MCDB 4650 Class 25

Sex determination in different species
An example of patterning and differentiation

Learning Goals:

- Explain the difference between primary and secondary sex determination in mammals (gonad determination vs. ductal systems).
- Predict the outcome of gonad differentiation and phenotypic sex characteristics when certain gene products are missing.
- Relate to each other the multiple factors in both male and female that ultimately determine gonadal sex.
- Compare the general ways that sex can be determined in different organisms.
- Explain how the X:A ratio is used to determine sex in *C. elegans* and *Drosophila,* and compare the two systems.

In most organisms, sex is determined genetically either by:

1. sex chromosomes
   XX (female) vs. XY (male) : mammals
   ZY (female) vs. ZZ (male) : birds

2. the ratio of sex chromosomes to autosome (many invertebrates use this method)
   (two X chromsomes and two of each autosome is a 1:1 ratio)

But, sex determination can also depend on environmental conditions

Alligator mississpiensis

Parrotfish

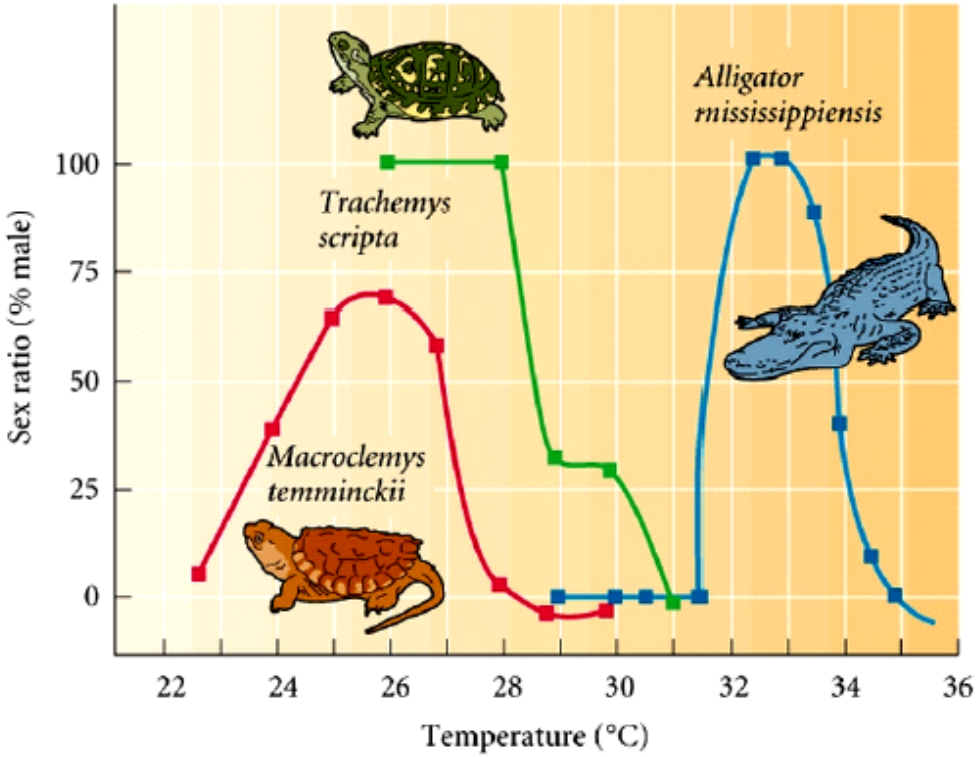
In some amphibians and reptiles, temperature affects sex determination by affecting hormone levels

aromatase

testosterone → estrogen

- Aromatase activated by certain temperature
- Other factors present at lower temperatures may generate estrogen production

Sex determination by temperature



Fun examples of sex determination
Some organisms can change sex

- Parrotfish: If there aren't many males, the largest female can become male.

- Clownfish: all born as males. When one male encounters another, the smaller one becomes a female. If the female dies, the most dominant male of the group becomes female!

- The <u>situation</u> (environment, not genetics) defines the hormones being secreted, and this defines the sex of the animal.

Mammalian sex determination

Sex in mammals is determined by
a. Hormones
b. Temperature
c. Ratio of sex chromosomes to autosomes
d. The number of X chromosomes
e. The combination of sex chromosomes

