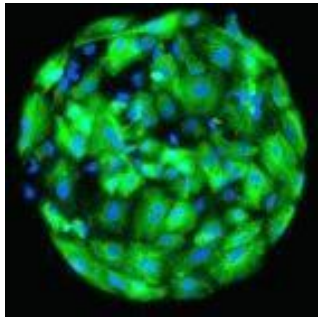
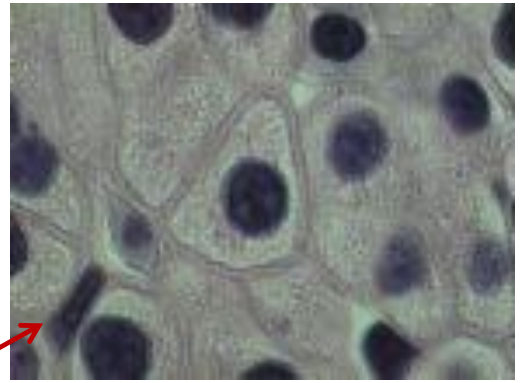
Gene Regulation / Expression in Eukaryotes & Prokaryotes (lac operon) HOX genes (body pattern development)

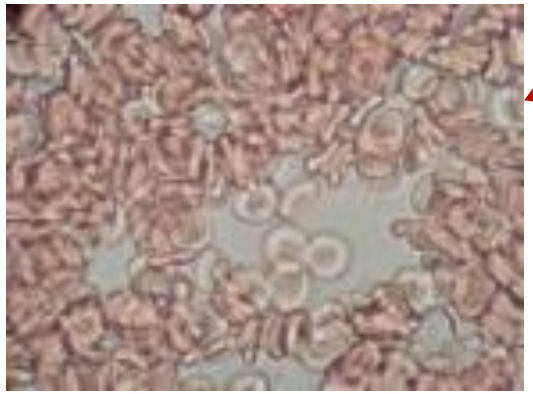
What makes cells from the same individual look and function differently?



