

Animal reproduction

Reproduction is the most important thing any organism does:

- no reproduction = no fitness
- **very strong selection** to maximize reproductive success - have as many offspring as possible; more precisely, **make as many copies of your DNA as possible.**
- every aspect of biology is simply a means towards achieving successful reproduction:

“Animals, including humans, are just big lumbering robots that our DNA uses to make copies of itself.” -- Richard Dawkins

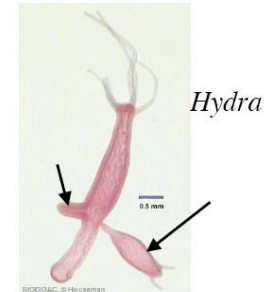
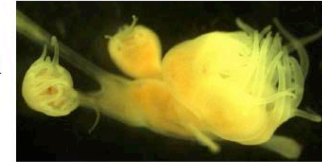
But there are many different ways to get the most reproductive success!

Animal reproduction

How to reproduce?

budding:

Moon jellyfish
Aurelia



fission (division)
or fragmentation:

Asexual

Anthopleura
Sea anemone



Animal reproduction

How to reproduce?

via gametes (eggs, sperm):

- requires haploid life stage
- requires complex developmental process
- **permits sexual reproduction**

Why are most animals sexual?

- An interesting question, because **sex has a large fitness cost:** you ‘throw away’ half of your DNA when you make a haploid gamete by meiosis: your offspring’s DNA is only 50% yours. **But you use all of your DNA if you make a diploid offspring by mitosis** -- your offspring’s DNA is 100% yours!

Animal reproduction

Sexual species **CAN** evolve loss of sex and become **parthenogenic:** females only, like these whiptail lizards.

Recently evolved:

- **Still undergoes meiosis**, but haploid egg undergoes ‘doubling’ to form diploid ‘zygote’.
- **Still has mating behavior**, although no gametes are transferred.



Each individual alternates between “male” and “female” behavior, according to hormonal cycles.

Other species are **partially** parthenogenic: in bees, ants, and wasps, females are made sexually (sperm and eggs), but males are made by parthenogenesis (unfertilized eggs become males)

Animal reproduction

Why are most animals sexual?

➡ Sex is useful because it **increases the genetic diversity of offspring, which permits more rapid evolutionary change**. GOOD if the environment changes -- including predators, competitors, parasites, etc.

➡ If your 'opponent' is sexual and you're not, the opponent can 'out-evolve' you, and you will be in big trouble quickly.

Animal reproduction

These are important issues because **reproduction is costly** to animals, in two ways:

Cost 1: Energy and materials that need to be used to make offspring, instead of growth. A **trade-off:** more reproduction = less growth.

➡ A potential cost to **future** reproduction because in most animals, you can make more babies if you're bigger. So:

no reproduction **now** = more growth = more **future** reproduction

Animal reproduction

No matter how an animal reproduces, there are several important 'decisions':

- **When** and **how often** should it reproduce?
 - > begin reproduction early or late in life?
 - > reproduce once during the life cycle (*uniparous*) or many times (*iteroparous*)?
- **How many babies** should it have?
- **How much resources should be invested** in each baby?
- If sexual, **who to mate with?**

Animal reproduction

These are important issues because **reproduction is costly** to animals, in two ways:

Cost 1: Energy and materials that need to be used to make offspring, instead of growth. A **trade-off:** more reproduction = less growth.

To reproduce, animals need to gain the necessary energy and materials; many ways to do this:

- **Income** breeders 'pay' for reproduction while it is occurring (like us).
- **Capital** breeders store up the energy and materials **before** reproduction starts.

Animal reproduction

Cost 2: Reproduction is **dangerous** -- it tends to cause increased risk of death and injury and reduced survival for parents.

- Less resources to heal wounds, resist disease.
- Decreased mobility (easier for predators to catch you).
- ‘Wear and tear’ on the body.
- In some species, fighting to obtain mates.

Reproducing **now** means an animal is **less likely to be able to reproduce in the future** -- a **trade-off** of present versus future reproduction.

EXAMPLE: death risk of reproduction in humans

Surviving pregnancy is no guarantee of successful reproduction:

- Currently about 0.7% of US babies die within a year or two of birth (that is twice as high as in some countries).
- Worldwide infant mortality rates are presently around 8% on average and in underdeveloped nations they can reach 15-20%.
- Infant mortality in prehistoric human populations is unknown but probably 20-50%.

These numbers don't include other childhood deaths before kids reach reproductive age.

EXAMPLE: death risk of reproduction in humans

In the US, childbearing is very safe: less than 1 in 10,000 pregnancies results in maternal death. **This is unusual:**

- In 1900, pregnancy deaths were 100X higher in the US.
- In undeveloped countries, up to 2% of pregnancies (1 in 50) result in maternal death.
- **Lifetime** risk of pregnancy-related death is as high as 7 to 10% in some African countries.
- Pregnancy death rates are 2-5X higher for women 10-19 than for women in their 20s; about 3-4 times higher for twins or triplets than for single births.

