Big Idea 4: Biological systems interact, and these systems and their interactions possess complex properties.

Enduring understanding 4.A: Interactions within biological systems lead to complex properties.

Essential knowledge 4.A.3: Interactions between external stimuli and regulated gene expression result in specialization of cells, tissues and organs.

a. Differentiation in development is due to external and internal cues that trigger gene regulation by proteins that bind to DNA. [See also 3.B.1, 3. B.2]

A program of differential gene expression leads to the different cell types in a multicellular organism

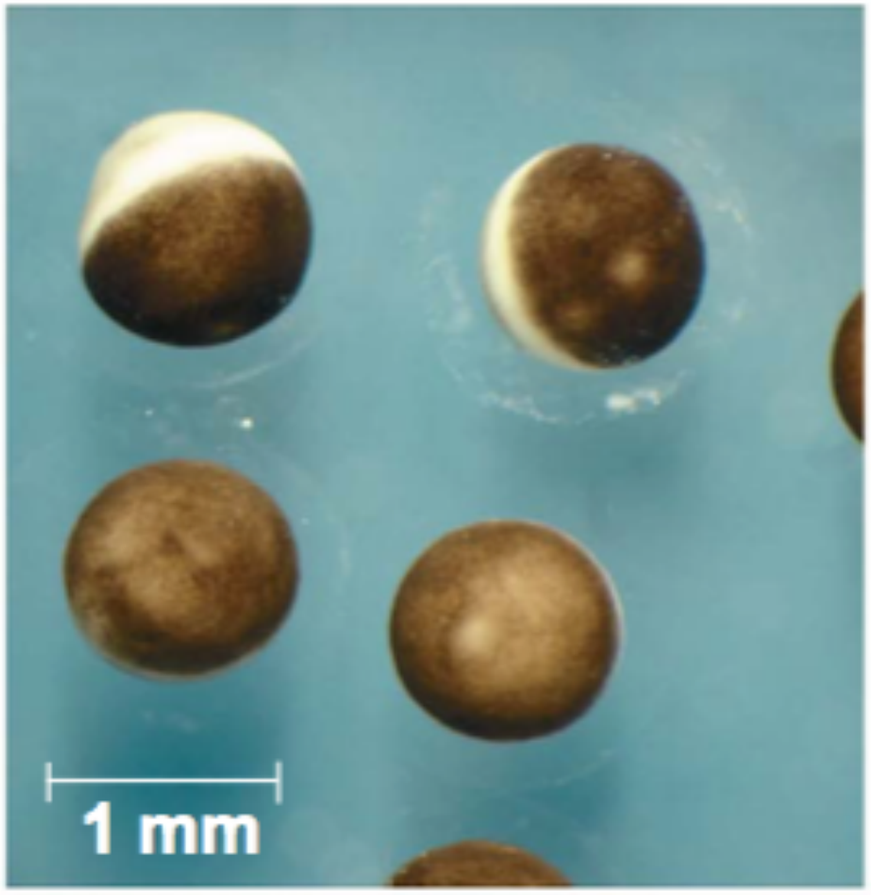
- During embryonic development,a fertilized egg gives rise to many different cell types

- Cell types are organized successively into tissues, organs, organ systems, and the whole organism

- Gene expression orchestrates the developmental programs of animals

A Genetic Program for Embryonic Development

- The transformation from zygote to adult results from cell division, cell differentiation, and morphogenesis



(a) Fertilized eggs of a frog

(b) Newly hatched tadpole

- **Cell differentiation** is the process by which cells become specialized in structure and function

- The physical processes that give an organism its shape constitute **morphogenesis**

- Differential gene expression results from genes being regulated differently in each cell type

