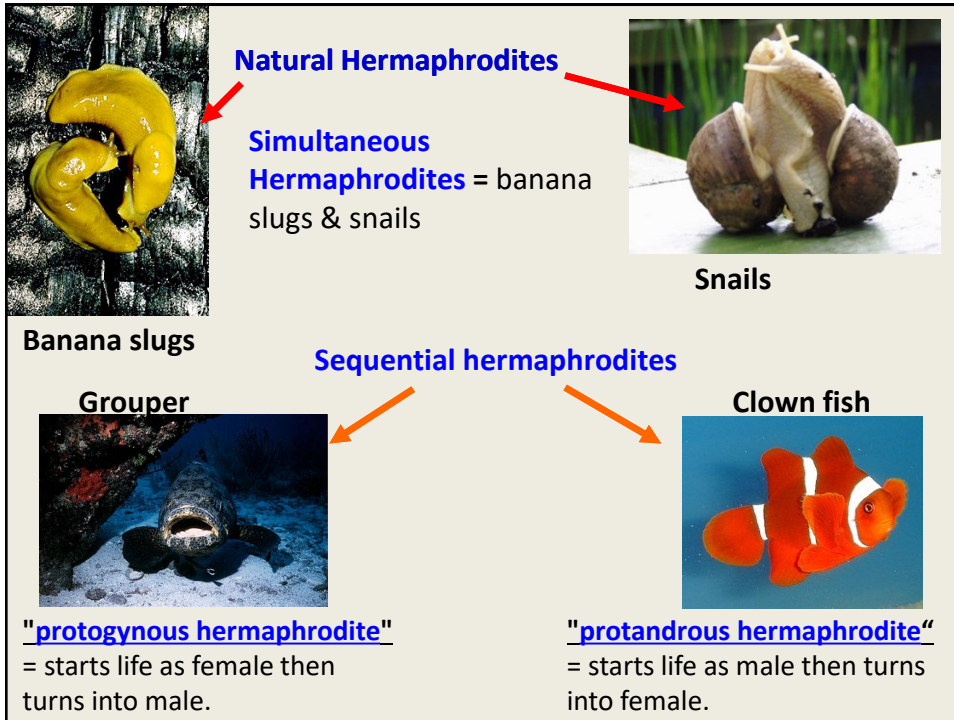
***Hermaphrodite bullfrog***



***Hermaphrodite cardinal***



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### 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:

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



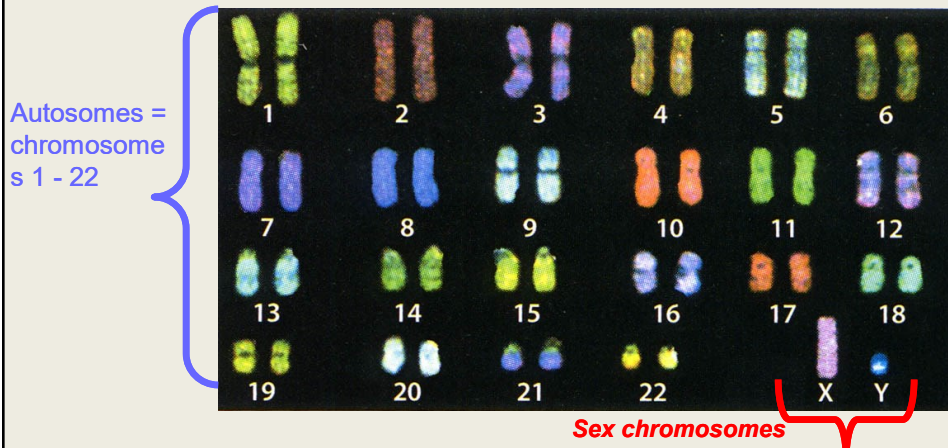
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## Sex determination in humans

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

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

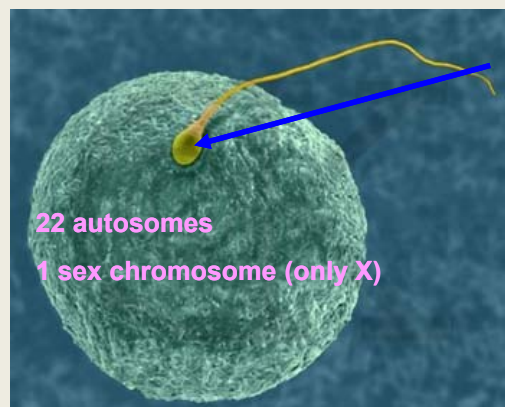
**1 pair sex chromosomes** (XX or XY) - carry genetic info. for sex only