This is for *normal* complications of pregnancy -- doesn't include additional predation, etc. for early humans.

Animal reproduction

So, reproduction is costly and requires compromises.

When and how often to reproduce?

- Animals that have **short life expectancies** (high predation, don't survive winter, etc.) are selected to
 - **reproduce early in life** (may not get another chance)
 - **invest heavily in offspring** (no sense saving energy if you're not likely to reproduce again)
 - many species are **uniparous**: -- **one** reproductive event in their lives ('big-bang' reproduction) -- most die immediately after reproducing -- put **all available resources into offspring**

Animal reproduction

So, reproduction is costly and requires compromises.

When and how often to reproduce?

- Animals that have **long life expectancies** are selected to
 - **reproduce late in life** (growth instead of reproduction when young; few babies early = more babies late in life)
 - **invest modestly in offspring** (save energy and lower risks to make sure you survive to reproduce later)
 - these species are **iteroparous**: -- many reproductive events in their lives

Animal reproduction

So, reproduction is costly and requires compromises.

How much to invest in each offspring?

Because animals don't have unlimited resources for reproduction, there is a '**trade-off**' between **number** and **quality** of offspring. They can make:

- **large numbers of small, cheap, low-quality offspring**
- **small numbers of large, expensive, high-quality offspring**

or some intermediate compromise

Animal reproduction

Examples of uniparous animals:

- most insects and spiders
- squids and octopuses
- Pacific salmon
- Antechinus* (marsupial)

Examples of long-lived iteroparous species:

- sharks
- turtles
- Large birds
- elephants
- primates

Animal reproduction

So, reproduction is costly and requires compromises.

How much to invest in each offspring?

This depends a lot on how well offspring of different sizes can survive.

If small offspring can survive, then parents may benefit from making many small babies.

- Many species have small larval forms (i.e., different morphology and ecology than adults)
- Also works if 'miniature adults' are viable

Animal reproduction

Example of species that make large numbers of small offspring:

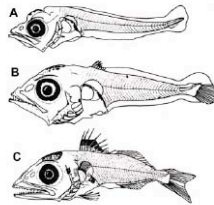
Bluefin tuna adult: 2.5 meters long, up to 600 kg (1,300 pounds)



Lays several million eggs each year

Eggs are about 3 mm in diameter and weigh about 0.03 g -- mother is about 20 million times bigger than each baby

Various stages of tuna larvae



Animal reproduction

So, reproduction is costly and requires compromises.

How much to invest in each offspring?

If offspring cannot survive unless they are large, then selection will favor parents that make a small number of large, capable offspring.

- Big eggs, large babies, etc.
- **Parental care** in many species: all mammals, almost all birds, some fish, a few reptiles (like crocodiles), some invertebrates

Animal reproduction

If sexual, who should you mate with?

A very complicated question; start with a few basic principles:

1. **Individuals are selected to maximize their own reproductive success.**
2. **Females almost always can produce fewer offspring than males:**
 - each egg or sperm can produce an offspring
 - eggs are big, sperm are small, so males can produce more sperm than females can produce eggs
3. **What's best for one sex may not be what's best for the other sex**

Animal reproduction

If sexual, who should you mate with?

Since eggs are expensive and sperm are cheap, *if all the parents contribute to offspring is gametes*, then:

Female reproductive success is limited by how many offspring (eggs) they can make, and what their quality is.

Male reproductive success is limited by how many females they can fertilize.

SO:

- **Females** should be very selective about mates to ensure they get the best possible sperm.
- **Males** should compete with each other to try to mate with as many females as they can.

Animal reproduction

If sexual, who should you mate with?

Selectivity by one sex and competition within the other sex leads to **sexual selection**, and often **sexual dimorphism** (males and females don't look or act alike).

Two forms of sexual selection:

1. **Intrasexual:** one sex aggressively compete among themselves for access to the other sex (evolve combat attributes: size, weapons, armor). Usually, males compete for females.
2. **Epigamic:** one sex competes to be the most attractive to the other sex (evolve ornaments and displays). Again, usually males compete for females: **'female choice'**

Sexual selection

Under either form of sexual selection -- **intrasexual** or **epigamic** -- you get very different distribution of reproductive success among males and females:

- One sex (usually females) has modest **but relatively constant and reliable** reproductive success -- limited by the physiological capacity to make offspring.
- The other sex (usually males) has **highly variable** reproductive success dependant on *how good a competitor* each individual is:
 - **many** males have zero reproductive success
 - **a few** males have very high reproductive success

Sexual selection: Epigamic (female choice)

Why do bizarre male appearance and behavior evolve in a female choice system?

