Sophia Breslin

Thomas Desvignes & John H. Postlethwait

Generally, male and female fish are indistinguishable in appearance.

Antarctic marbled notothens

Male ♂

Female ♀

♀

♂

In other cases, males and females may look slightly different, making them **sexually dimorphic.**

Antarctic painted notothens

Striped anal fin

Black anal fin

And sometimes, males and females of the same species are so distinct that previously they were thought to be different species!

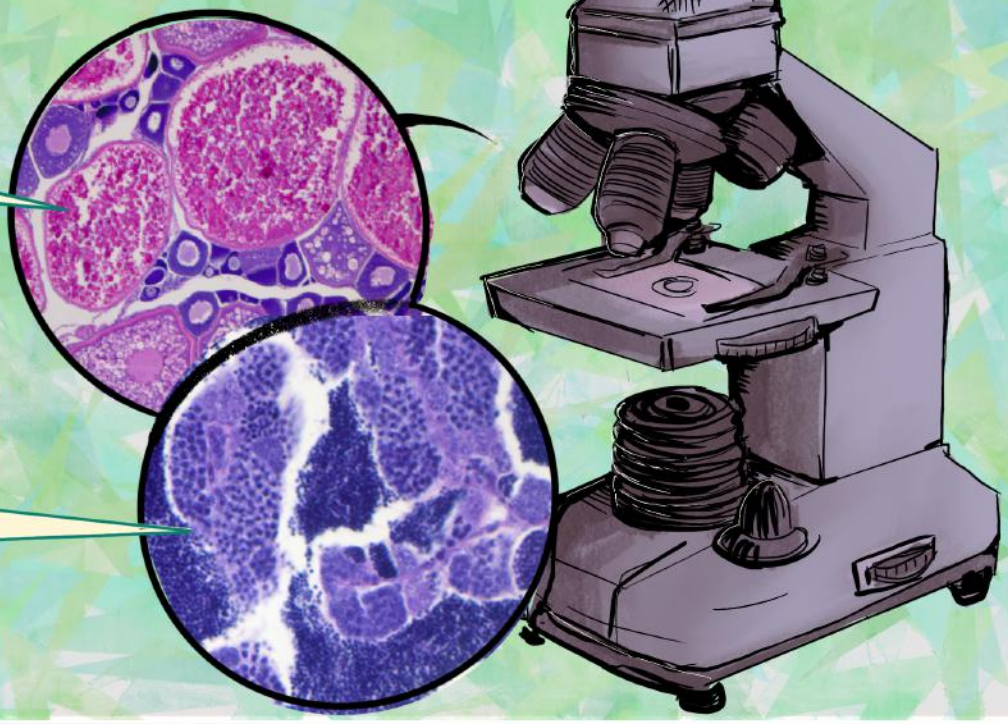
Bluehead wrasses

♂

♀

Beyond physical appearance, males and females differ in other ways, especially having different **gonads**—organs that make **gametes:** eggs and sperm.

