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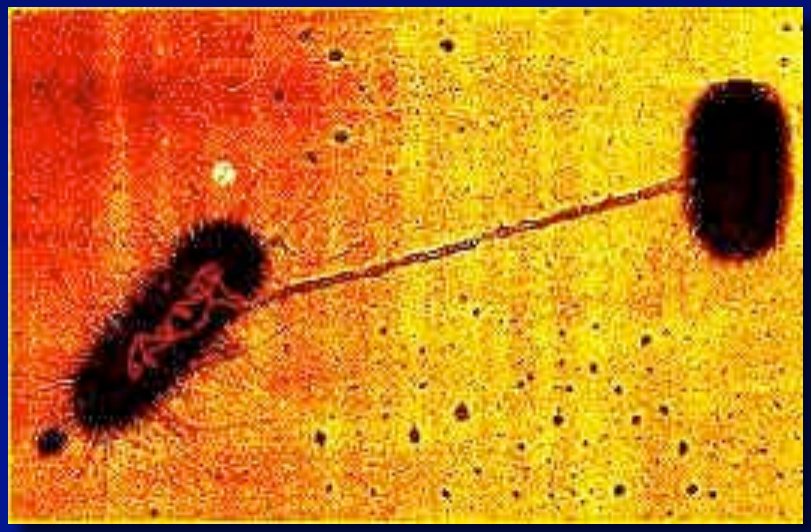
Evolution of Sex

No area of evolutionary biology offers … a more fascinating mixture of strange phenomena … than the evolution of sex…



(Stearns, 1987)

Sex

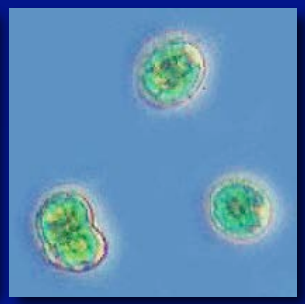
- Refers to union (SYNGAMY) of two genomes
  - usually carried by gametes
  - followed later by reduction (meiosis)
- Individuals need not have distinct sexes
  - defined as differences in size or structure of gamete

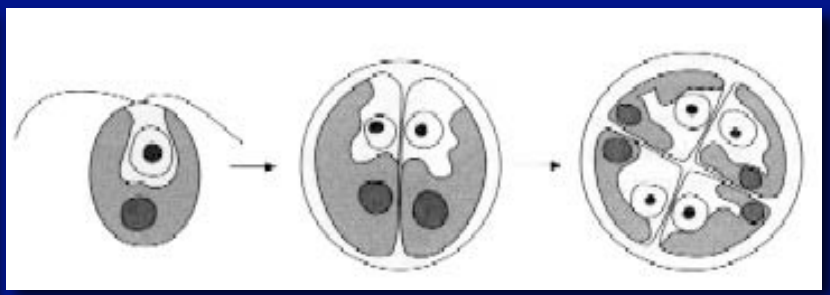
Sexual Dimorphism

- sexual dimorphism occurred late in evolution of life
  - major onset with the development of eukaryotes
  - feature of most vertebrates

Isogamous Organisms

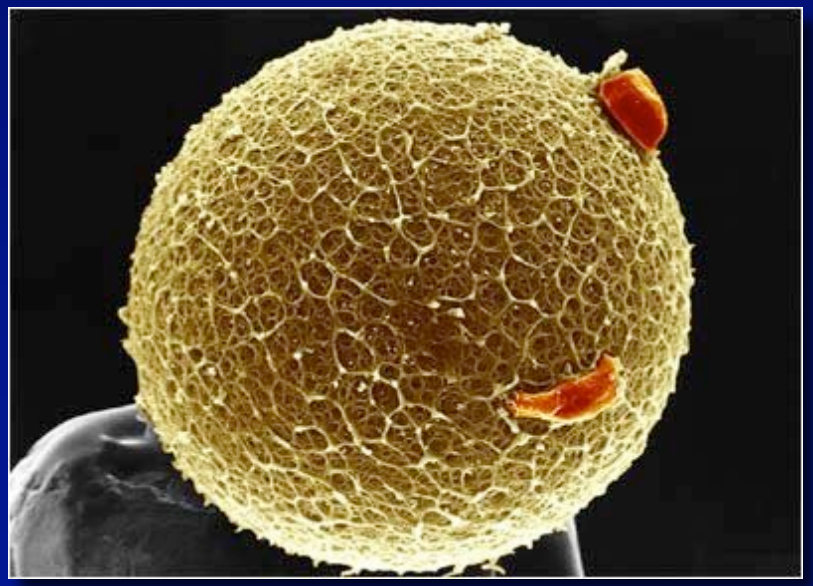
- Isogamous - gametes are not distinct in size or shape
  - Many fungi (yeasts)
  - Algae
- Same size gametes unite if different mating type (+ or -)