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## Sex determination in humans

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



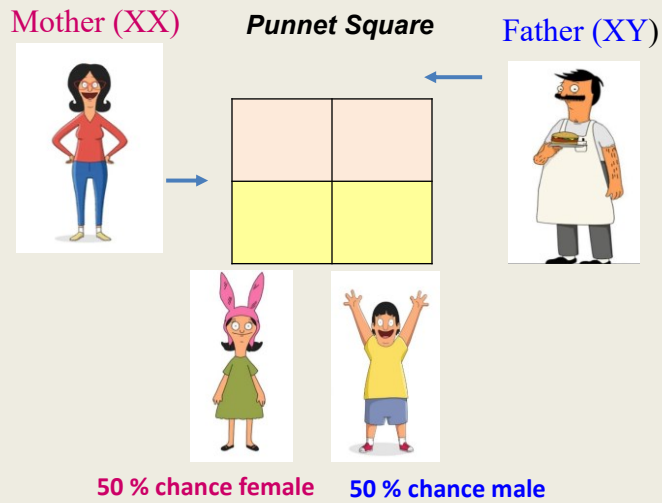
22 autosomes  
1 sex chromosome  
(either X or Y)

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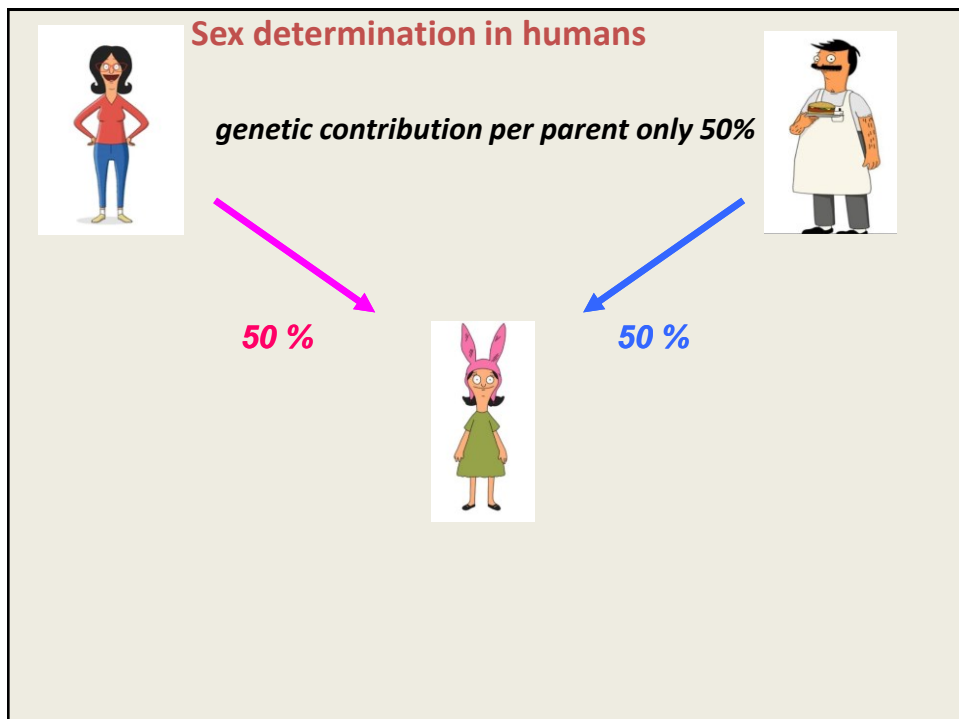
## Sex determination in humans

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:



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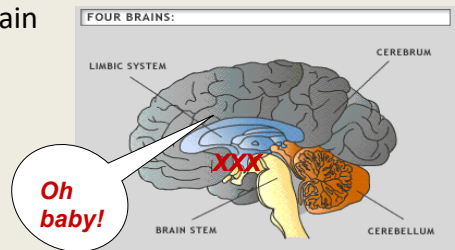
## Sexual Reproduction

- 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.
  - 2.
  - 3.
  - 4.



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## 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](http://people.fmarion.edu/tbarbeau/CNN_Faking_Orgasms_Brain.pdf)

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## 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).

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## 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.