Females have **ovaries** that produce large **eggs.**



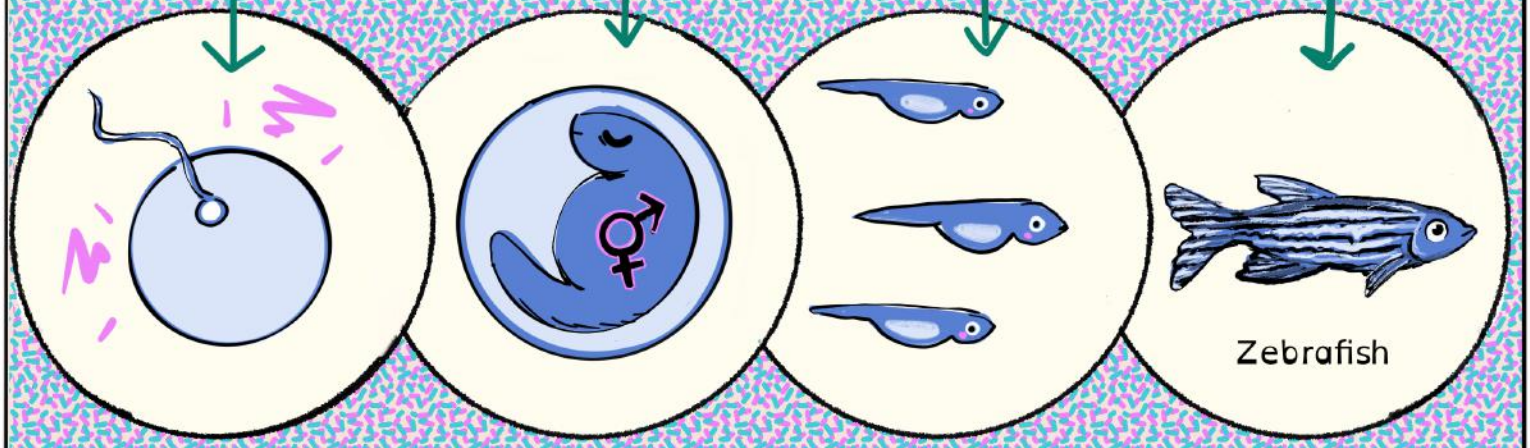
Males have **testes** that produce microscopic **spermatozoa!**

During reproduction, a sperm fuses with an egg to form a **zygote,**

which develops into an **embryo,**

that hatches into a **juvenile,**

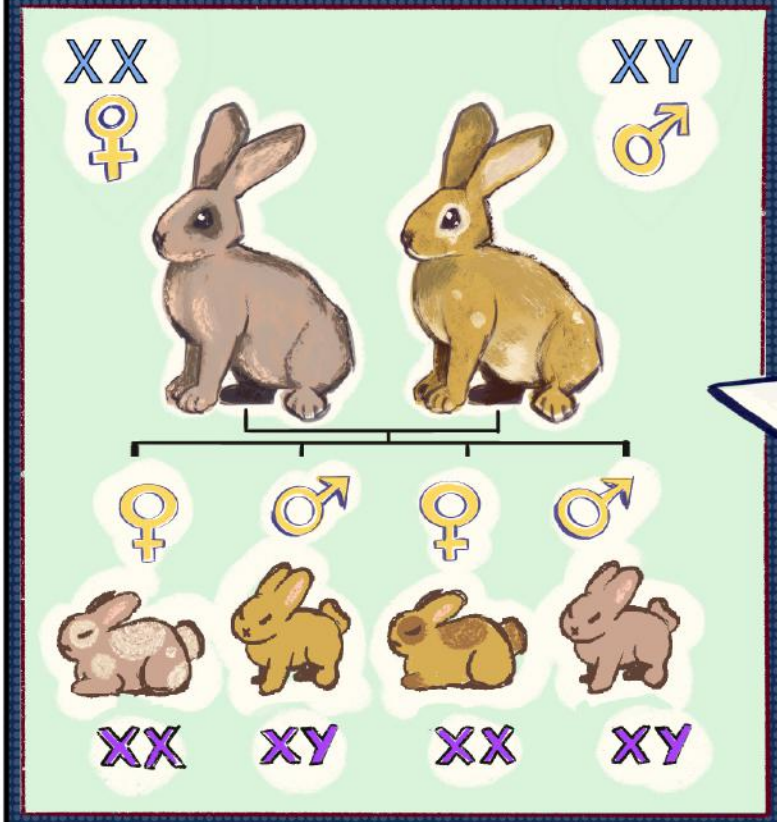
that becomes an adult as it develops mature ovaries or testes.



Zebrafish

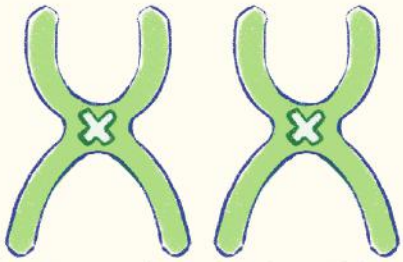
What factors cause gonads to become ovaries or testes?

For most vertebrates, the sex of an animal is determined by its genes, we call that Genetic Sex Determination or **GSD.** A major Sex Determining Gene **(SDG)** on a sex chromosome regulates ovary or testis development.