Anisogamous Organisms

- Anisogamous - large (egg) and small (sperm) gametes
  - GONOCHORISTIC - individual can only be male or female
  - HERMAPHRODITIC - individual can be male and female
    - sequential
    - simultaneous



Gonochoristic

- Sexual phenotype is determined early in the life history of these animals
- Once established it persists throughout adult life
- Most common pattern of sex allocation

Sequential hermaphroditism

- producing both male or female gametes sequentially
  - not at same time
- Undergo sex reversal
  - -Protoandry: male first
  - -Protogyny: female first
- East Asian swamp eel
  - Presently invading Florida wetlands (protogyny)
  - Also observed in hagfish, reef fishes

Simultaneously hermaphroditic

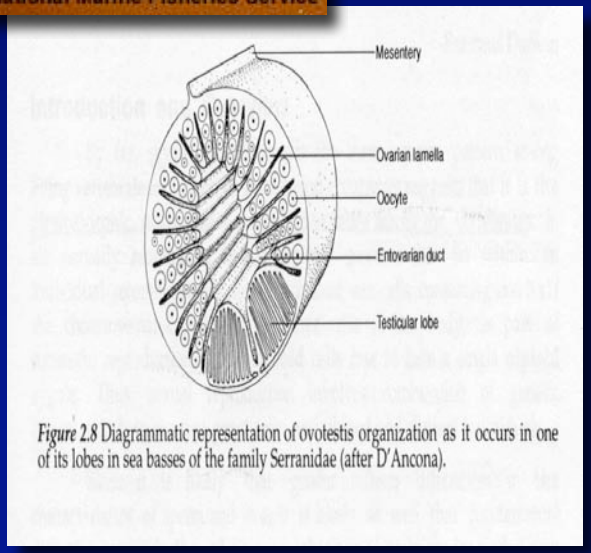


Figure 2.8 Diagrammatic representation of ovotestis organization as it occurs in one of its lobes in sea basses of the family Serranidae (after D'Ancona).

- Simultaneously male and female
  - Not common
- Possess an *ovotestis* containing oogenic and spermatogenic tissue
- Most are not self fertilizing
- -2x the chance of meeting a potential mate
  - important in low density populations

Acquired 'hermaphroditism'

- Deep sea ceratioid angler fish
- Male fish fuses body with female fish
- - shares blood supply and all his organs degenerate (except male reproductive organs)

Two parts to the evolution of sex

- 1) the origin of sexual reproduction (cellular evolution)
- 2) the evolution and maintenance of sexual reproduction and recombination

- Recombination is like sex in that it reassorts genetic material

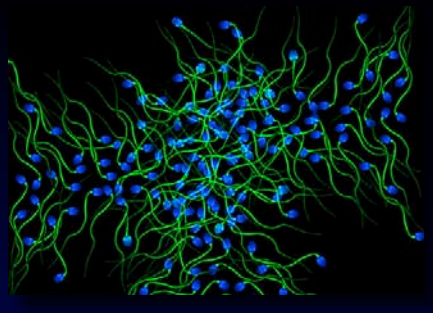
Advantages with Sex

- Recombination increases rate of adaptive evolution
  - Does sex increase the rate of evolution?
  - Does this explain the origin versus persistence of sex?