An XXY individual will be:
a. Male
b. Female
c. A little of both

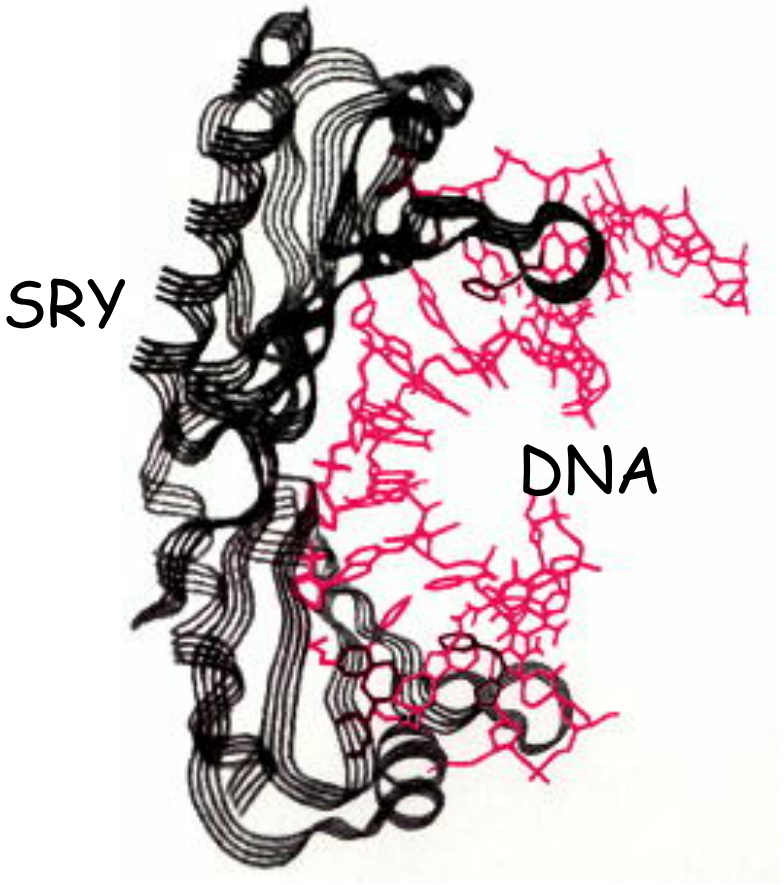
Primary Sex Determination: sex reversals gave first clue

Individuals that appeared male
but upon closer inspection were XX

had a translocation of part of the Y chromosome

Individuals that appeared female
but were XY, missing a piece of the Y chromosome

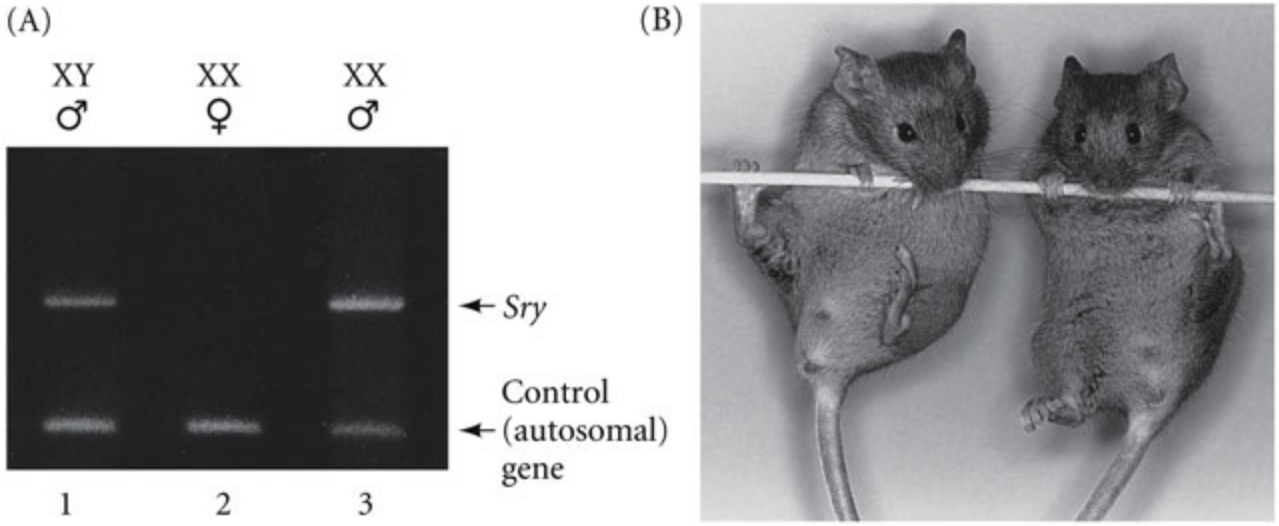
Later, a single gene was found to be responsible for testes development: the SRY gene (Sex determining Region of the Y chromosome)