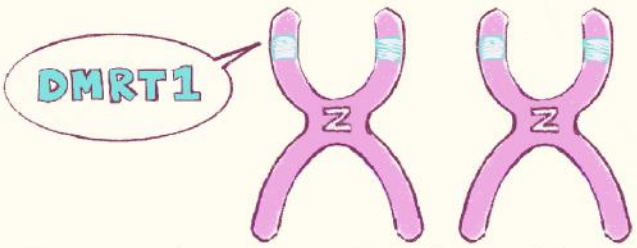


The **SDG** in mammals is *SRY*, located on the Y chromosome. Individuals with an **X** and a **Y** chromosome usually develop testes.

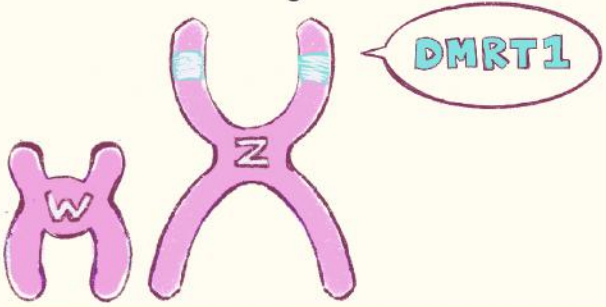
Individuals with two X chromosomes usually develop ovaries.

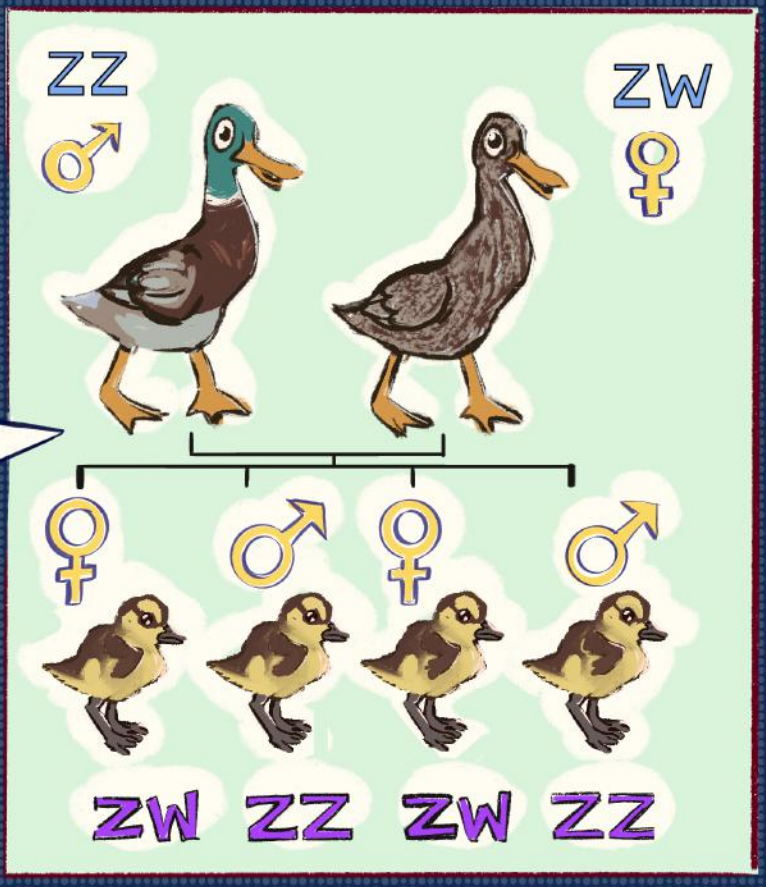


Birds have the opposite system: their SDG is *DMRT1* located on the Z chromosome. Males have two Z chromosomes and two *DMRT1* genes.