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## 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)

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### 1) Asexual reproduction

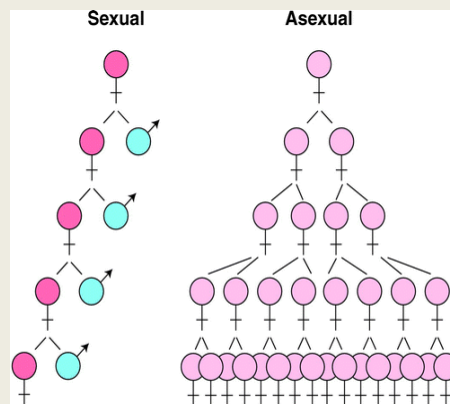
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2) "cost of males" = \_\_\_\_\_

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**R** Milinski M. 2006.  
Annu. Rev. Ecol. Evol. Syst. 37:159–86

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## Asexual Reproduction - Advantages

**Darwin's Question??**

– **WHY** don't more organisms have asexual reproduction?

**Answer**

many organisms do just that!

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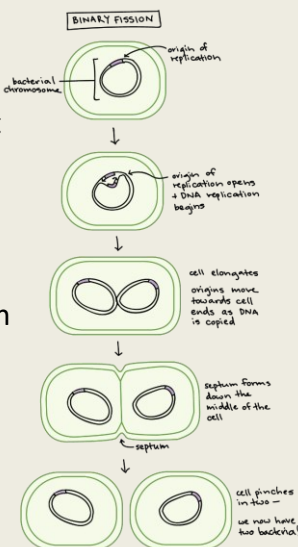
## Types of Asexual Reproduction

**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

\_\_\_\_\_



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## Types of Asexual Reproduction

### *More Cloning -*

#### **Ex. C)** \_\_\_\_\_

= 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.

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#### **Ex. D) Human clones?**



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## Ex. D) Human clones?



**We already have them! They're called:**

Mary Kate and Ashley Olsen

\_\_\_\_\_ = 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.)

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

### TECHNOLOGY A Noah's Ark of Cloned Animals

[PREV](#)

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.

[PREV](#)

3 of 7

[NEXT](#)



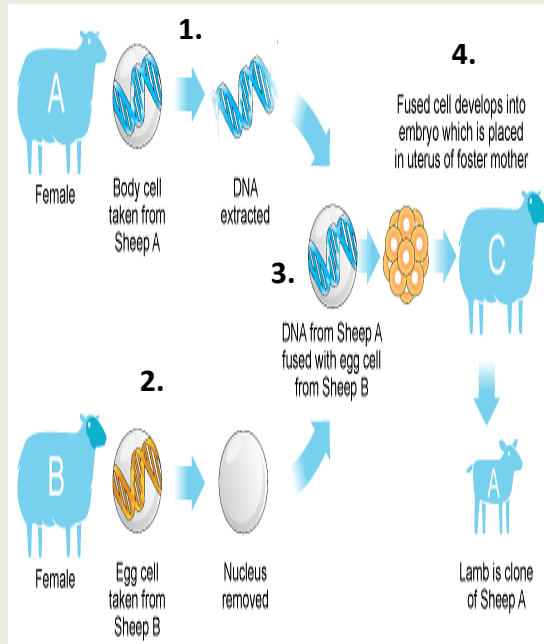
Dolly and friend at the Roslin Institute in Scotland.  
(Photo: Roslin Institute)

[August 8, 2005](#)

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## 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.



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## Other cloned animals

**TECHNOLOGY**  
**A Noah's Ark of Cloned Animals**

5 of 7

Born July 5, 1998 at the Ishikawa Prefectural Center for Animal Husbandry and Research in Japan, the calves were the first twins ever cloned from somatic cells taken from an adult cow. The twins were named "Noto" (back) and "Kaga." In 2000 one of the calves, Kaga, gave birth to a calf conceived by artificial insemination at the center.

Cloned twin calves at the Ishikawa Prefectural Center for Animal Husbandry and Research  
(Photo: London) August 8, 2005

**2nd cloned mammal = Noto and Kaga the cows**



**3rd cloned mammal = Rhesus monkey**

**TECHNOLOGY**  
**A Noah's Ark of Cloned Animals**

2 of 7

The world's first cloned kitten, CC, was born Dec. 22, 2001, at the College of Veterinary Medicine, Texas A&M University. The announcement of the first successful cat cloning was delayed until the agricultural commodity is not viable and its immune system was fully developed.