Sry encodes an HMG box DNA binding protein

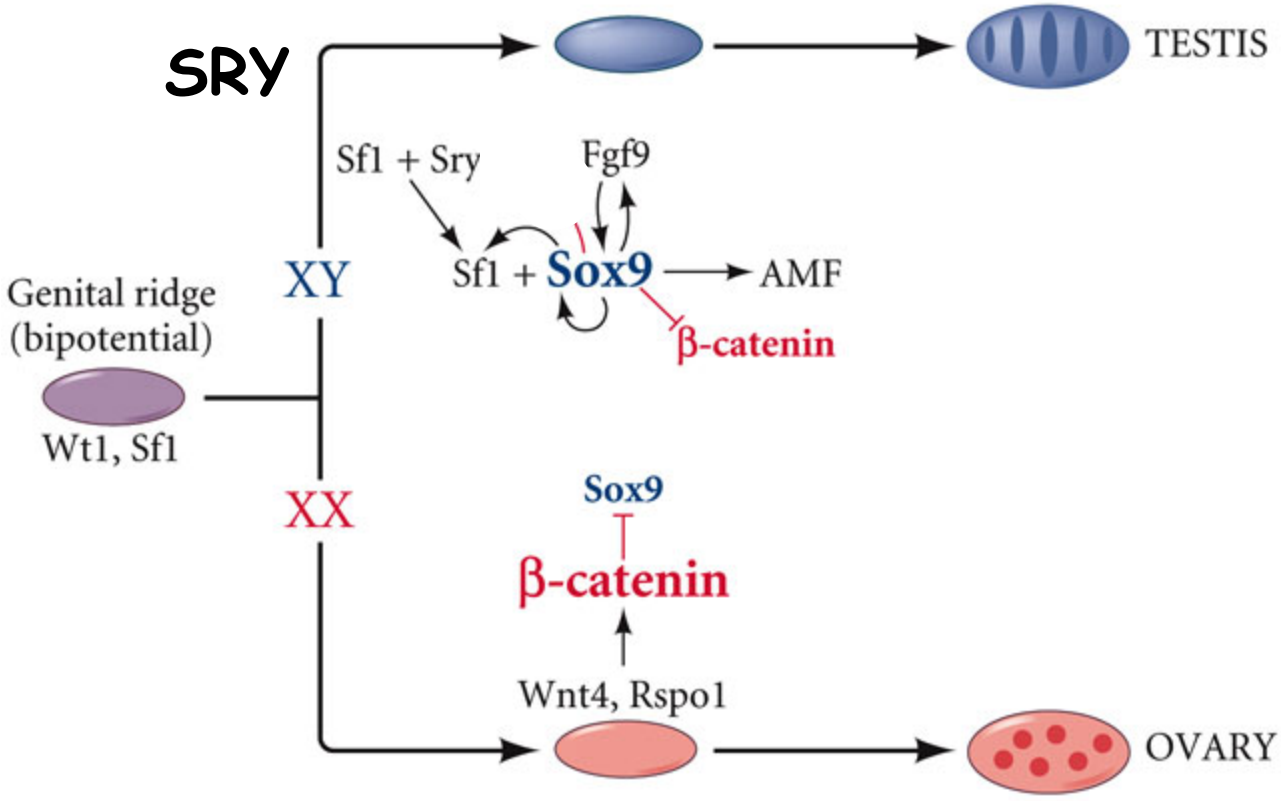
- Probably works by bending the DNA when it binds (thus making it easier to transcribe)
- The SRY gene is not well conserved across mammals suggesting it arose relatively recently (evolutionarily)

An XX individual with a copy of the SRY gene looks male



DEVELOPMENTAL BIOLOGY, 9e, Figure 14.6

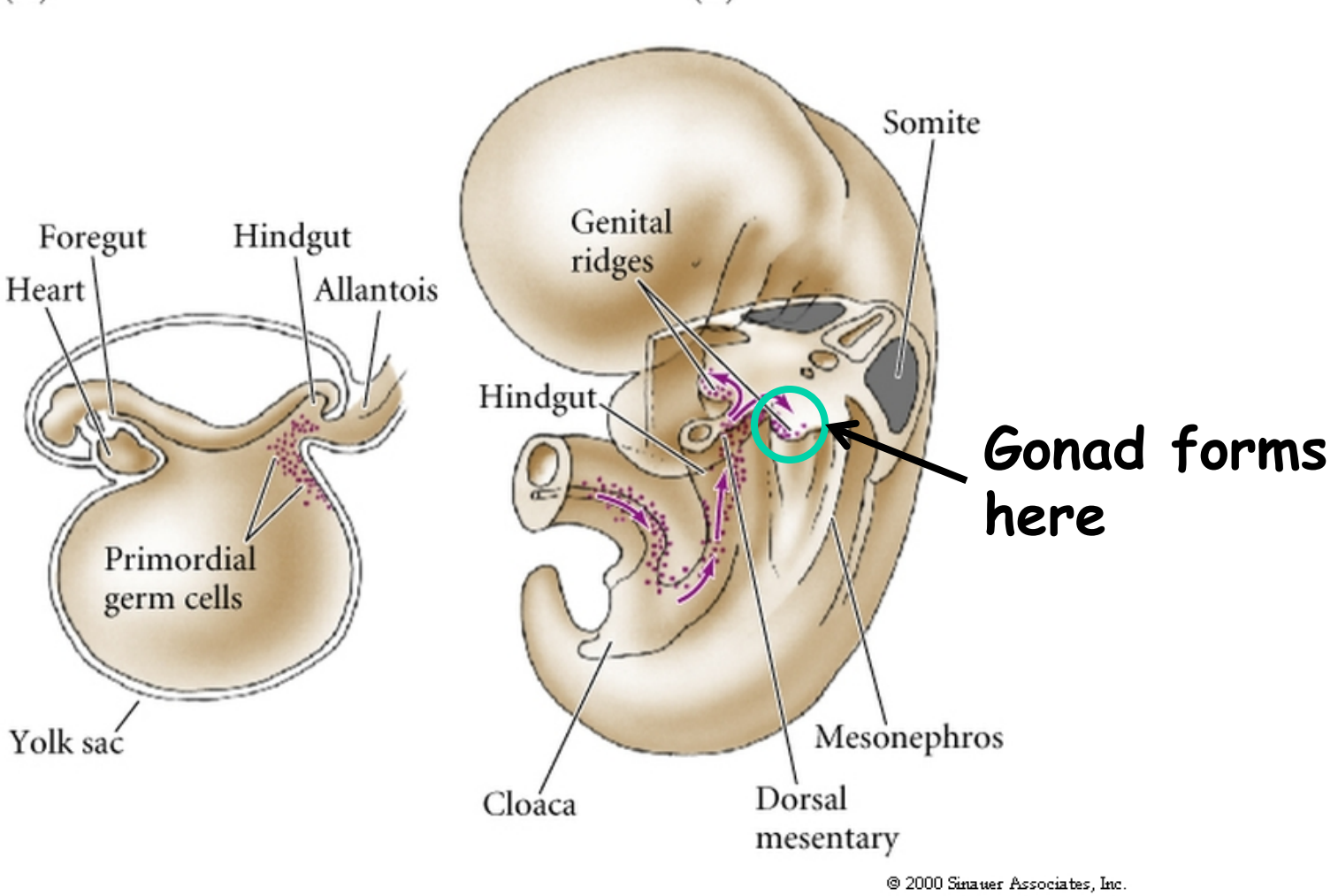
Model for molecules involved in gonad determination