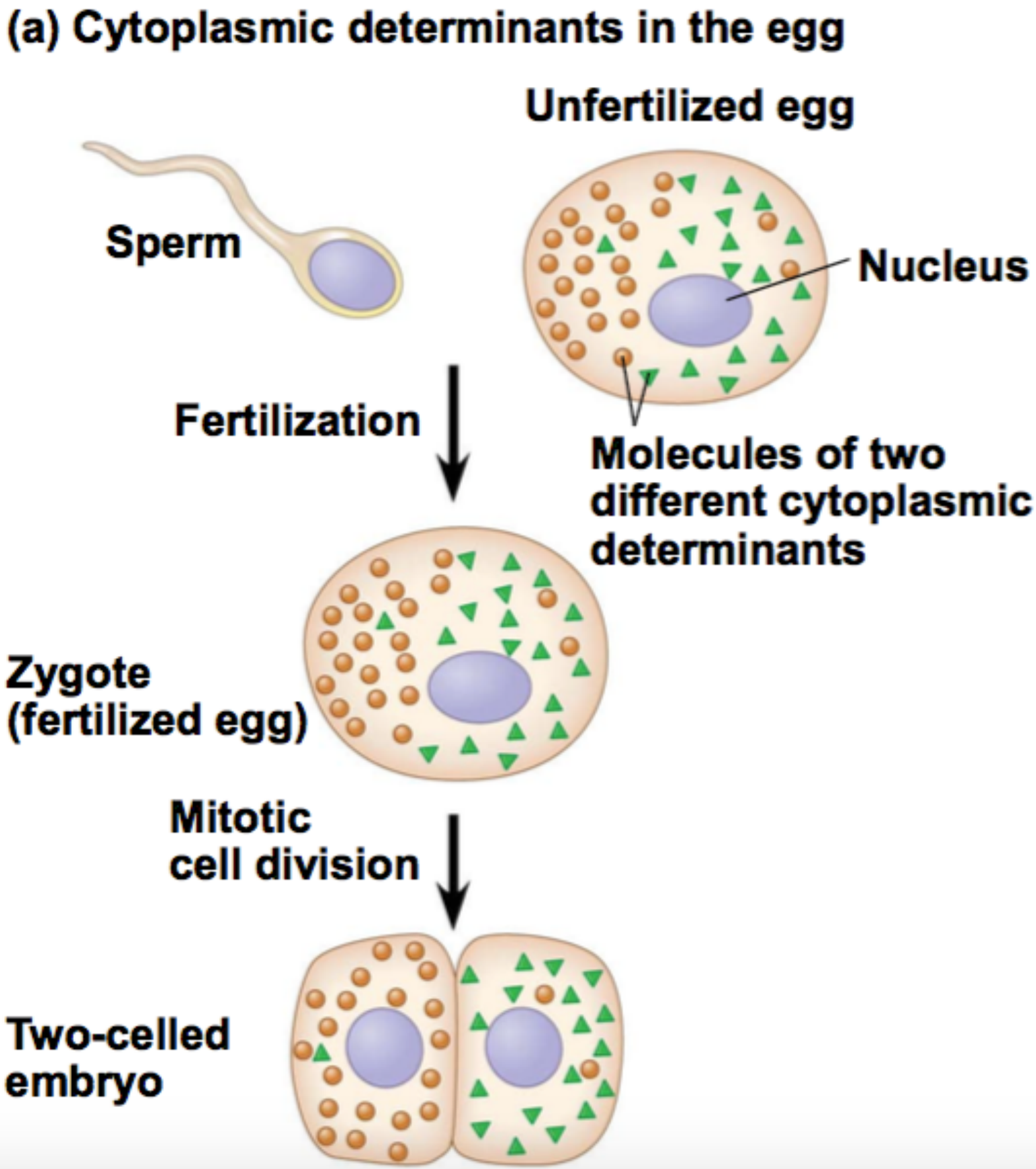
- Materials in the egg can setup gene regulation that is carried out as cells divide

Cytoplasmic Determinants and Inductive Signals

- An egg's cytoplasm contains RNA,proteins,and other substances that are distributed unevenly in the unfertilized egg

- **Cytoplasmic determinants** are maternal substances in the egg that influence early development

- As the zygote divides by mitosis,cells contain different cytoplasmic determinants, which lead to different gene expression