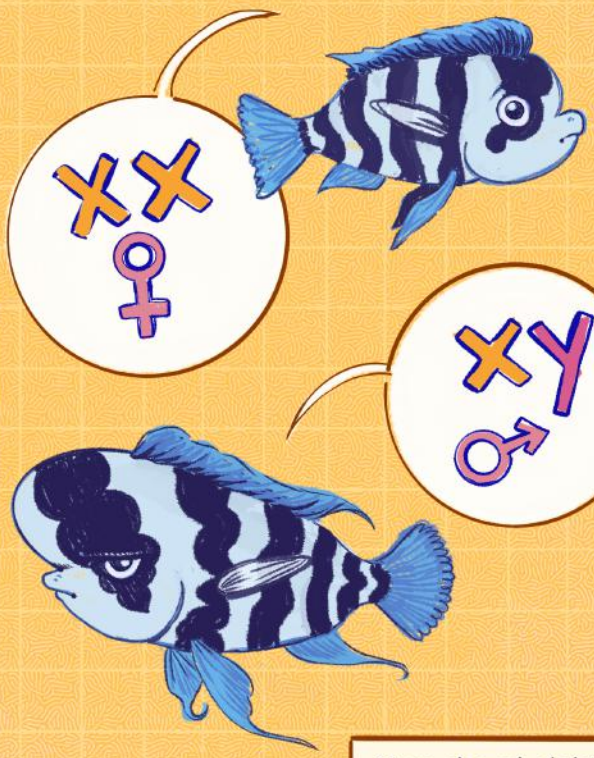


Females have one Z and one W chromosome, and so have only one *DMRT1* gene.



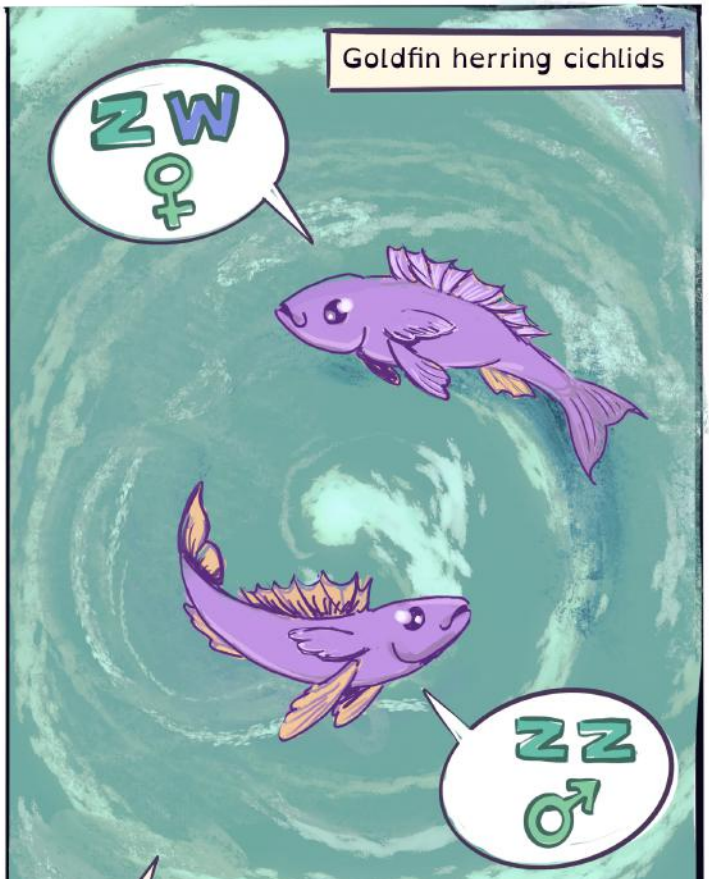


Like mammals, many fish have an **XX-XY** genetic sex determination system...



Humphead cichlids

Goldfin herring cichlids



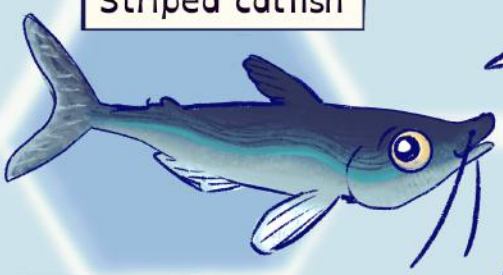
Some other fish have a ZZ-ZW chromosome system like birds.

Sailfin icefish

Some fish have other sex chromosome variations. For example, males of several Antarctic fish species have a Y chromosome formed by the fusion of a sex-chromosome with a non sex-chromosome.