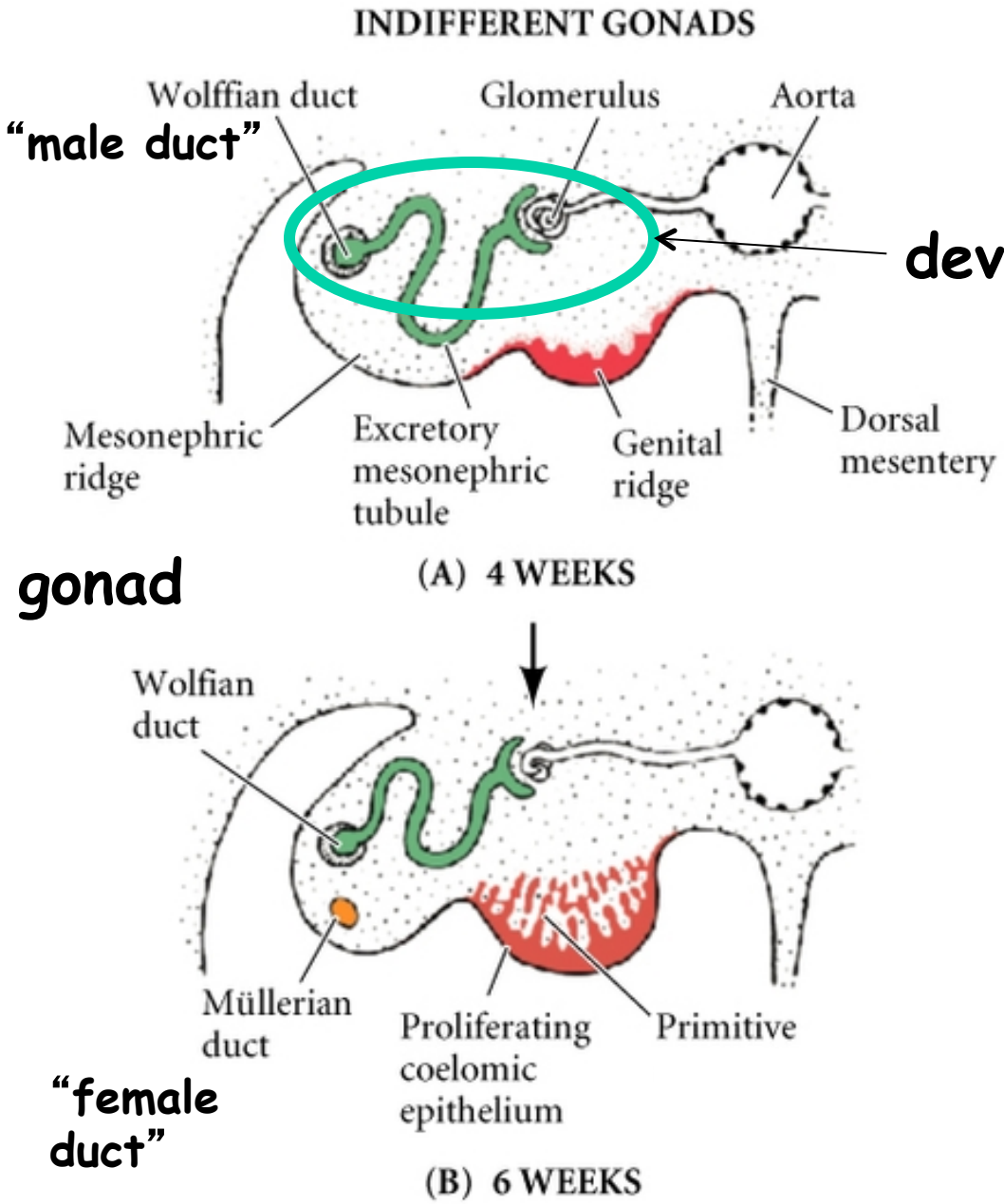


DEVELOPMENTAL BIOLOGY, 9e, Figure 14.4

Formation of the gonad

The Primordial Germ Cells (PGCs) migrate into the "genital ridges" of the embryo early in development