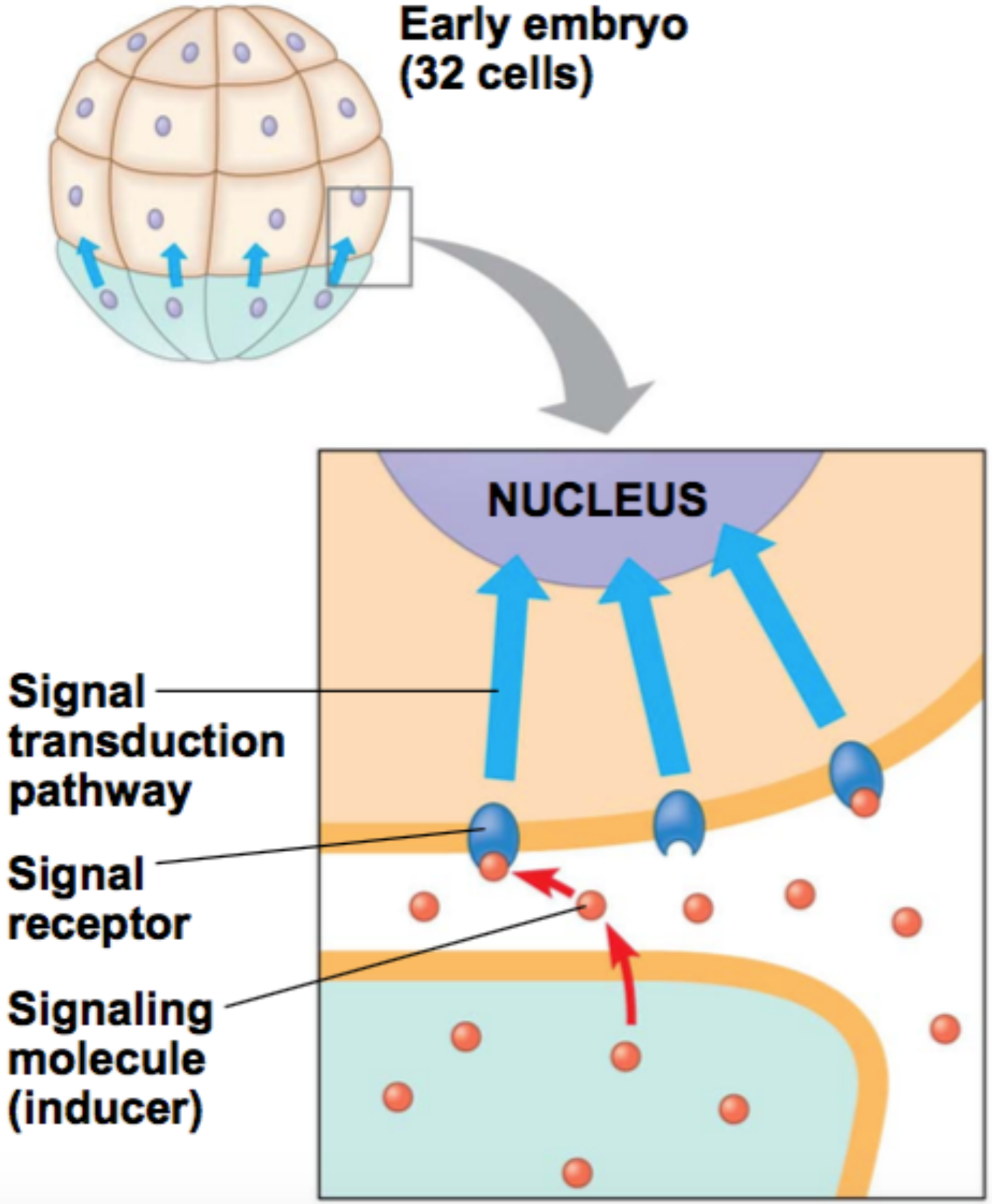

(a) Cytoplasmic determinants in the egg
Unfertilized egg
Sperm
Nucleus
Fertilization
Molecules of two different cytoplasmic determinants
Zygote (fertilized egg)
Mitotic cell division
Two-celled embryo

- The other important source of developmental information is the environment around the cell, especially signals from nearby embryonic cells

- In the process called **induction**,signal molecules from embryonic cells cause transcriptional changes in nearby target cells

- Thus,interactions between cells induce differentiation of specialized cell types

(b) Induction by nearby cells



Essential knowledge 4.A.3: Interactions between external stimuli and regulated gene expression result in specialization of cells, tissues and organs.

b. Structural and functional divergence of cells in development is due to expression of genes specific to a particular tissue or organ type. [See also 3.B.1, 3.B.2]

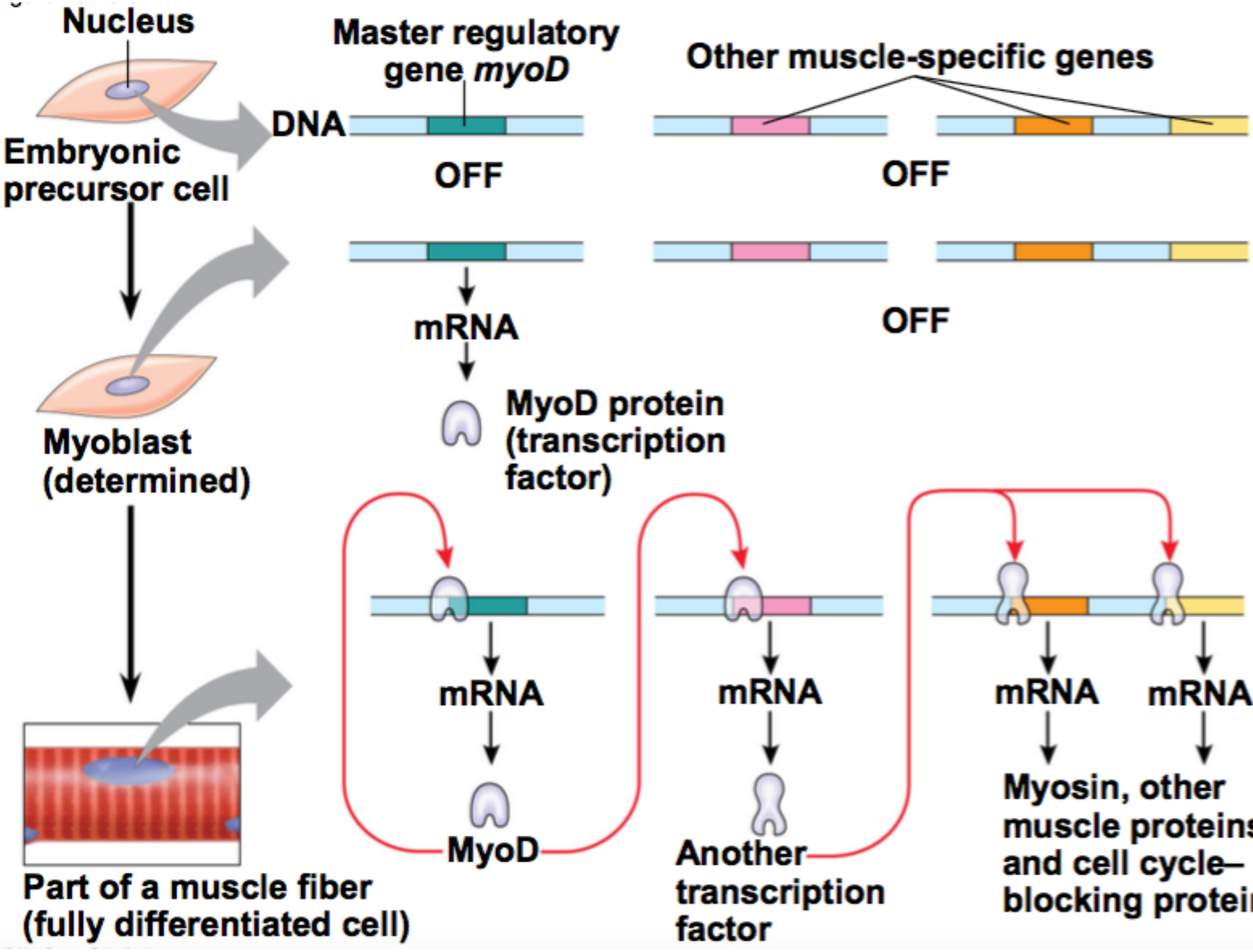
Sequential Regulation of Gene Expression During Cellular Differentiation