Genetic Savings & Clone, a Houston, Calif.-based firm has led the way in commercial cat cloning, generating more than 100 per month and has any company or individual that has cloned a cat will be able to purchase a cat at \$50,000 a piece.

The Rhesus monkey cat offspring from all seven monkeys (Photo: Courtesy of the College of Veterinary Medicine, Texas A&M University) August 8, 2005

**4th cloned mammal = "CC" the cat**

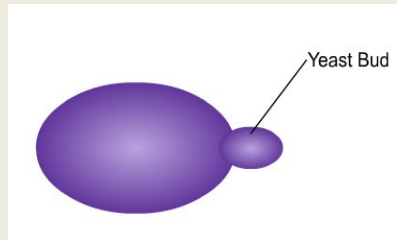
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## Types of Asexual Reproduction – contin...

### 1. Cloning

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

Ex. Yeast



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## 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

**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

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## Types of Asexual Reproduction – contin...

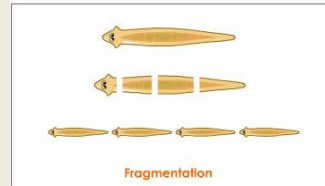
**4. Fragmentation** = when part of organism breaks off, the broken piece can become a whole new organism.

*Ex: Sea sponges and Flatworms*

### Sea sponge



### Planaria (a flatworm)



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



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## 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!

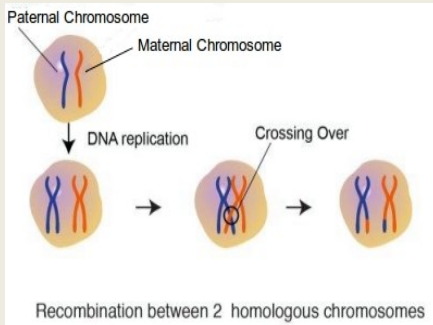
#### Disadvantages

- 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**"

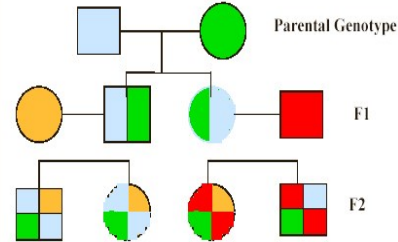
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## Sexual Reproduction - Disadvantages

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.



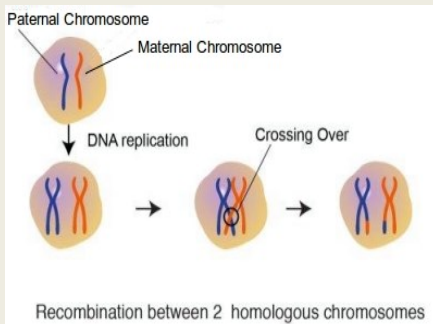
**Evolutionary Disadvantage of Sexual Reproduction**  
(ancestral genome halved with each successive generation)



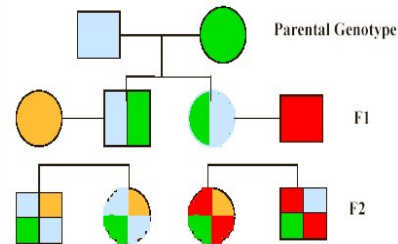
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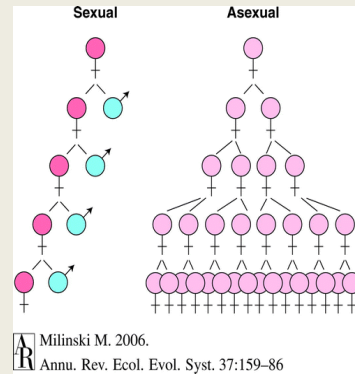
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## Sexual Reproduction - Disadvantages

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)



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

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## 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.

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## 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.

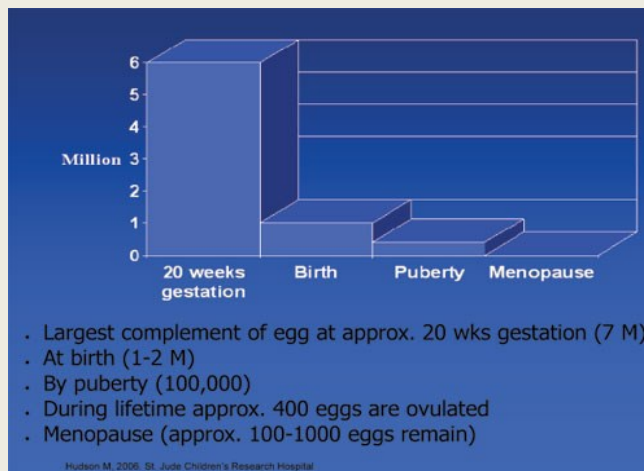


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## Sexual Reproduction - Disadvantages

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 (this is called "**atresia**")
- Sexually producing females don't have same reproductive capacity as males.