"male duct"

developing kidney

Bipotenital gonad

"female duct"

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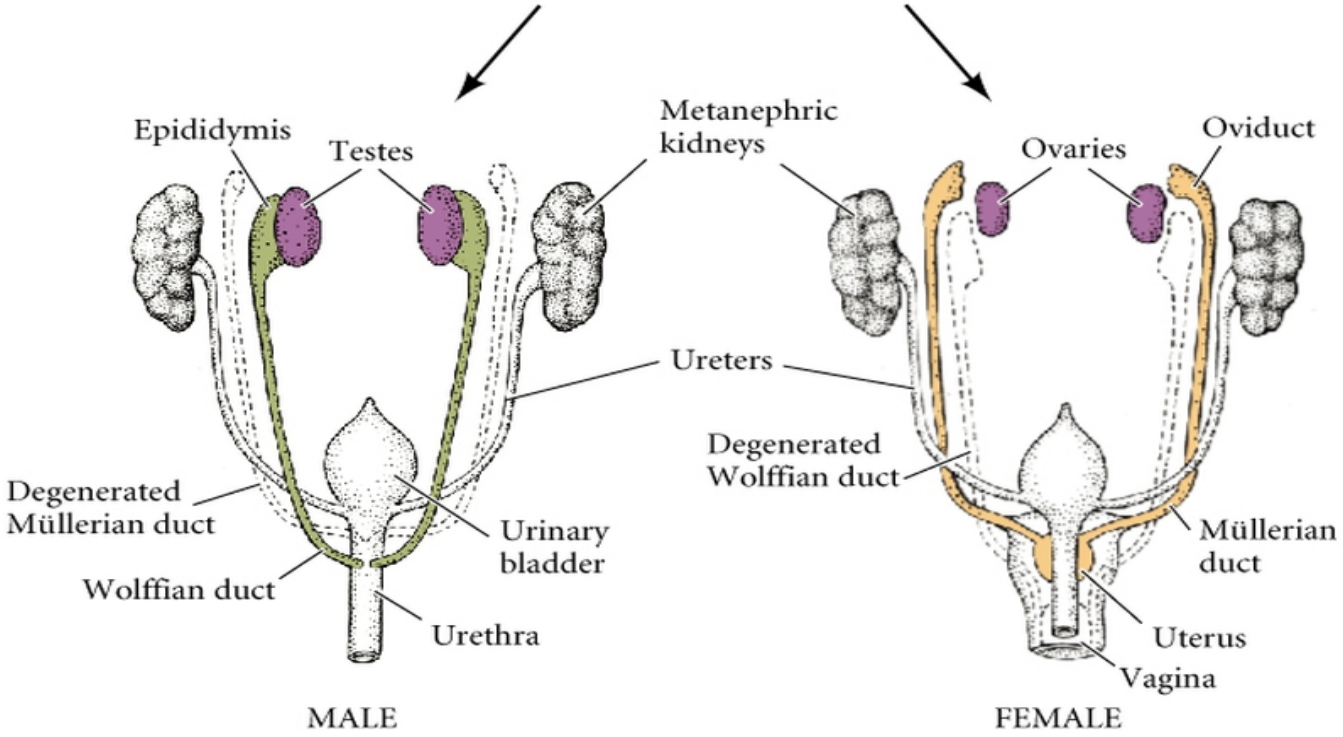
At 8 weeks of development: gonad cells differentiate into testes or ovaries; hormones secreted from the gonad then determine the ductal systems and the sexual phenotype



In testes: Anti-Mullerian Factor (AMF)—degrades female duct.
Testosterone: required for maintenance of male duct

In ovaries: Estrogen--required for maintenance of female duct

Primary vs. Secondary sex determination

Primary sex determination: identity of the gonad, ovaries or testes

Secondary sex determination: outward sex-specific physical appearance: dependent upon hormones produced by the male- or female-specific ductal systems

Worksheet:

- **Use terms to make a flow chart of sex determination, connecting the genotype (of a human) at the top with the internal and external structures listed at the bottom**

- **When you're done, do the back side of the worksheet**

Another example of "sex reversal" due to hormones during development

Androgen (testosterone) Insensitivity Syndrome:

Genotype: XY

Mutation: loss of function in testosterone receptor

Gonad?

1.

a. testes
b. ovaries

2.

a. produce testosterone
b. produce anti-Mullerian factor
c. produce estrogen
d. all of the above
e. None of the above