- **Determination** commits a cell to its final fate
- Determination precedes differentiation
- Cell differentiation is marked by the production of tissue-specific proteins

- Myoblasts produce muscle-specific proteins and form skeletal muscle cells

- *MyoD*is one of several“master regulatory genes” that produce proteins that commit the cell to becoming skeletal muscle

- The MyoD protein is a transcription factor that binds to enhancers of various target genes


Nucleus
Embryonic precursor cell
Myoblast (determined)
Part of a muscle fiber (fully differentiated cell)
Master regulatory gene myoD
DNA
OFF
Other muscle-specific genes
OFF
OFF
mRNA
MyoD protein (transcription factor)
mRNA
MyoD
mRNA
Another transcription factor
mRNA
mRNA
Myosin, other muscle proteins, and cell cycle–blocking proteins

Pattern Formation: Setting Up the Body Plan

- **Patternformation**isthedevelopmentofaspatial organization of tissues and organ
- Inanimals,patternformationbeginswiththe establishment of the major axes
- **Positionalinformation**,themolecularcuesthat control pattern formation, tells a cell its location relative to the body axes and to neighboring cells

The Life Cycle of Drosophila

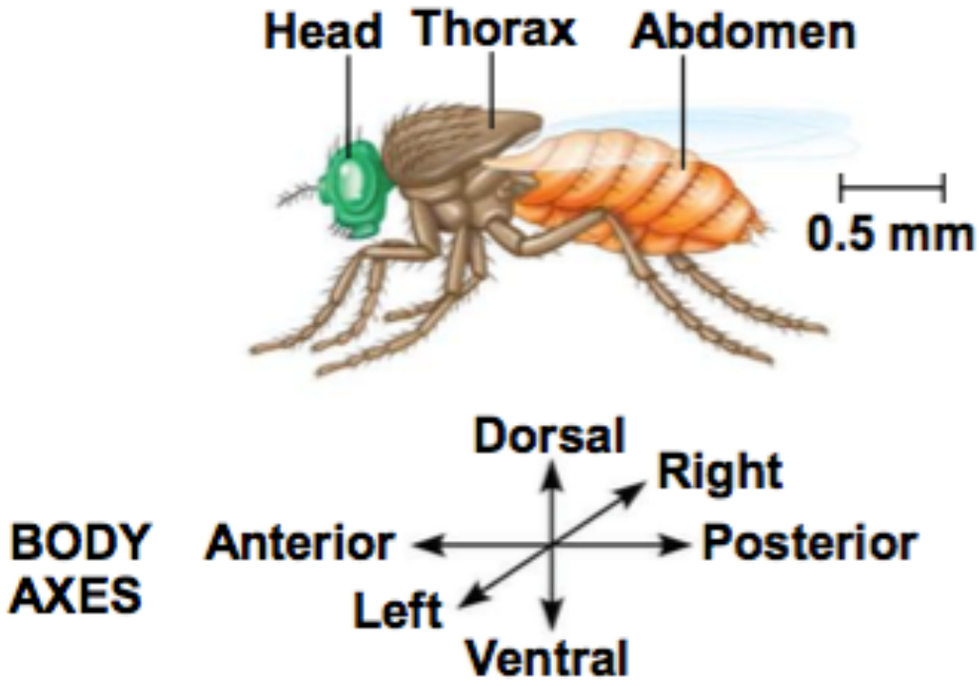
- In*Drosophila*,cytoplasmic determinants in the unfertilized egg determine the axes before fertilization

