The Ecology of Sex Part 3: Males and Females

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Biol 417: Evolutionary Ecology

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Review

Review

We have been covering the costs and benefits of sexual reproduction.

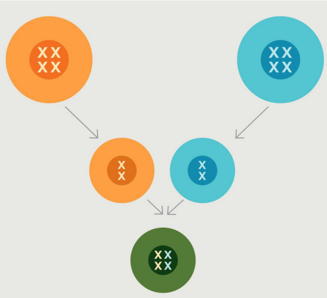
In particular, how environmental conditions play an important role in tipping the balance in favour sexual or asexual reproduction.

... but that the prevalence of sex is still largely an evolutionary paradox.

Today we will be talking about an important consequence of sexual reproduction, male and female phenotypes.

Sex Determination Systems

Sexual reproduction

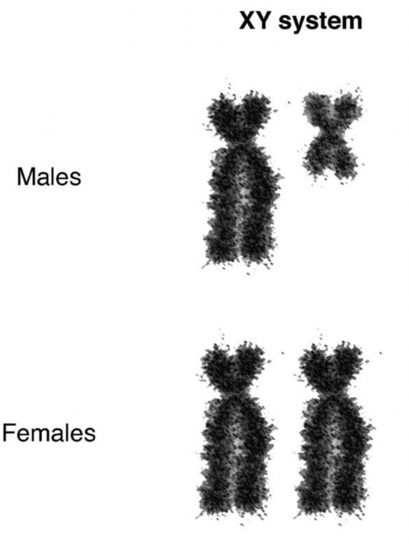


Sexual reproduction requires two compatible gametes to meet and fuse to generate progeny.

For the vast majority of multicellular organisms, sexual reproduction has resulted in the selection for male and female phenotypes.

... but what are males and females?

Chromosomal sex determination



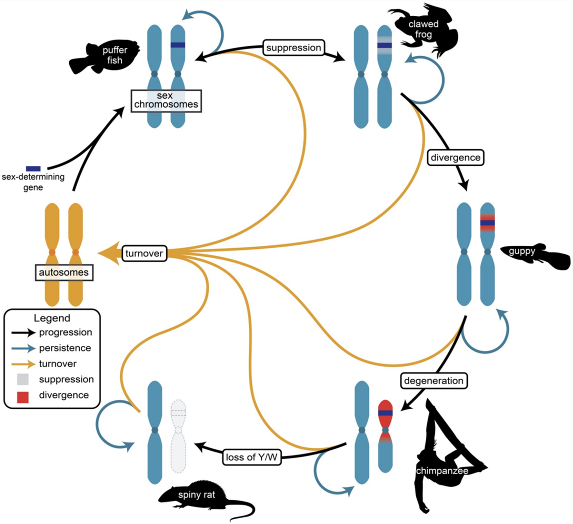
Johnson & Lachance (2012)

In mammalian species, sex is chromosomally determined.

For the most part, females are homogametic (XX) and males are heterogametic (XY).

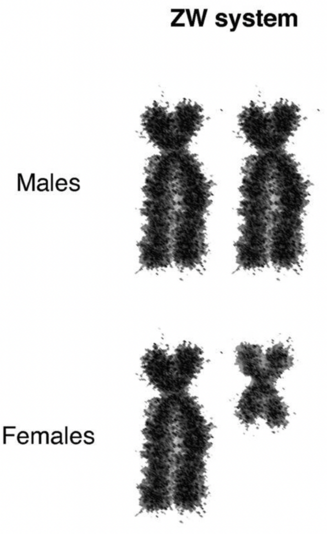
The XY sex-determination system is found in mammals, some insects, some snakes, some fish, and some plants.

Chromosomal sex det. cont.



Furman *et al.* (2020)

Chromosomal sex det. cont.

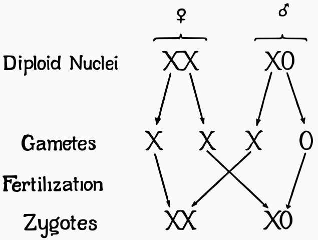


Johnson & Lachance (2012)

... but in birds, some fish and crustaceans, some insects, flatworms, and some reptiles males are homogametic (ZZ) and females are heterogametic (ZW).

No genes are shared between the avian ZW and mammalian XY chromosomes, bird and snake ZW are unrelated, so there is little evidence of common ancestry in chromosomal sex determination.