Problems with Sex

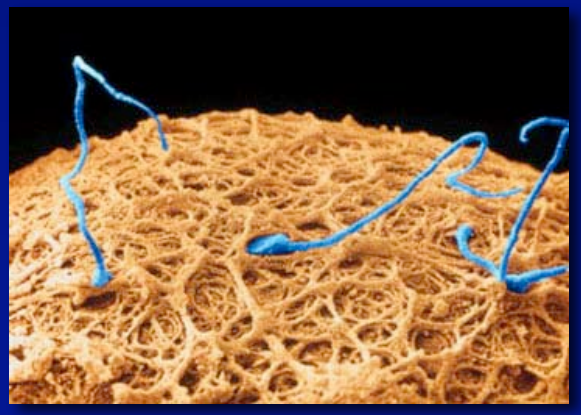
- Even if rate of evolution increased - two problems
  - 1) Recombination destroys adaptive combinations of genes
  - 2) cost of sex
    - Half of the offspring are males!
    - "cost of males"

Cost of Anisogamy

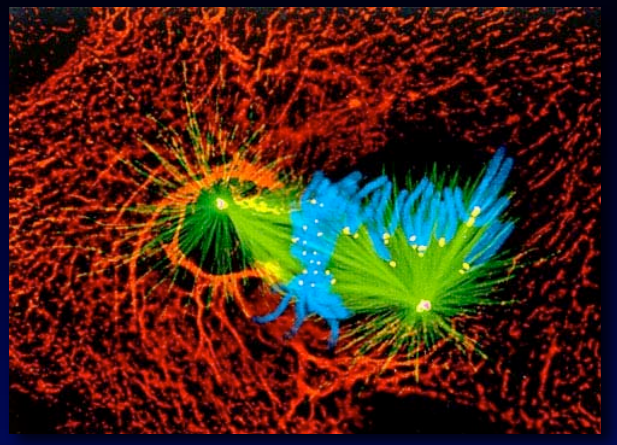


- Male contributes only the genome of the sperm
- Female ovum provides
  - Nuclear genes
  - Mitochondrial genes
  - Cellular environment necessary for embryonic development

Females invest more energy per viable gamete than males



Cost of meiosis



- Loss of genetic information
- Gametes contain $\frac{1}{2}$ of the parental genotype
  - Clonally reproducing form passes 100% of its genetic material on to offspring
  - Sexually reproducing form must produce 2 fit offspring to pass on the same amount of genetic material to the next generation

Cost of genetic recombination

- Genetic recombination dismantles two successful genotypes and recombines them into a novel combination in the next generation
- Adaptive allele combinations may be lost
- Recombined genome may not be as successful
  - May contain deleterious recessive alleles

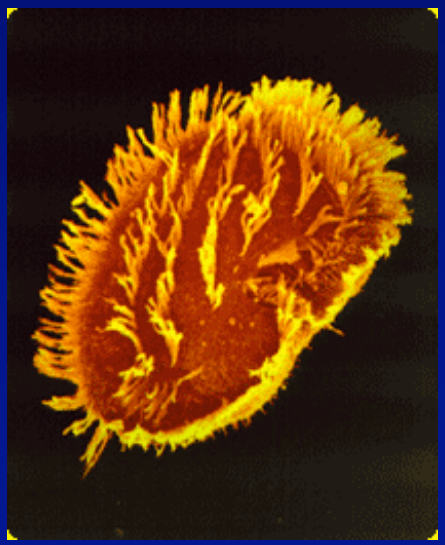
Cost of mating

- Energetic costs of mating are associated with sexual dimorphisms and mating behaviors
- Increased risk of predation?