- After fertilization,the embryo develops into a segmented larva with three larval stages

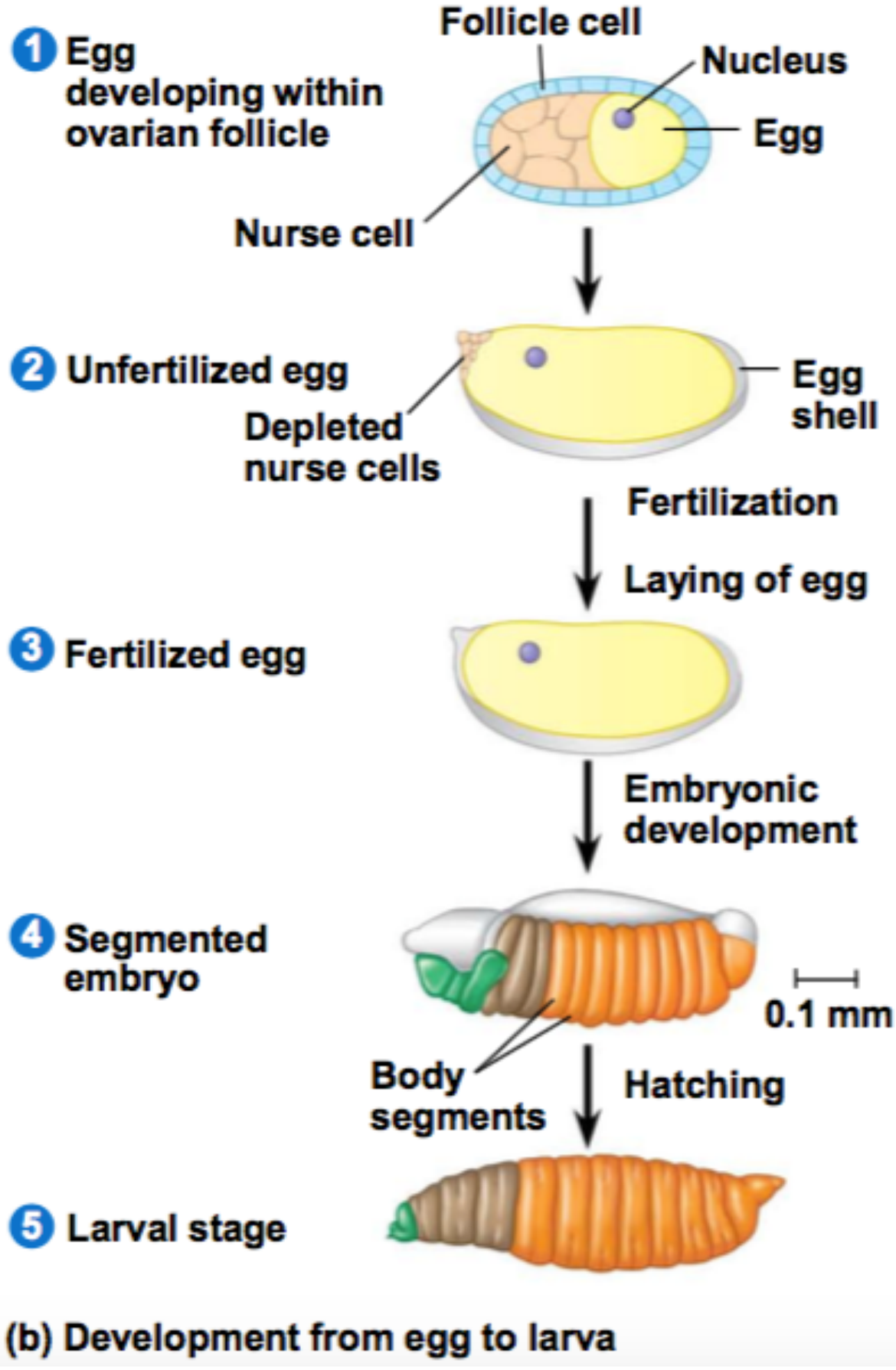
Genetic Analysis of Early Development: Scientific Inquiry

- EdwardB.Lewis,Christiane Nüsslein-Volhard, and Eric Wieschaus won a Nobel 1995 Prize for decoding pattern formation in *Drosophila*

- Lewis discovered the **homeotic genes**,which control pattern formation in late embryo, larva, and adult stages