Chromosomal sex det. cont.



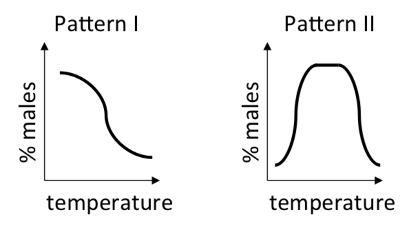
Source: Wikipedia

... and there's also an X0 sex-determination system in which there is only one sex chromosome.

In the X0 sex-determination system, males only have one X chromosome (X0), while females have two (XX).

Temp.-dependent sex determination

In many species of reptiles and fish, the temperatures experienced during embryonic/larval development determine the sex.



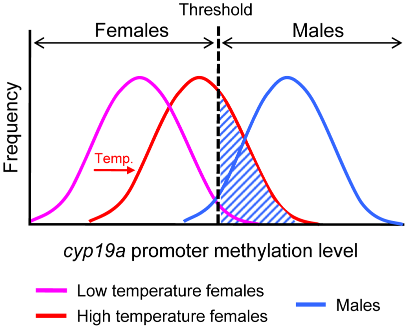
Source: Wikipedia

Other conditions including density, pH, and even environmental background colour, have been shown to alter sex ratios (Shen & Wang, 2014).

Temp.-depend. sex determin. cont.

Environmentally driven sex determination appears to be tied to environmentally driven patterns in DNA methylation.

Source: Wikipedia



Navarro-Martín *et al.* (2011)

Fertilisation dependent sex determin.

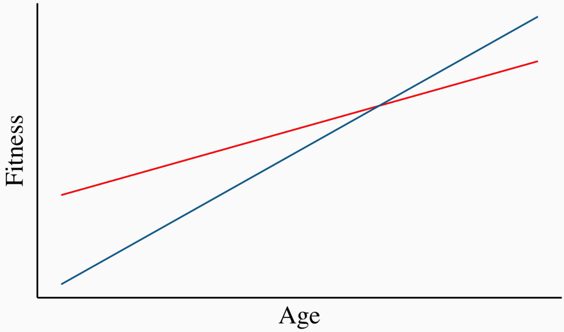
Source: Wikipedia

In the Hymenoptera, sex determination is controlled by zygosity.

Unfertilised eggs develop into haploid males, fertilised eggs develop into diploid females.

In some species individuals can change sexes over their lifetime, switching between male and female phenotypes.

This is expected to occur when sexes gain fitness with age at different rates.



Sequential hermaphroditism cont.

Source: Wikipedia

In the bluehead wrasse (*Thalassoma bifasciatum*), individuals start their lives as females, which have a slow and steady spawning rate.

Sequential hermaphroditism cont.

Source: Wikipedia

After they reach a certain age they switch to being males.

Males spawn multiple times per day (energetically costly) and have to defend a territory (will get outcompeted if too small).

Mechanism: Duplicate copies of genes get switched on/off, so they have all of the genetic material to function as males or females (Todd *et al.*, 2019).

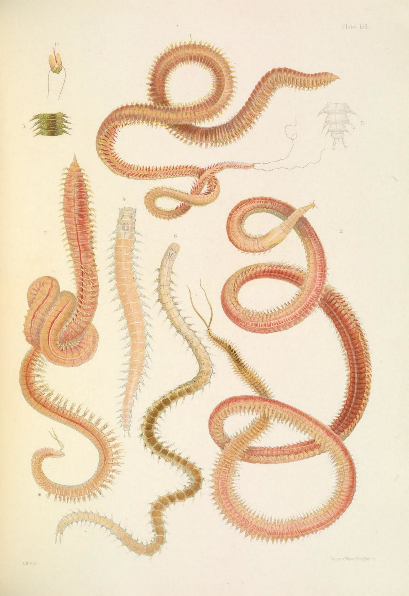
Sequential hermaphroditism cont.

In most species females are the larger sex (eggs are costly and larger body sizes are favoured).

(Yang *et al.*, 2017)

Shrimp from the family Pandalidae start their life as males and then switch to being females once they reach a sufficient age and body condition.

Sequential hermaphroditism cont.



Source: Wikipedia

The polychaete worm *Ophryotrocha puerilis* can switch sex back and forth between male and female phenotypes.

Rationale: Producing eggs is energetically expensive, while sperm is cheap. It loses condition as a female, but gains condition as a male and switches when it passes a body-size threshold.