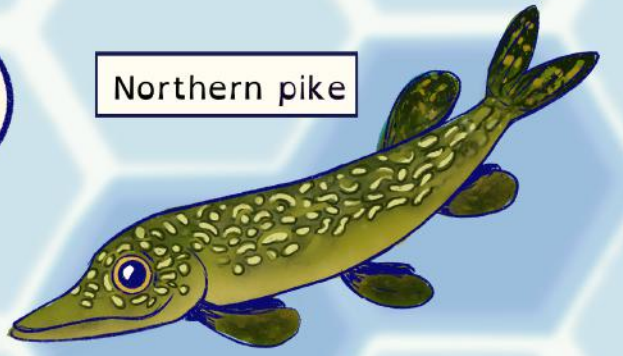
Strangely, fish have a variety of different SDGs rather than a single gene, like in all mammals or in all birds.

Striped catfish



amhr2

Northern pike



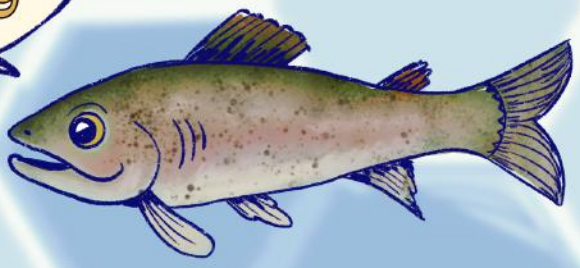
amh

Herring

irf9

Rainbow trout

bmpr1b



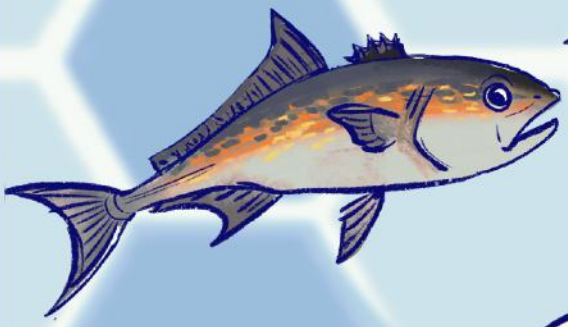
Mexican blind cavefish

gdf6

Japanese ricefish

dmy

Greater amberjack



hsd17b1

Luzon ricefish

gsdf

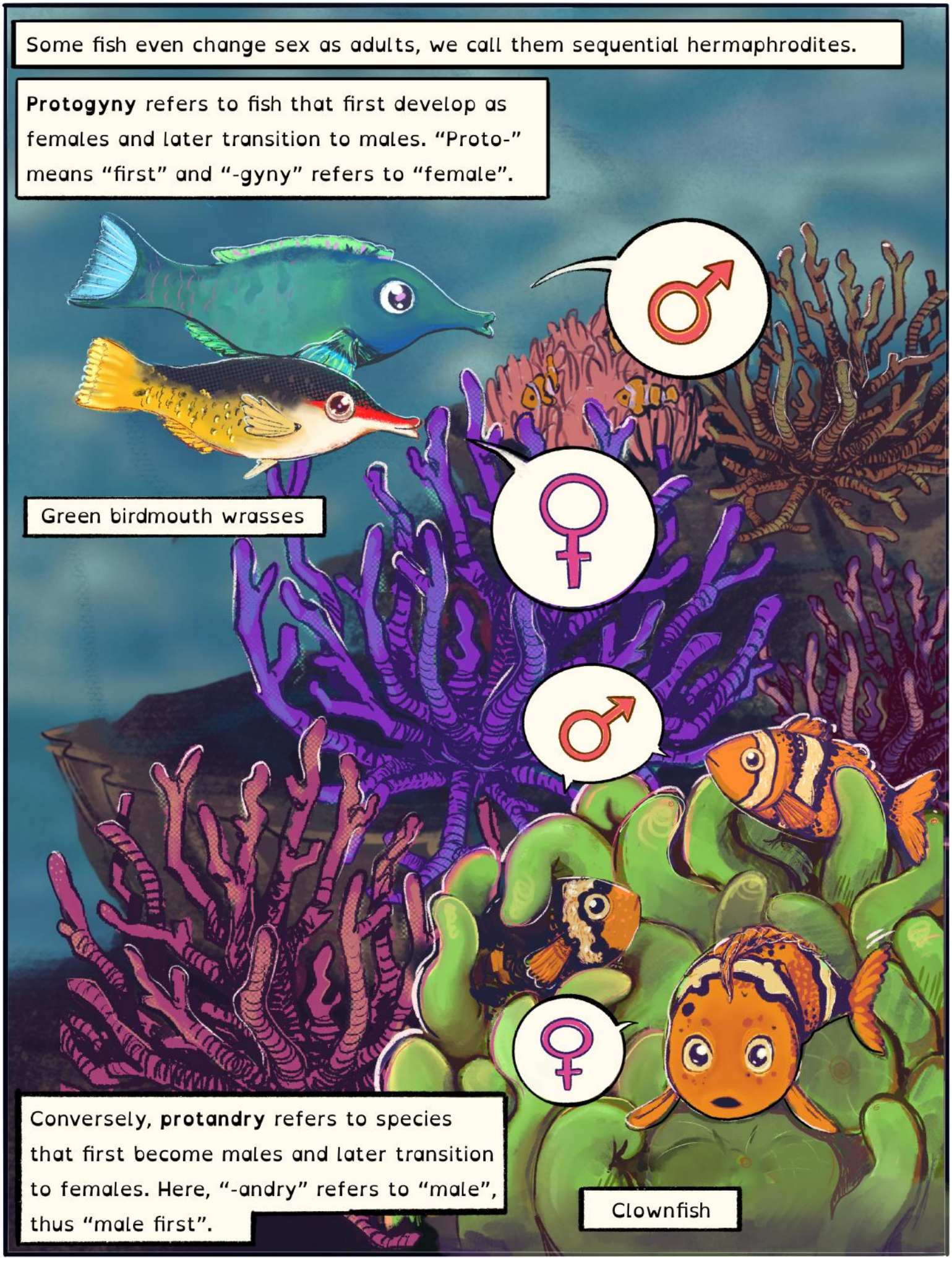
Senegalese sole

fshr

Indian blue ricefish

sox3