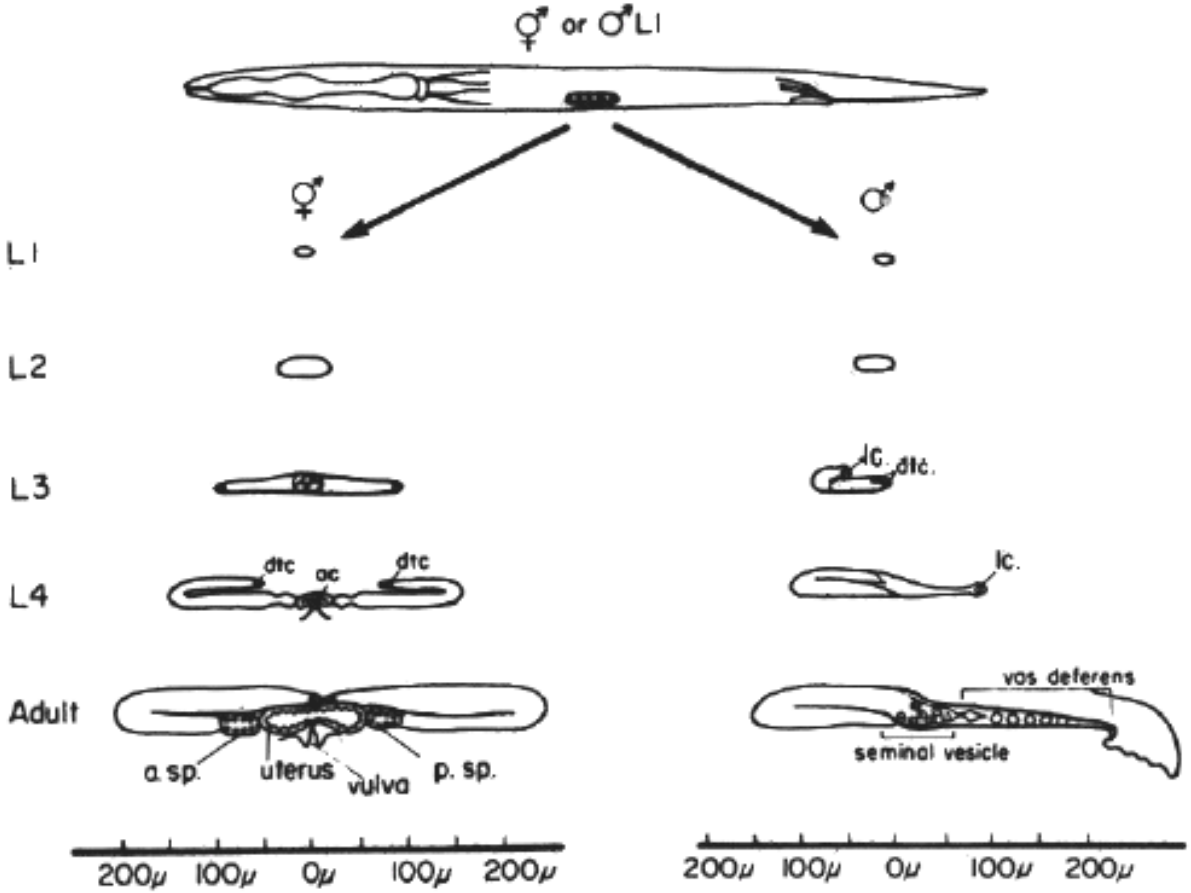
3. Phenotype?

a. differentiate the structures of the male duct
b. differentiate the structures of the female duct
c. have female external characteristics
d. have male external characteristics
e. more than one of the above

Mechanisms of sex determination used by other organisms

Other ways of sex determination

C. elegans **Hermaphrodite: XX** **Male: X (referred to as "XO")**



Somatic gonad has two "arms"
Produces both eggs and sperm

Somatic gonad has one "arm"
Produces only sperm

In invertebrates, mutagenesis screens allowed identification of genes involved in sex determination

C. elegans sex determination mutants

Mutant Gene(s)	Sexual Phenotype	
	XX	XO
None	hermaphrodite	male
tra-1(lf)	male	male
her-1(lf)	hermaphrodite	hermaphrodite

From this information, what is the normal function of *her-1*?

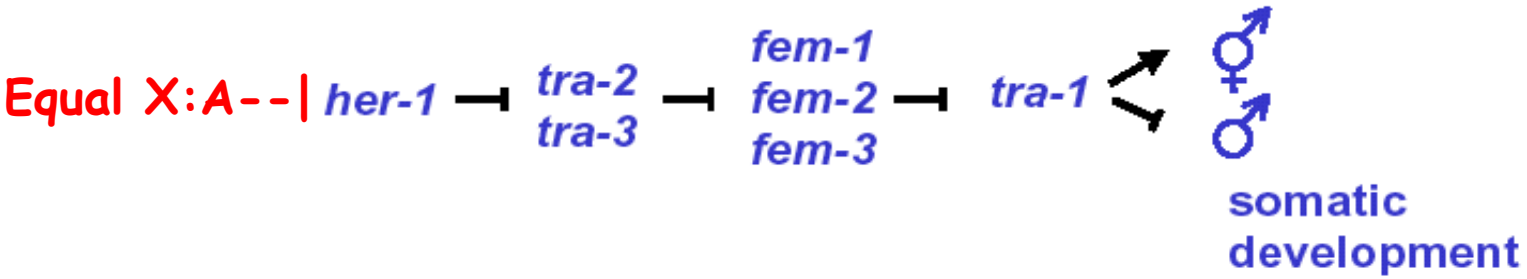
a. To make the gonad hermaphrodite

b. To make the gonad male

The X:A ratio controls sex determination

High X:A ratio inhibits her-1 while Low X:A ratio activates her-1
What does that mean?