(a) Adult

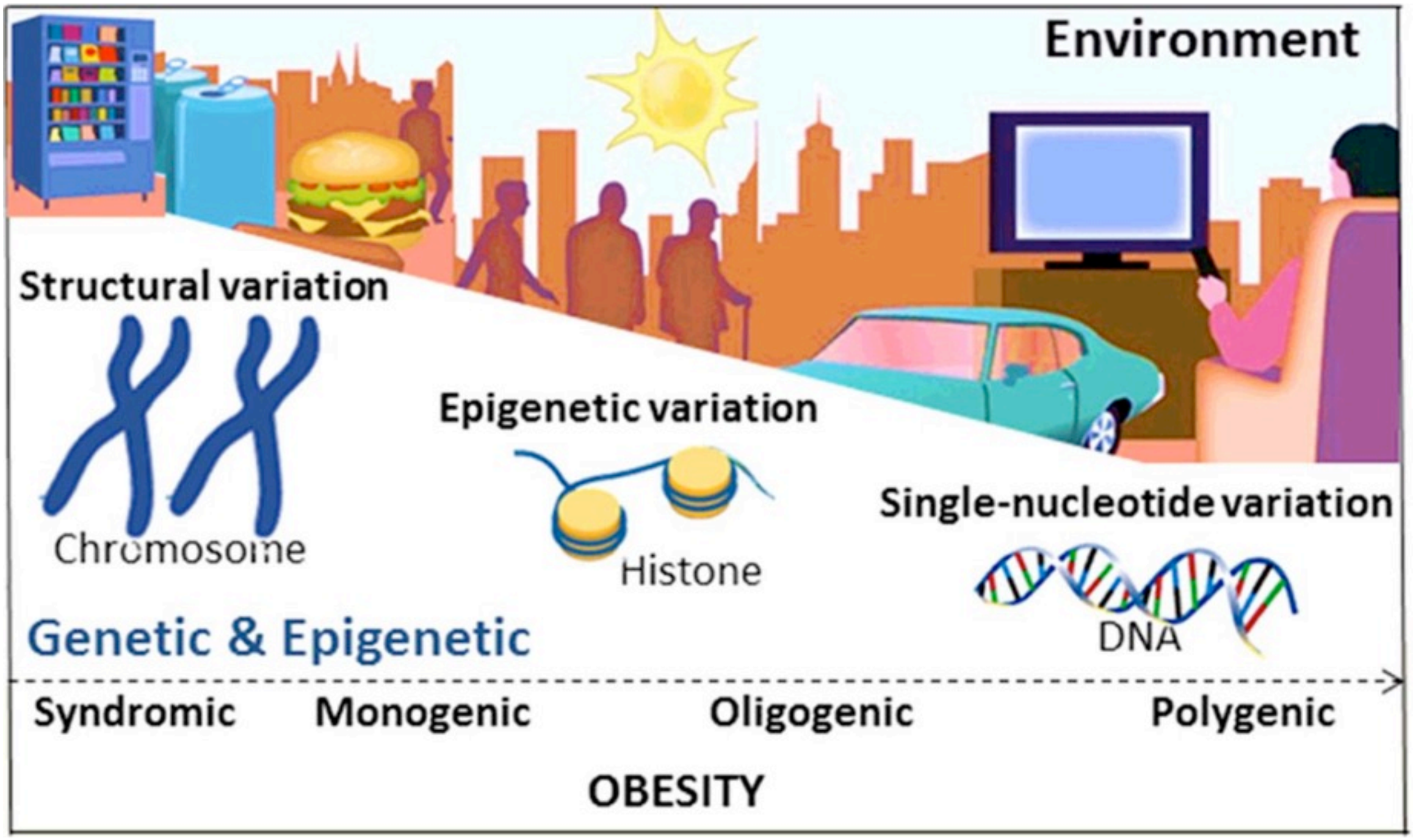


(b) Development from egg to larva

Essential knowledge 4.A.3: Interactions between external stimuli and regulated gene expression result in specialization of cells, tissues and organs.

c. Environmental stimuli can affect gene expression in a mature cell. [See also 3.B.1, 3.B.2]

Your behavior can affect gene expression, because environmental stimuli can cause cells to turn on and turn off certain genes.



What is Epigenetics?

- The study of changes in the way a gene is carried out without any actual changes to the DNA occurring
- Literally Epigenetics means “above genetics”

What does it do?

- Think of it this way, if the genome was a computer, the hardware of the computer, then the epigenome would be the soft ware of the computer. It tells the computer when to work, how to work and how much of that work to do.

The epigenome never actually does the work. The genome does the work that the epigenome tells it to do.

How it works.

- Methyl groups
  - (made of one carbon and three hydrogen atoms), latch onto DNA near a gene and tells it whether to express the trait or not
- Histones also play a part
  - Histones are a type of protein that genes coil around
  - Tightly wound= gene is expressed less
  - Loosely wound= gene is expressed more

Inheritance

So if you do something during your life that gives you a specific epigenome will it be passed down?