But sometimes, even closely related fish have different SDGs, like these three ricefishes.


Some fish even change sex as adults, we call them sequential hermaphrodites.
Protogyny refers to fish that first develop as females and later transition to males. "Proto-" means "first" and "-gyny" refers to "female".
Green birdmouth wrasses
Conversely, **protandry** refers to species that first become males and later transition to females. Here, "-andry" refers to "male", thus "male first".
Clownfish

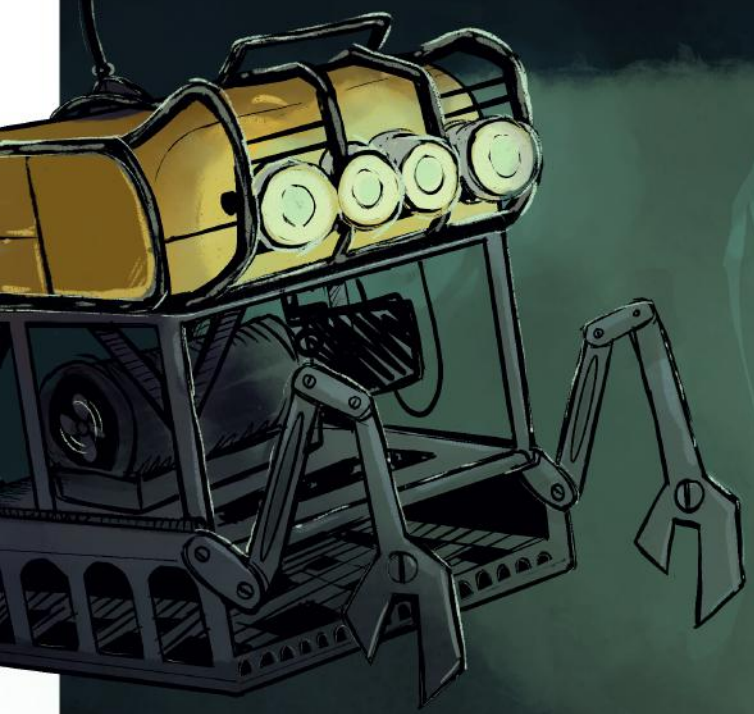
There are more atypical ways the sex of a fish is determined—or not...