Immortality versus Mortality

- individual protozoans are potentially immortal
- multicellularity has a heavy price - individuals become mortal



Sex Must Be An Advantage

- Sexual reproduction persists in many, many populations
- Must be great enough to offset 2X disadvantage

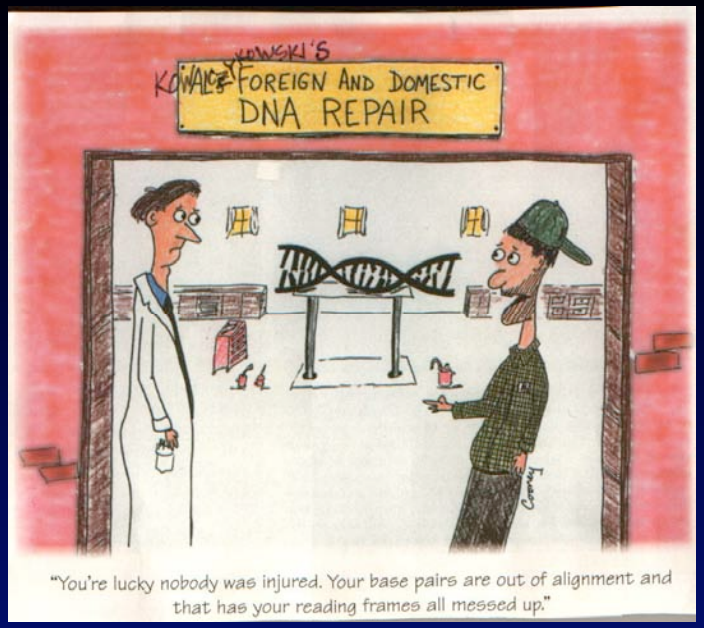
Sexual Reproduction

- 1: can bring together beneficial mutations
  - aids in the spread of advantageous traits
- 2: can bring together deleterious mutations
  - severely unfit individuals eliminated
  - removal of deleterious genes