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## 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]

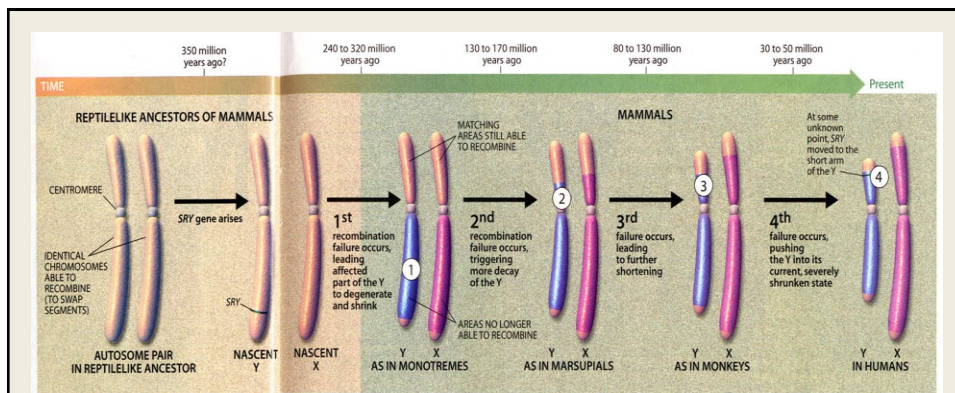
11) the Y-chromosome is shrinking!

- 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.

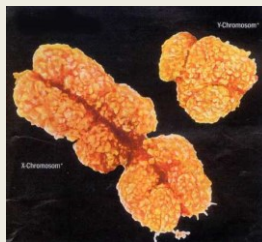
See reading assignments: **“Why Sex?”**, **“Why the Y?”**, **“The Trouble With Sex”**, & **“Rediscovering Biology” Pgs 1 - 4**

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**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

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### 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!

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## Sexual Reproduction

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

**WHY SEX?**

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

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## Sexual Reproduction - Advantages

### 3 Hypotheses for why sex exists and persists

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## Sexual Reproduction - Advantages

### 3 Hypotheses:

1. \_\_\_\_\_
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)

### Forest Floor Diorama



*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.

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## Sexual Reproduction - Advantages

2. \_\_\_\_\_ (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.*

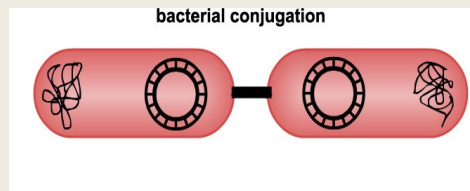


We are running to stay one step ahead of parasites & pathogens. We do this through sexual reproduction, which ↑ genetic variation in offspring to help do this.

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## 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.

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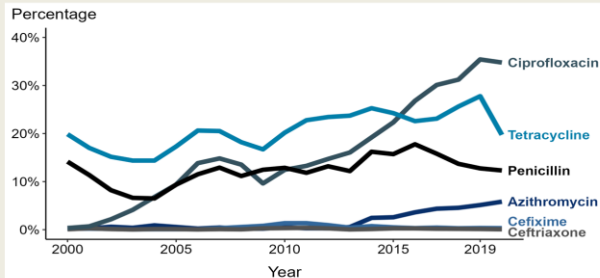
## Sexual Reproduction - Advantages

### 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  $\geq 0.25$   $\mu\text{g}/\text{mL}$

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## 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 =**

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

*Eventually immune system suppressed and develop*

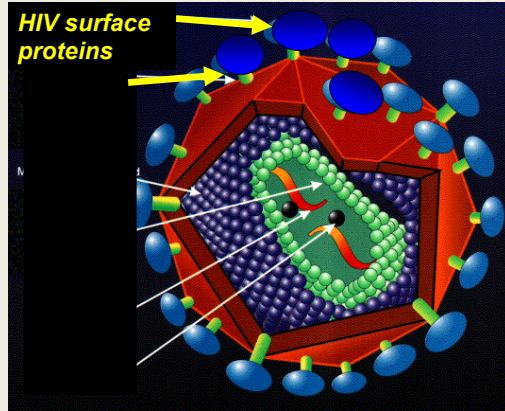
**AIDS =** \_\_\_\_\_

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## Sexual Reproduction - Advantages