In some species, individuals can alternate between being males or females: a bidirectional sex change.

Bluebanded gobies

In a few species, an individual fish can even have both ovaries and testes and produce eggs and sperm at the same time! They are simultaneous hermaphrodites.

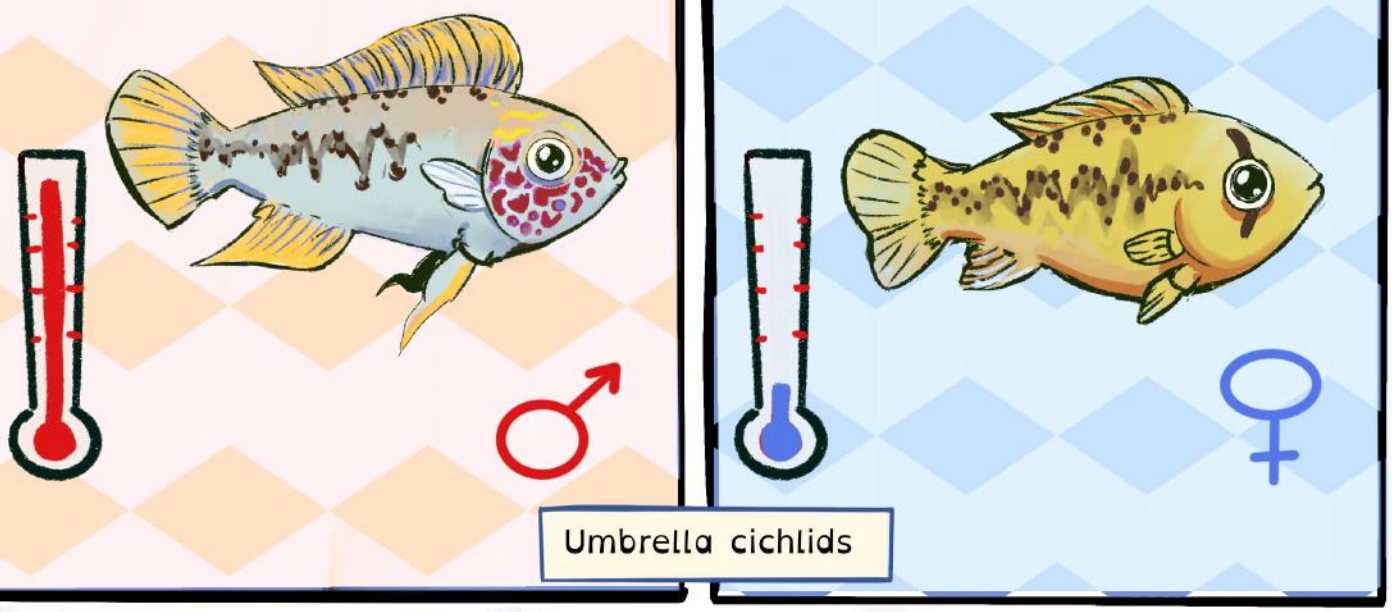
Remotely Operated Vehicles **(ROVs)** can explore the ocean's depths and observe such rare fish!