- 3: creates new gene combinations
  - maybe more fit than existing ones
  - or reduced competition among relatives.

Immediate Benefit Hypothesis

- Immediate benefit hypothesis
  - (Bernstein and Bernstein, 1991)
  - Molecular recombination facilitates DNA repair
    - Breaks/lesions in DNA molecule can be repaired by copying homologous chromosome
  - Formation of new gene combinations are a by-product of DNA repair
    - not reason for evolution of recombination/sex

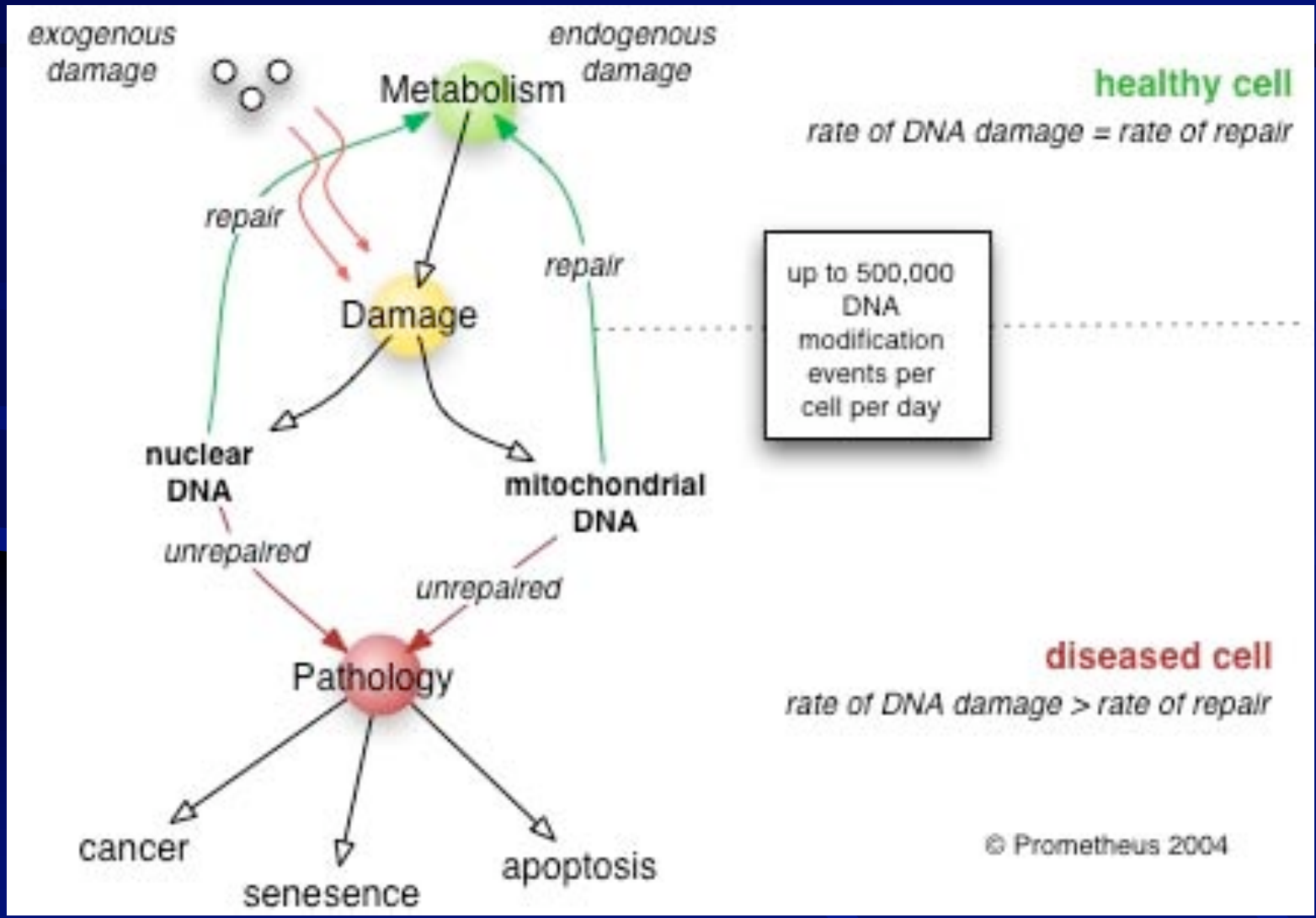
Problem?