->

- Sometimes yes and sometimes no…
  - Some epigenetic tags stay in place when someone has offspring
    - This is epigenetic inheritance
  - Others are completely wiped away so the child can start from scratch

The difference is?

Genome

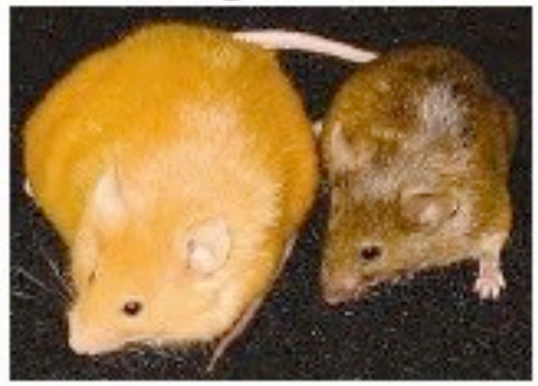
- Your actual gene
- Does the work assigned to it

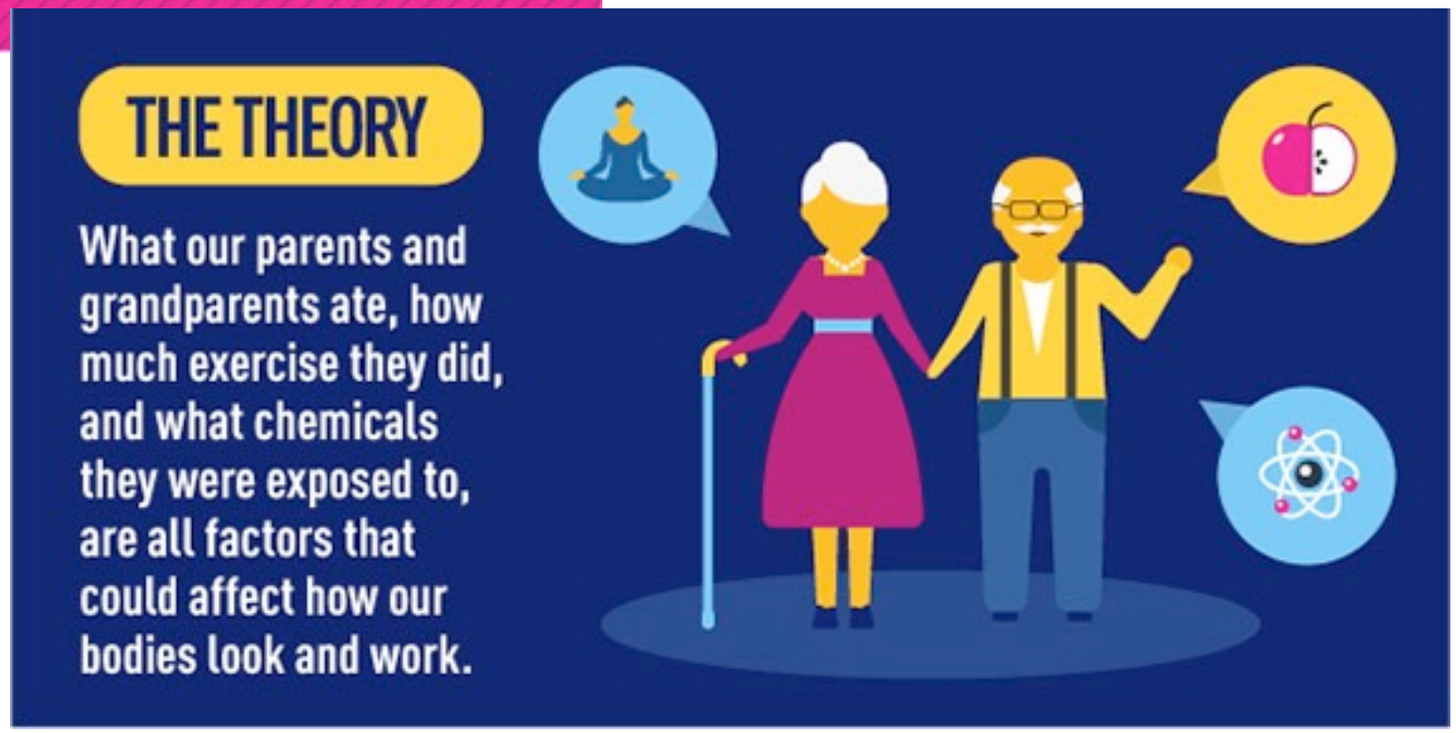
Epigenome

- Attaches itself to your gene
- Tells your gene what to do (like how to express a trait)

Example of this is:

- An experiment was done with genetically identical mice. Most were fat but some were skinny. Both these mice have a one gene called agouti but in the yellow mouse it stays on all of the time, and this causes obesity.
- So why is the thin mouse thin, if they are genetically identical?
  - Well, in the brown (thin) mouse there is a tiny chemical "tag" that has attached itself to the agouti gene shutting it down.
  - In order to get thin brown mice instead of fat yellow mice, you can feed the pregnant mothers a diet rich in methyl groups to form tags and ultimately turn the gene off. This dramatically shifted the coat color from yellow to brown and produced many more brown mice.
  - This is important because the coat color is a tracer, or an indicator that the gene is in fact turned off. This shift of the phenotype is called an epigenetic fix, and it was also inherited by the next generation of mice, regardless of what their mothers ate.