Abyssal tripodfish

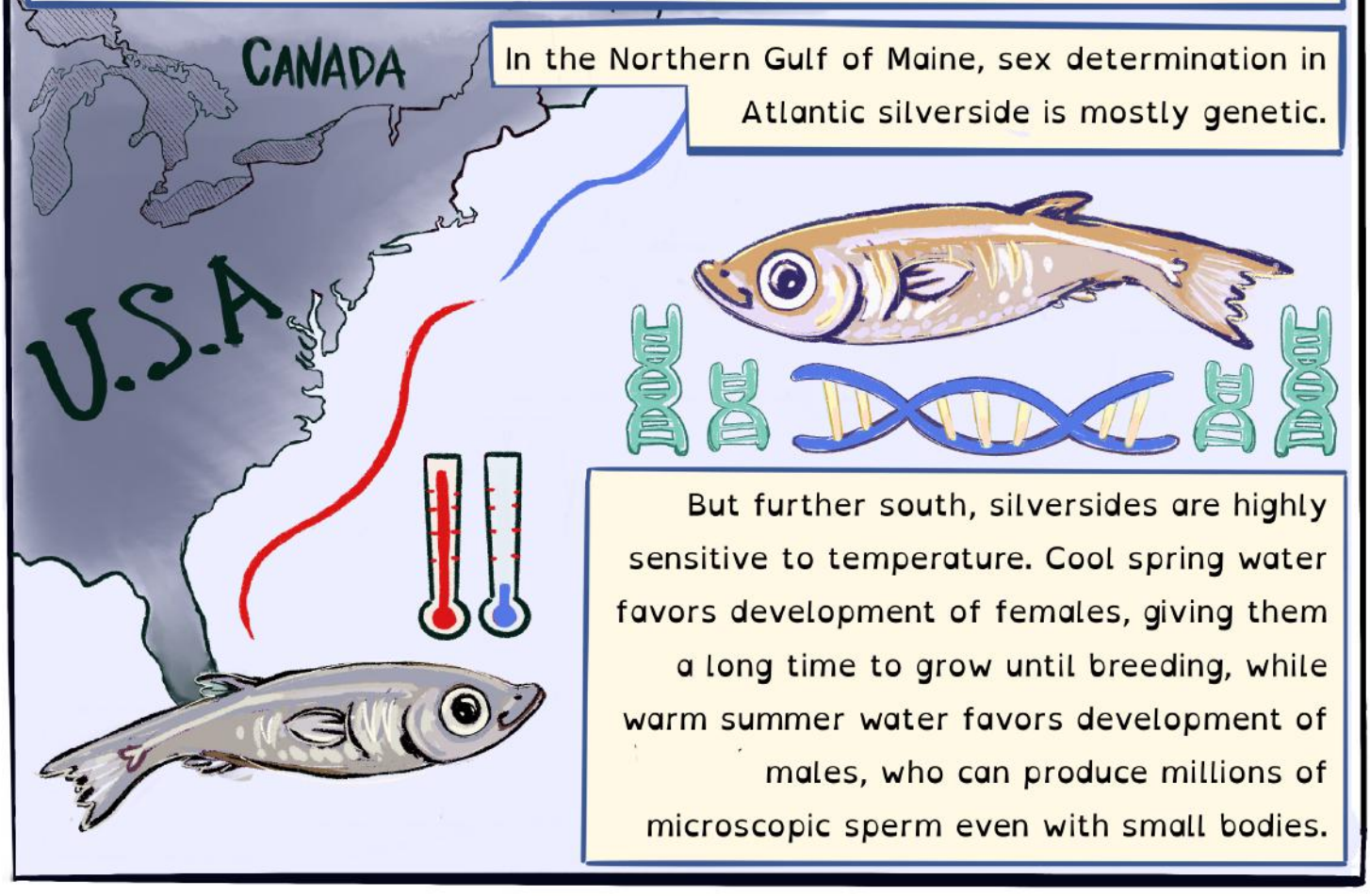
In some cases, genes don't determine the sex of a fish, instead their environment determines their sex, we call that Environmental Sex Determination or **ESD.**

For example, sometimes temperature can determine the sex of a fish.



Umbrella cichlids

And finally, genes and environment can interact: in some species, the effect of the environment can overrule the **SDG;** this system is referred to as **GSD + ESD.**



In the Northern Gulf of Maine, sex determination in Atlantic silverside is mostly genetic.

But further south, silversides are highly sensitive to temperature. Cool spring water favors development of females, giving them a long time to grow until breeding, while warm summer water favors development of males, who can produce millions of microscopic sperm even with small bodies.

And those are not all the ways by which sex is determined in fish. Almost anything you can imagine exists!
Why are fish sex determination mechanisms so diverse while all birds and all mammals seem to just have one mechanism?
Have changes in sex determination systems contributed to the diversification of fish species? We have much to learn.

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