"You're lucky nobody was injured. Your base pairs are out of alignment and that has your reading frames all messed up."

- DNA repair does not require meiosis or syngamy (fertilization)
- Permanent diploid species exist - thus can repair DNA without the above
- Origin of recombination could have been a response driven by need for DNA repair
  - but what about meiosis & syngamy?

DNA Repair


exogenous damage
endogenous damage
Metabolism
healthy cell
rate of DNA damage = rate of repair
repair
repair
Damage
up to 500,000 DNA modification events per cell per day
nuclear DNA
mitochondrial DNA
unrepaired
unrepaired
Pathology
diseased cell
rate of DNA damage > rate of repair
cancer
senesence
apoptosis
© Prometheus 2004

Why Sex?

- The Red Queen Theory
  - "It takes all the running you can do, to keep in the same place." Red Queen - *'Alice in Wonderland'*
- Parasite-host interactions
  - Sexual reproduction persists because it enables species to rapidly evolve new genetic defenses against parasites
    - Guppy and snail species exhibit sexual reproduction when higher level of parasitism
      - (Dybdahl and Lively 1995; Howard and Lively 1994).

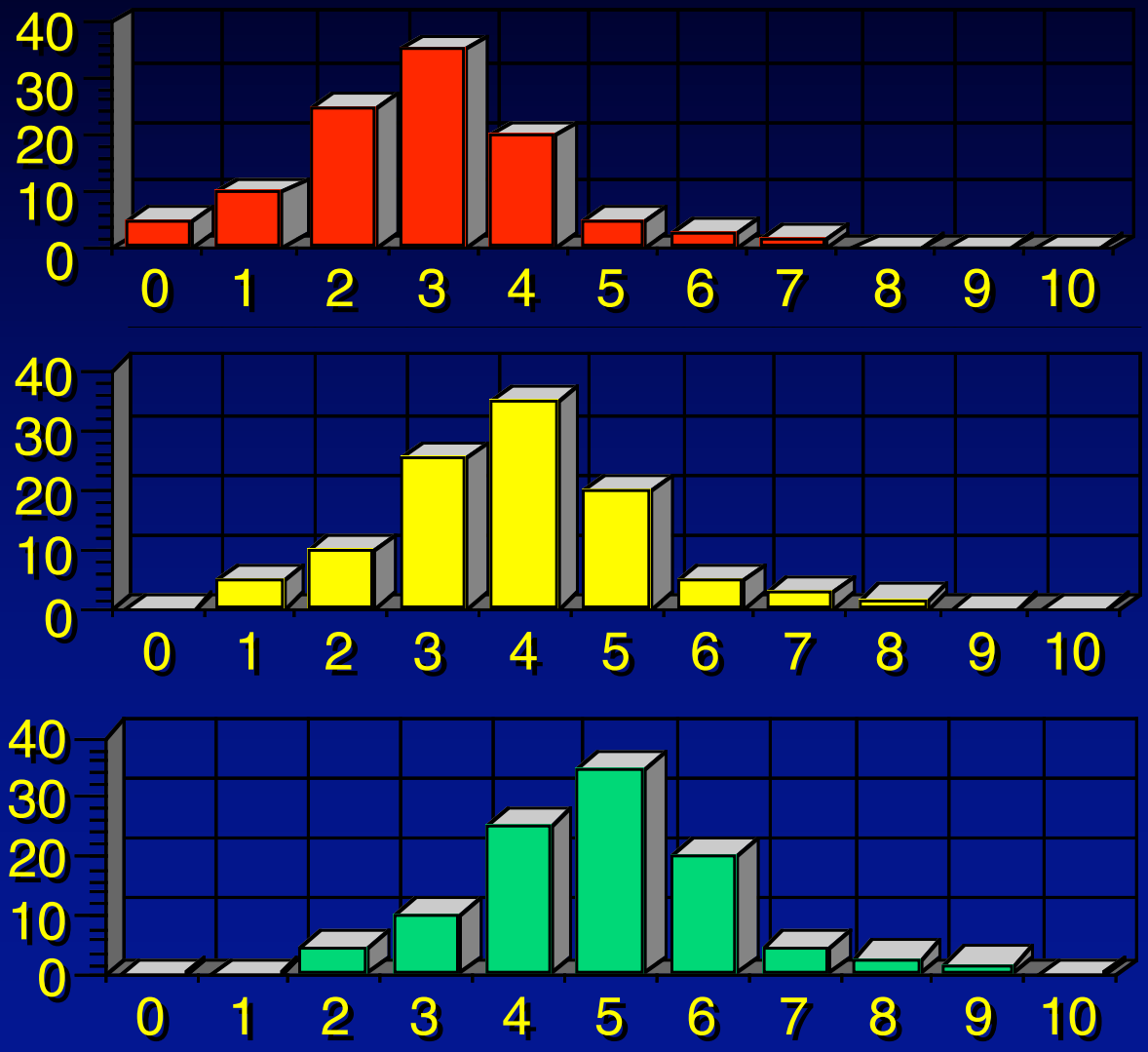
Additional Hypotheses

- Many
  - Fixation of rare beneficial mutations
  - Heterogeneous habitats
  - Deleterious mutations removed
    - Muller's ratchet

Muller's Ratchet

- Herman Muller (1964)
  - Nobel Prize for mutagenic effects of radiation
- Back mutation from deleterious to wild-type alleles is extremely rare
  - In asexual population mutations accumulate over time
  - Can't be removed
  - Zero mutation genomes become rare, then extinct

Muller's Ratchet



- Frequency of asexual individuals with different numbers of mutations at three time periods.

Evolution of Sexes

- Anisogamy evolved from isogamy
  - evolution of large versus small gametes

- If:
  - Large size enhances survival of offspring
    - Movement difficult
  - Selection for 'transport' of second gamete

Sex vs. Gender

Sex: either of the two major forms of individuals that occur in many species and that are distinguished respectively as female or male

- based on type of gonad/gamete produced

Gender: the behavioral, cultural, or psychological traits typically associated with one sex

Merriam-Webster online

Evolution of Gender

- Anisogamy gives rise to different mating types
  - (+ / -) (female/male)
- Recognition of opposite type has advantages
  - chemical (pheromones)
  - visual signals
    - secondary sex characters
      - coloration, horns, behavioral display