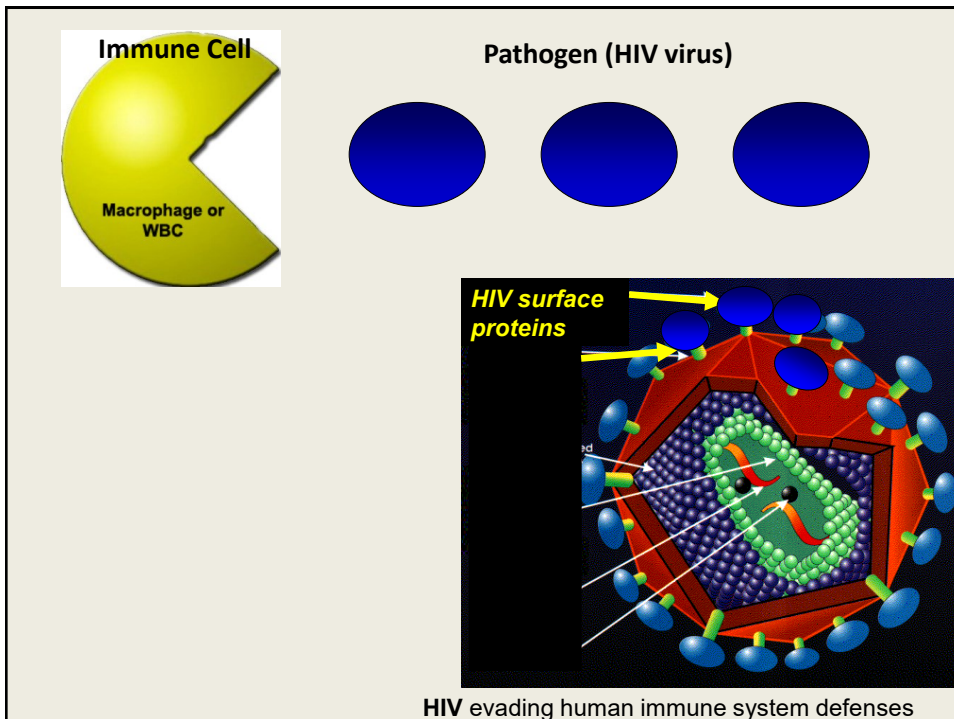
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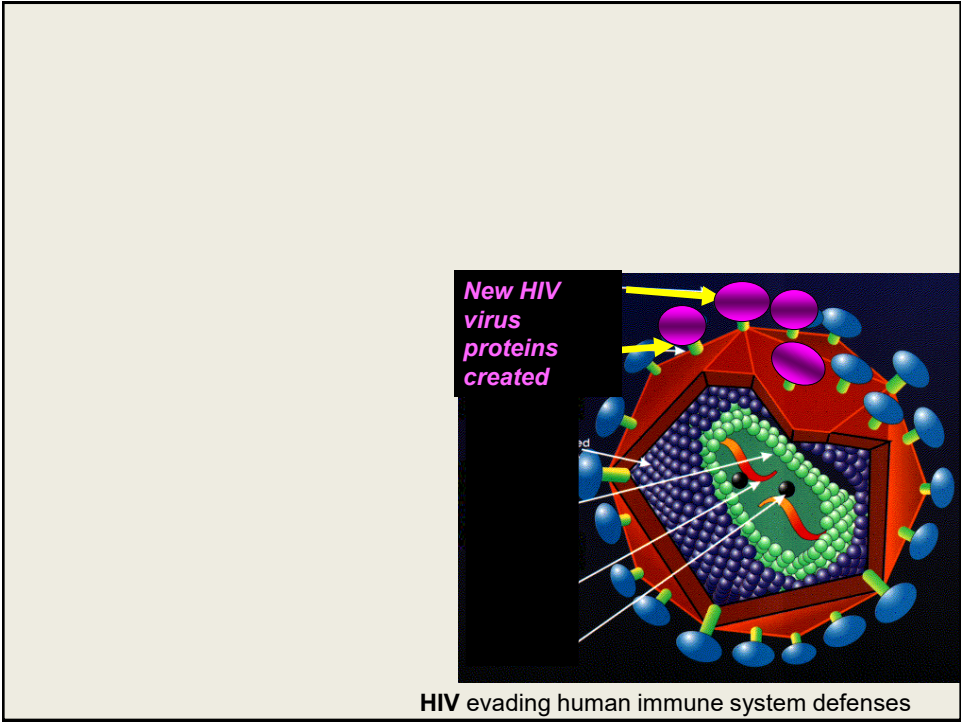