2 X chromosomes: two copies of every gene on the X
Enough products are transcribed to repress her-1
If only one X chromosome present, her-1 is not repressed



♂	on	off	on	off	Male
♀	off	on	off	on	Female

Drosophila sex determination: XX Female; XY Male

Based on the information in the table below, what determines whether a fly will be a normal male?

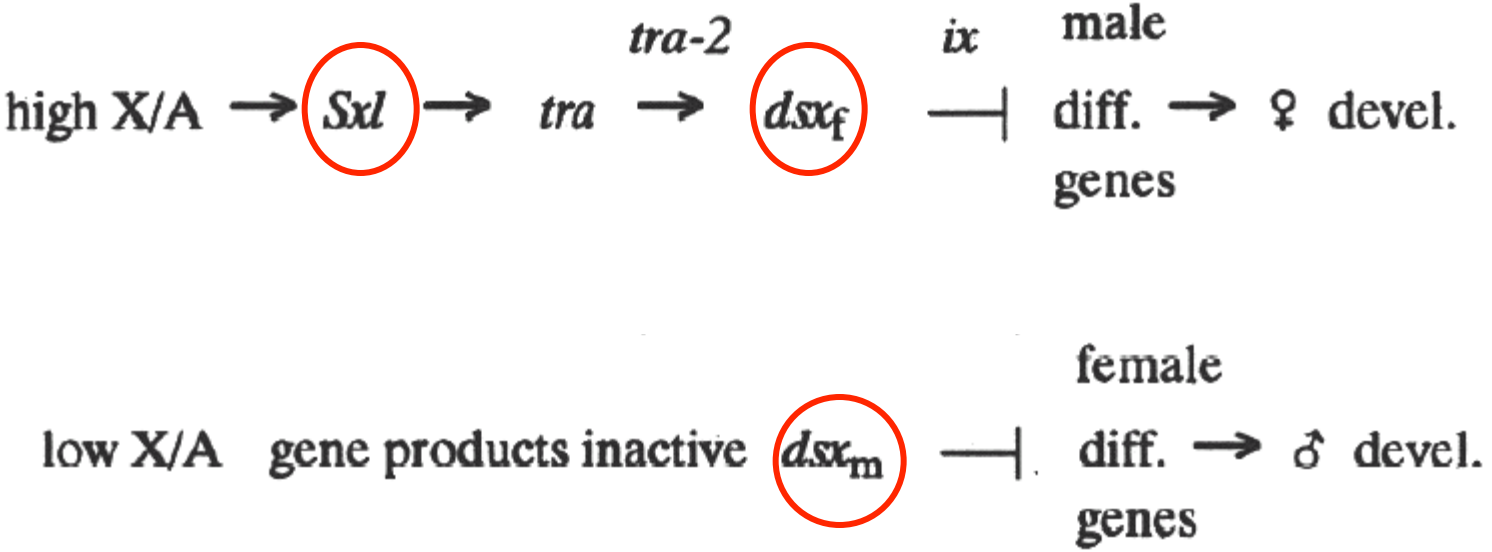
a. Number of X chromosomes
b. One Y chromosome
c. An X:A ratio of 1
d. An X:A ratio of less than 1
e. An X:A ratio of .5

X chromosomes	Y chromosome	Autosome Sets	Sex
4	0	4	female
2	0	2	female
2	0	3	intersex
2	1	4	male
1	1	2	male
1	0	2	male

X:A ratio controls both *Drosophila* and *C. elegans* sex determination

In Drosophila, the result of a 1:1 "X:A" ratio is the transcription of certain genes (Sex Lethal).

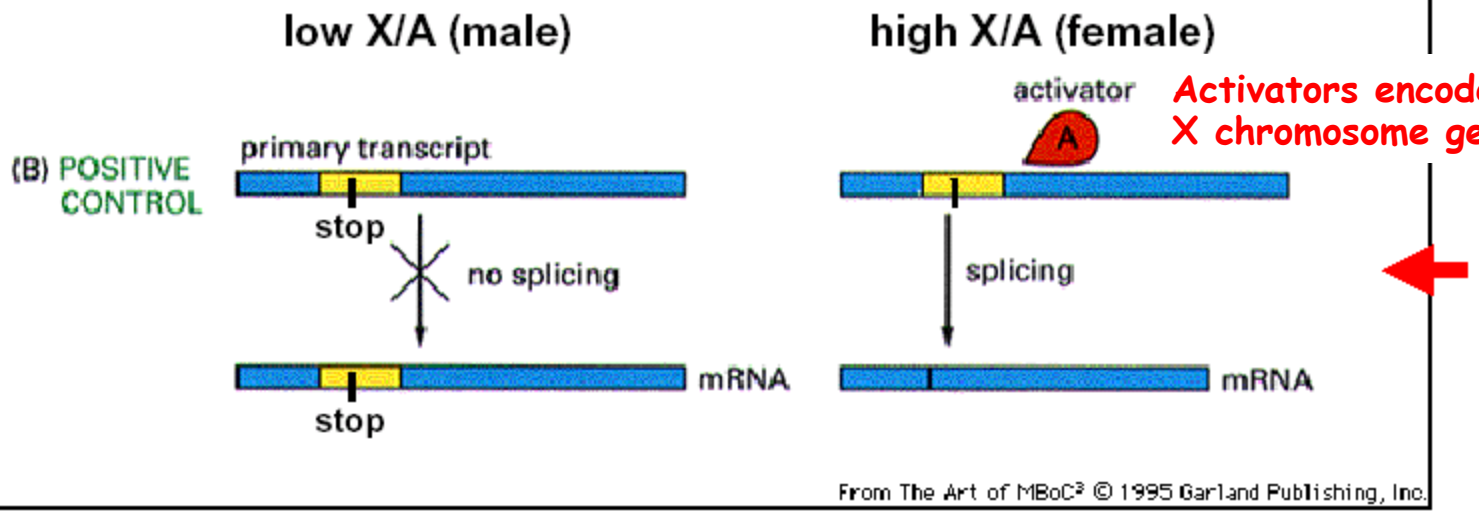
The genetic pathway controlling sex determination in Drosophila