In simultaneous hermaphrodites, both ‘maleness’ and ‘femaleness’ are expressed in the same individual at the same time.

Source: Marty Snyderman — Dive Training

Benefit: can mate with any individual encountered.

Cost: have to produce both male and female gametes (and any associated sexual organs).

Consequence: Can self fertilise.

Simultaneous hermaphroditism cont.

Source: Wikipedia

Scots pine *Pinus sylvestrus* expresses both male and female flowers.

The functional sex of any given pine tree can range from 0.069 (mostly male) to 0.825 (mostly female; Ross, 1990).

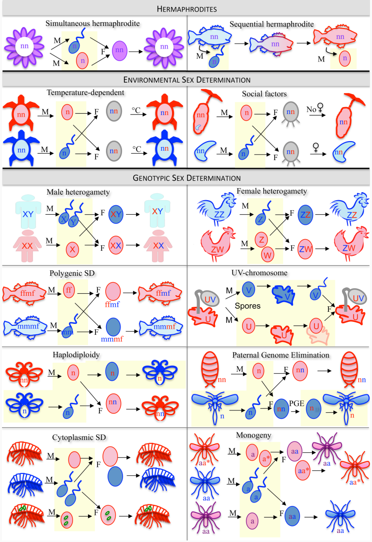
The male:female ratio depends on environmental conditions (stressed plants produce more male flowers, healthy plants produce female flowers).

Simultaneous hermaphroditism cont.

In many angiosperms ‘maleness’ and ‘femaleness’ are even expressed in the same flower.

Source: jardineriaon.com

Sex determination systems



Bachtrog *et al.* (2014)

Sex-determining mechanisms are extremely diverse and can evolve rapidly.

NB: M and F refer to meiosis and fertilization and haploid stages are shaded.

Sex determination systems cont.

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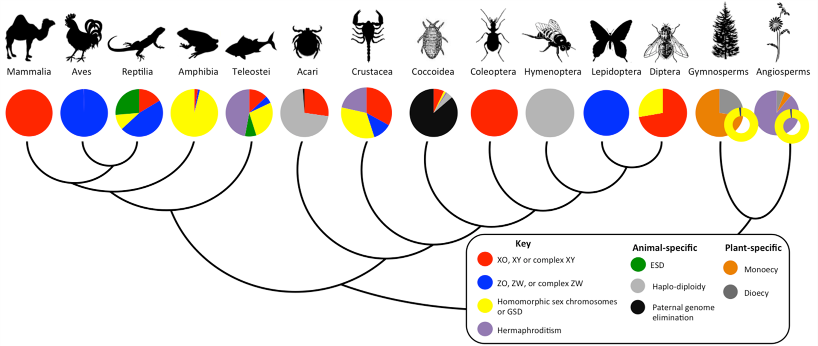
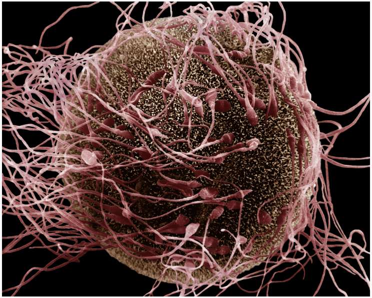


Bachtrog *et al.* (2014)

What are Males and Females?

There is no set genetic basis for sex, multiple factors can influence sexual phenotypes, and they are nor fixed in time (or even in the same individual).

As biologists, we define an individual's functional sex based on the gametes that it produces. Small = male, large = female.



Isogamy

Anisogamy is effectively universal in sexually reproducing multicellular plants and animals... but anisogamy is not the rule in sexually reproducing organisms.

Many unicellular organisms exhibit isogamy (i.e., identical investment in gamete size and structure).

Isogamy is the ancestral form and once anisogamy evolves it is rarely lost (Lehtonen *et al.*, 2016).

The isogamy—anisogamy dichotomy has important evolutionary consequences, but we are going to focus solely on anisogamic species.

Anisogamy and resource allocation

Irrespective of the mechanisms, anisogamy and differential investment into gametes has important consequences for the ecology of male and female phenotypes (or combinations thereof).

Investing resources into male or female offspring, or male or female gametes can have important fitness consequences that selection will act upon.

The existence of males and females also means selection will act on these phenotypes in different ways, leading to some interesting dynamics.

Next lecture we'll continue our focus on the ecological and evolutionary consequences of male and female phenotypes.

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