HIV evading human immune system defenses

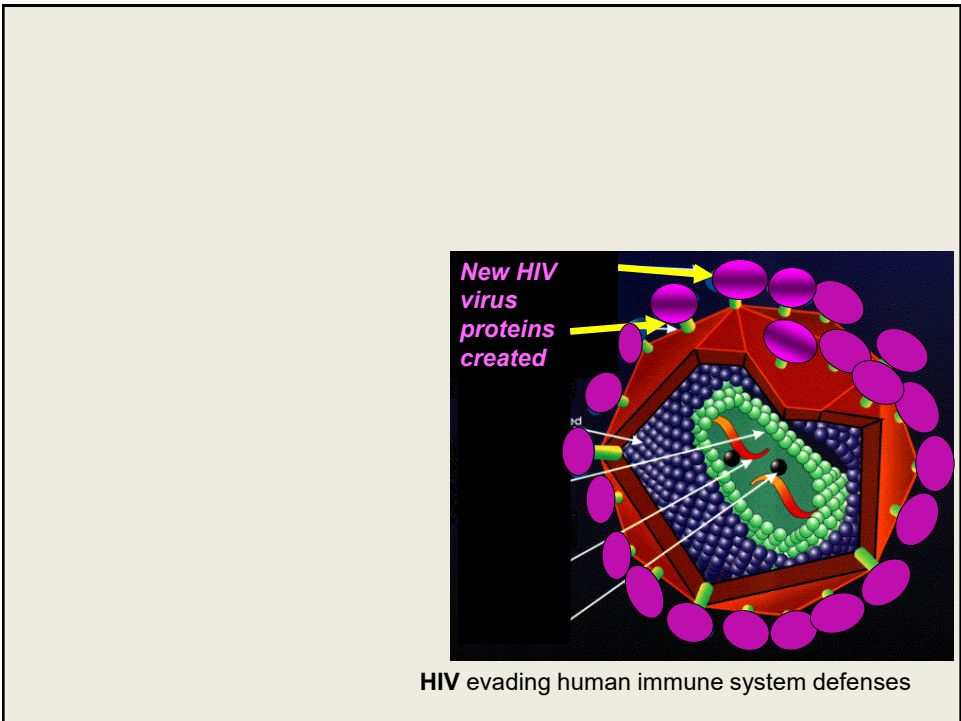
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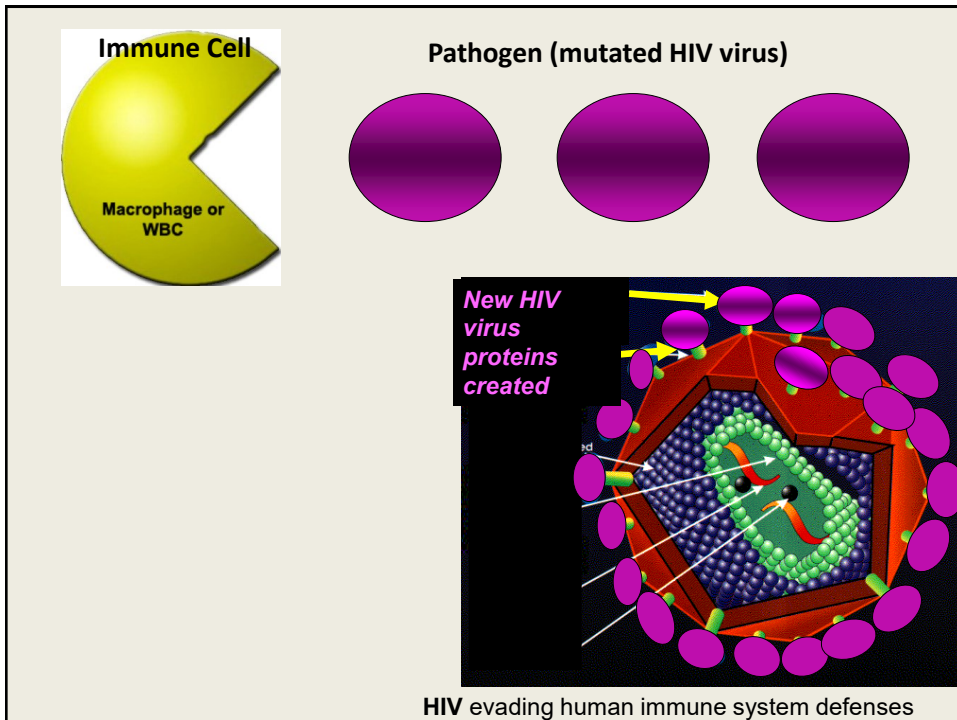
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## Sexual Reproduction - Advantages