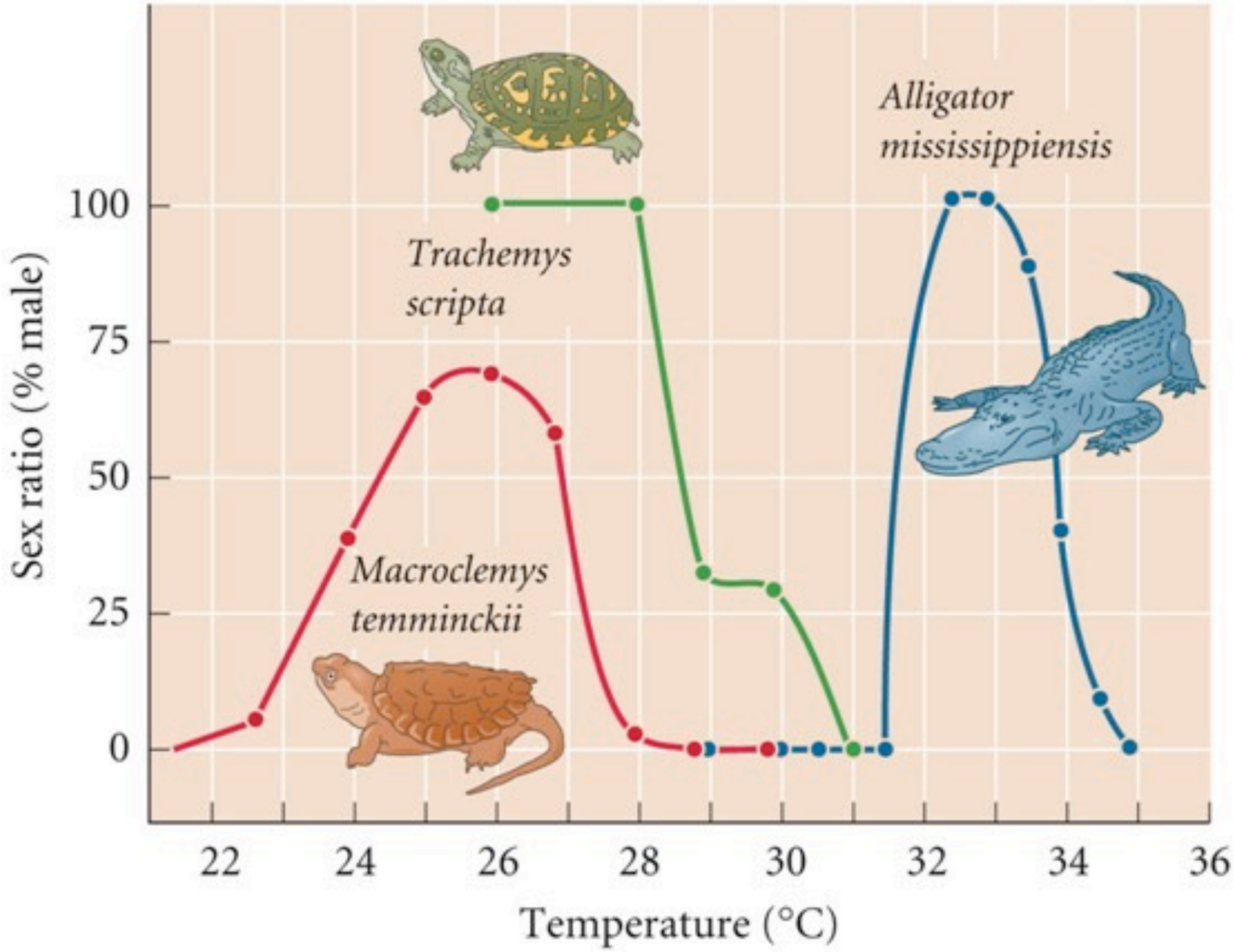


Thus your decisions today about what you eat, how much you exercise, etc can affect your children and grandchildren.

Another related example...

Temperature-dependent Sex Determination

- This is the condition where the sex of the offspring is influenced by the prevailing temperatures during embryonic development. In sea turtles, **warmer** temperatures produce more or all females, **cool** temperatures produce more or all males, and the **pivotal temperature** is the constant incubation temperature that produces equal numbers of males and females.



DEVELOPMENTAL BIOLOGY, 9e, Figure 14.22

Learning Objectives:

LO 4.7 The student is able to refine representations to illustrate how interactions between external stimuli and gene expression result in specialization of cells, tissues and organs. [See SP 1.3]