In Drosophila, the activation of products requires splicing

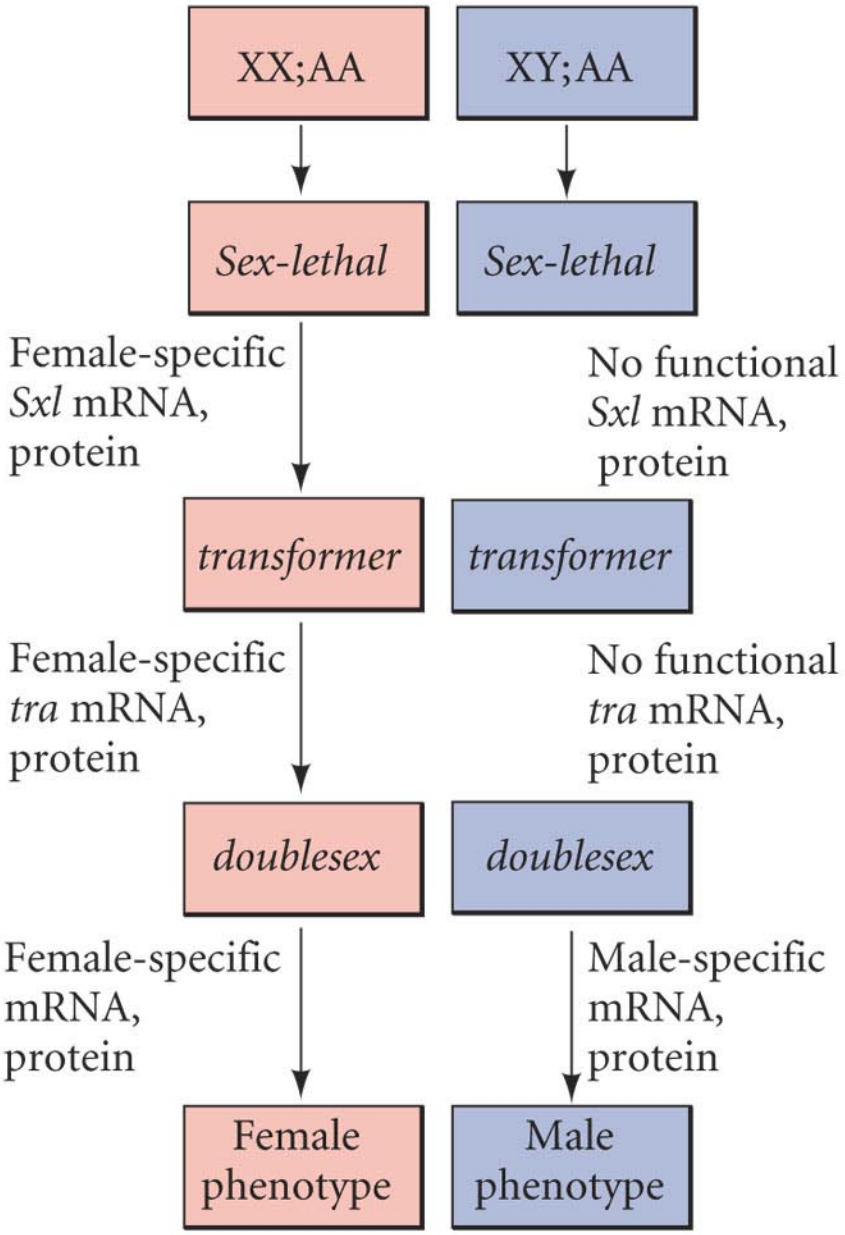
The splicing happens in females

Mechanism of switch (for Sxl gene)



9.74 Alberts

Sxl protein then goes on to allow transformer transcript to be spliced (not spliced in males)



DEVELOPMENTAL BIOLOGY, Seventh Edition, Figure 5.30 Sinauer Associates, Inc.

A Drosophila with a loss of function mutation in *transformer* will have what kind of gonad?

a. Male if it is XY, female if it is XX
b. Female if is XY, male if it is XX
c. Male no matter what
d. Female no matter what

In *C. elegans* and *Drosophila*, sex determination and dosage compensation are interconnected…
(next time!)