3. \_\_\_\_\_ (“Muller’s Ratchet”) = Sexual reproduction between parents having different DNA produces unique offspring with genetic variation that reduces the bad effects of mutations (recessive diseases & disorders). It produces “Hybrid vigor”

*Asexual reproduction produces offspring that are genetic clones of parent(s) – LOW GENETIC DIVERSITY makes these organisms vulnerable to buildup of genetic mutations known as “\_\_\_\_\_”,*

*This then leads to accumulate so many disorders & diseases that species goes extinct = \_\_\_\_\_*

**WHY do most human societies have an “incest taboo” (discourage inbreeding within closely related individuals)?**

**ANSWER:**

**To avoid “inbreeding depression” = buildup of harmful recessive traits that can lead to inbreeding depression and mutational meltdown.**

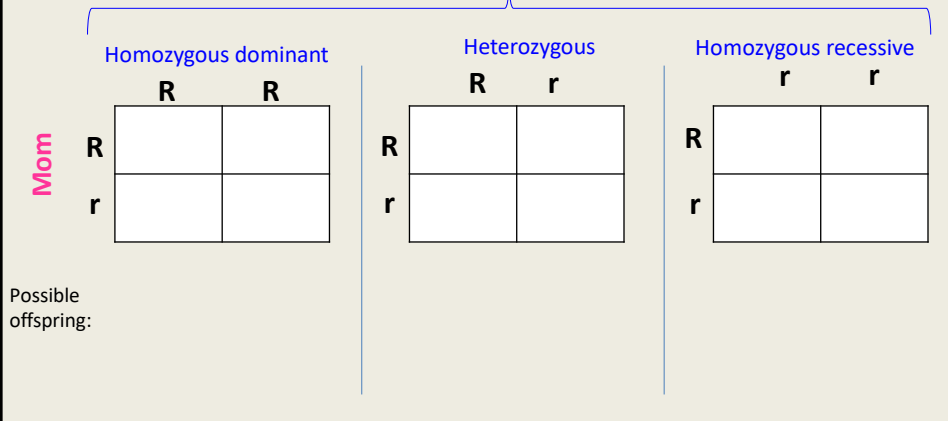
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**Autosomal recessive disorders** = recessive trait for a disorder/disease where offspring must inherit 2 copies (one from mom & dad) in order for it to be expressed.

**R** = normal gene (dominant)

**r** = recessive gene (with mutation for a disease)

**Possible Gene Contributions of Father:**

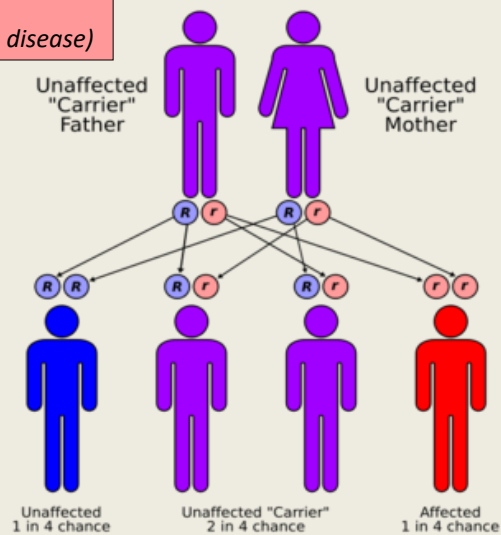


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**Examples of autosomal recessive disorders:**

**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.

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**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.**

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## REVIEW OF CONCEPTS

### WHY SEX?

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## 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!

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## 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**”)

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## REVIEW OF CONCEPTS: WHY SEX?

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

**We might not have sex at all!**

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