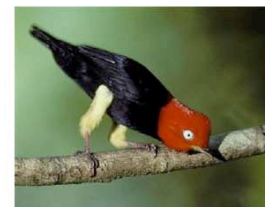
- Females only mate with the 'flashiest' males
- Why? By insisting that males exhibit costly, dangerous traits, females can 'test' that the male carries good genes.
→ **"handicap" model** -- males who survive *despite* carrying expensive traits **must** have good qualities.
- This choice improves **female** fitness (she has better offspring).

Sexual selection: variance in male success



Female elephant seals can expect to produce 1 baby/year for 10-15 years.

Most **male** elephant seals **never** mate, but a select few **successful** males can sire 50-100 pups per year.



In a group of 10 male manakins, 438 copulations occurred in one season.

- **One male had 75% of them (328)**
- 6 males mated a total of 10 times between them.

Animal reproduction

Should there be **parental care** after birth or hatching? If there is, who contributes care?

- Parental care will be favored by selection **if it increases the fitness of the parents**: parents have higher reproductive success if they contribute care than if they don't. This applies to both sexes independently.

➡ Another trade-off: either spend energy and materials on parental care, or spend it to produce **additional** offspring.

Animal reproduction: parental care

If parental care is necessary, it could be contributed by either sex, or by both sexes. What determines this?

- Each sex acts according to its own best interests.
- Males less likely to give parental care than females, but they will if it increases their fitness. Male parental care is common in species where offspring have very high requirements for care: especially birds.
- In a few species, males give **all** of the parental care: females provide eggs, males do the rest. Here, **female** success is limited by how many mates they have, so females compete among themselves for access to males.

➡ **Polyandry; sex role reversal**

Animal reproduction: parental care

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- Males in species with internal fertilization are under additional selection against parental care: they can't be totally confident they will be caring for their own offspring.
 - Females generally can be 100% sure they are the parent of their offspring.

Animal reproduction: sex role reversal

In seahorses, females lay eggs, but **males** become 'pregnant'. Males take eggs into a belly pouch, where they are nourished almost like in placental mammals. He carries them for weeks until they hatch.



Pregnant male

male with baby

Animal reproduction: mating systems

Animals have a wide range of **mating systems -- who mates with who --** within and between species.

Mating systems are affected by all of the factors mentioned previously:

- Life span and number of reproductive events
- Size and numbers of eggs or offspring
- Requirements for parental care
- Variation in reproductive success in the two sexes: competition, sexual selection, etc.

Animal reproduction: mating systems

Many species -- *including humans* -- use several mating systems:

- Less than half of human societies are monogamous (or serial monogamy). Polygyny is common. Polygynandry also occurs. One or two societies are at least partially polyandrous.
- Even in “monogamous” mating systems, *extra-pair copulations* are routine for both sexes.
 - In “monogamous” birds, about 10-30 % of babies are *not* fathered by the attending male. In one species, it's **60-70 %!**

Animal reproduction: mating systems

Standard mating system definition (in nature there is a continuum among these ‘categories’):

- **monogamy:** one male, one female in exclusive relationship. *Uncommon; most frequent in birds.*
- **polygyny:** one male mates with several females, who mate only with him. *Common in many animal taxa.*
- **polyandry:** one female mates with several males, who mate only with her. *Rarest mating system but widely distributed.*
- **polygynandry:** multiple mating by both sexes. *Commonest mating system.*

Animal reproduction: mating systems

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In “monogamous” human societies, a few DNA-based studies suggest that the fraction of children fathered outside the marriage pair bond is variable, from as low as 1-2% to as much as 10-20%.

- A fairly careful English study found that 4-5% of children were not offspring of the presumed father.
- In the US, surveys indicate that something like 30-60% of married men and women have had extramarital sex.

Alternative mating strategies

In many species where there is very strong sexual selection, one sex can have extremely high reproductive success: elephant seals, manakins, etc. -- much higher success than the other sex.

But most individuals of the competitive sex (usually males) have *little or no* reproductive success, and -- in terms of reproductive success -- would be better off if they were the *opposite* sex.

In a few species, *an ability to change sex* lets individuals 'use' the best gender for the situation they're in.

Sex change as a reproductive strategy

A complicated life history: **sequential hermaphroditism** in the **blue-headed wrasse** (a tropical reef fish)

Two kinds of males:

- **SECONDARY** males: Born female; when large, can change to male **IF** no other secondary male present. Secondary males reproduce by trying to aggressively exclude other males. **If successful**, secondary males reproduce much more than females.
- **PRIMARY** males: Born male, remain as small males throughout life, reproduce by 'sneaking' fertilizations from secondary males.

Anemonefish (several species in tropical oceans) are also sequential hermaphrodites -- but in the reverse order of blue-headed wrasses.

- All are born males.
- When they get large, a few change to females (big anemonefish have more reproductive success as females than as males).