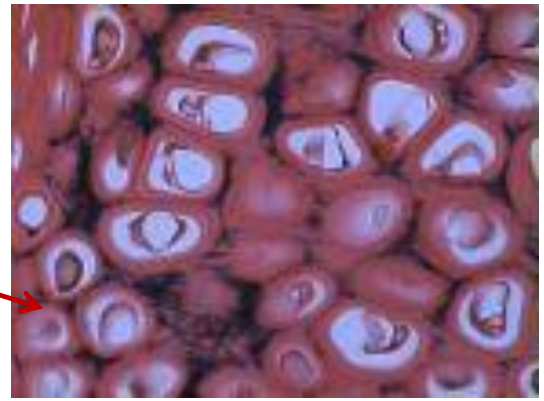
Stem Cells



Liver Cells

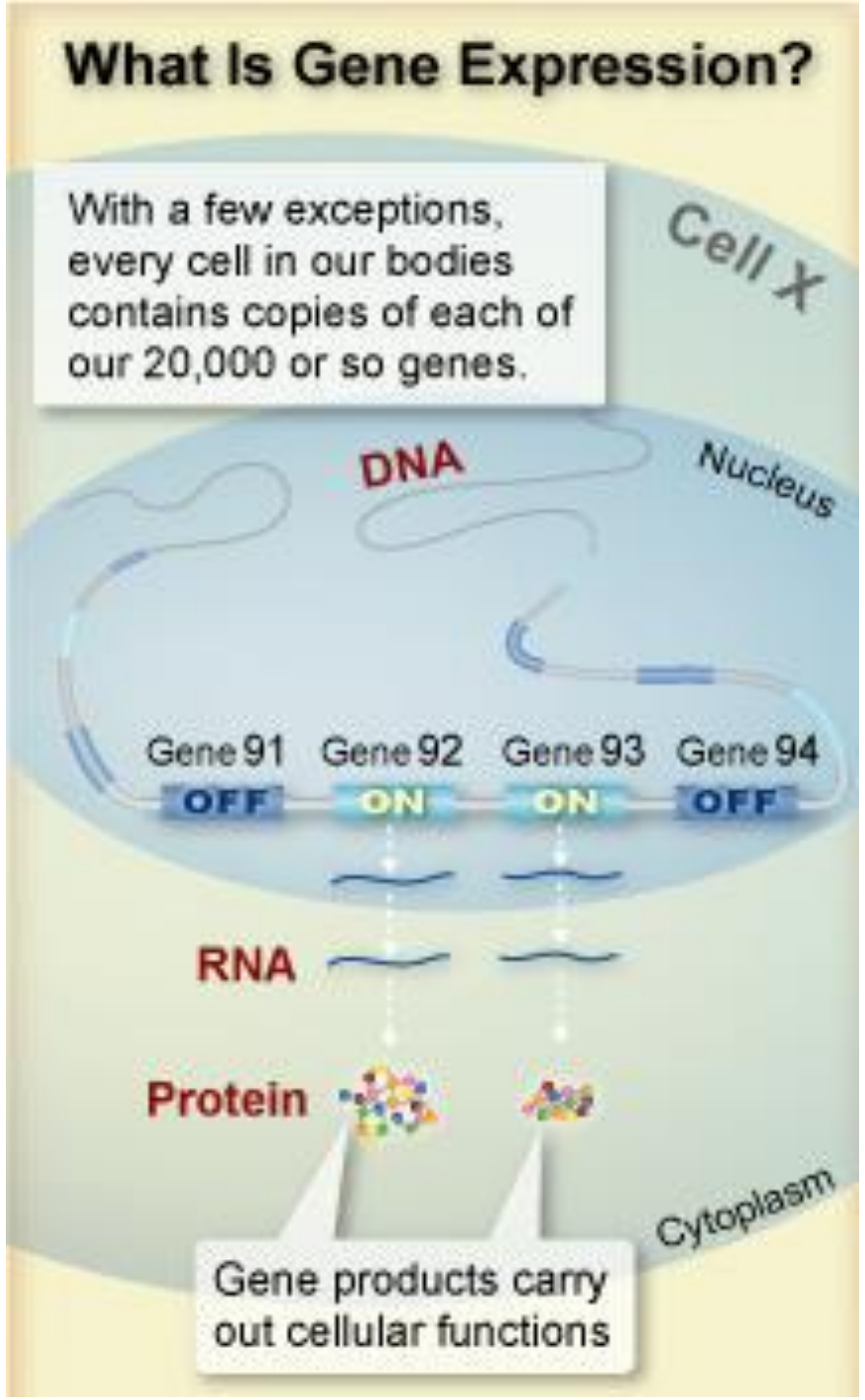


Red Blood Cells



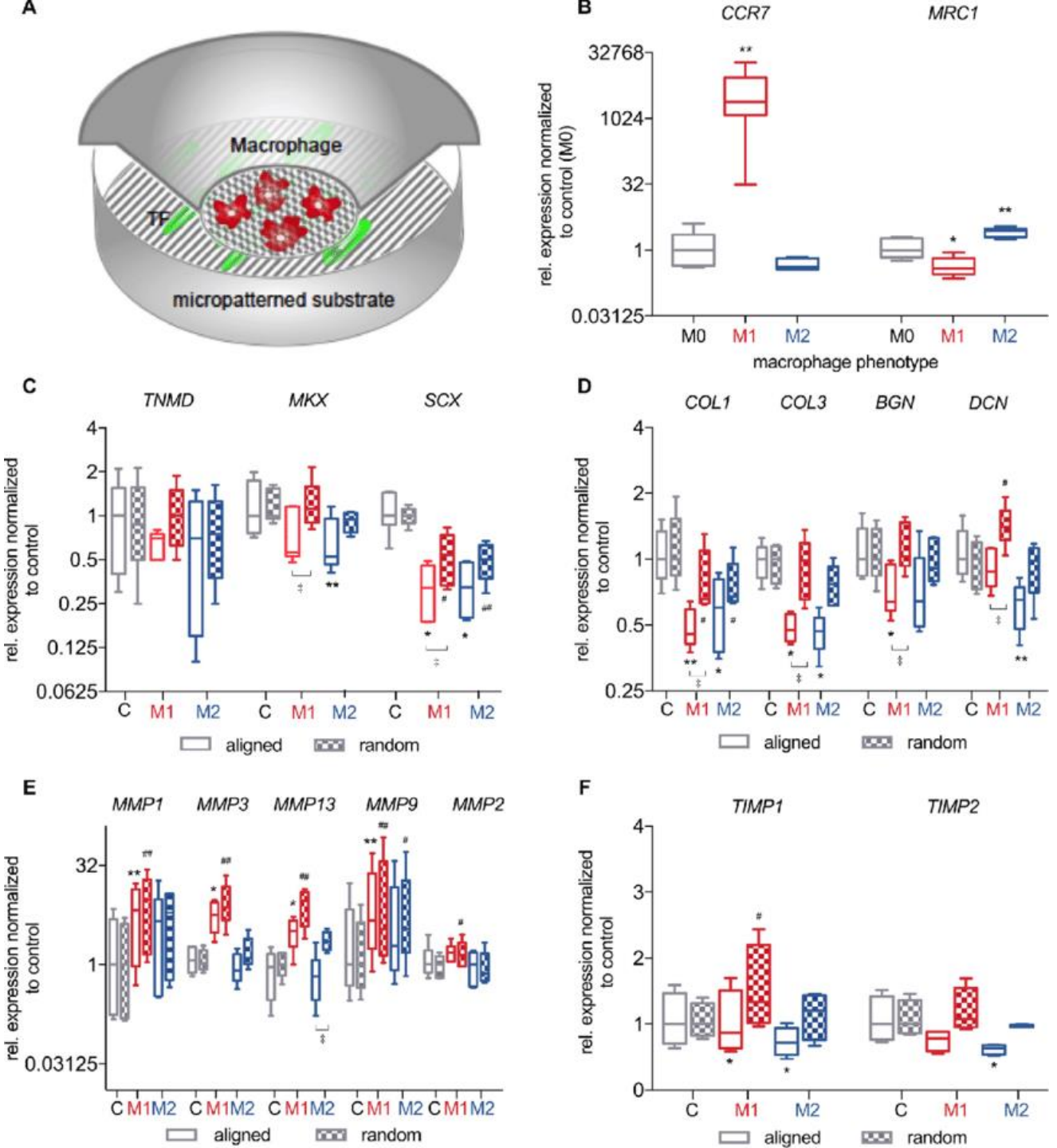
Cartilage Cells

DNA sequence in each cell is the same, but different cell types have different gene expression patterns.

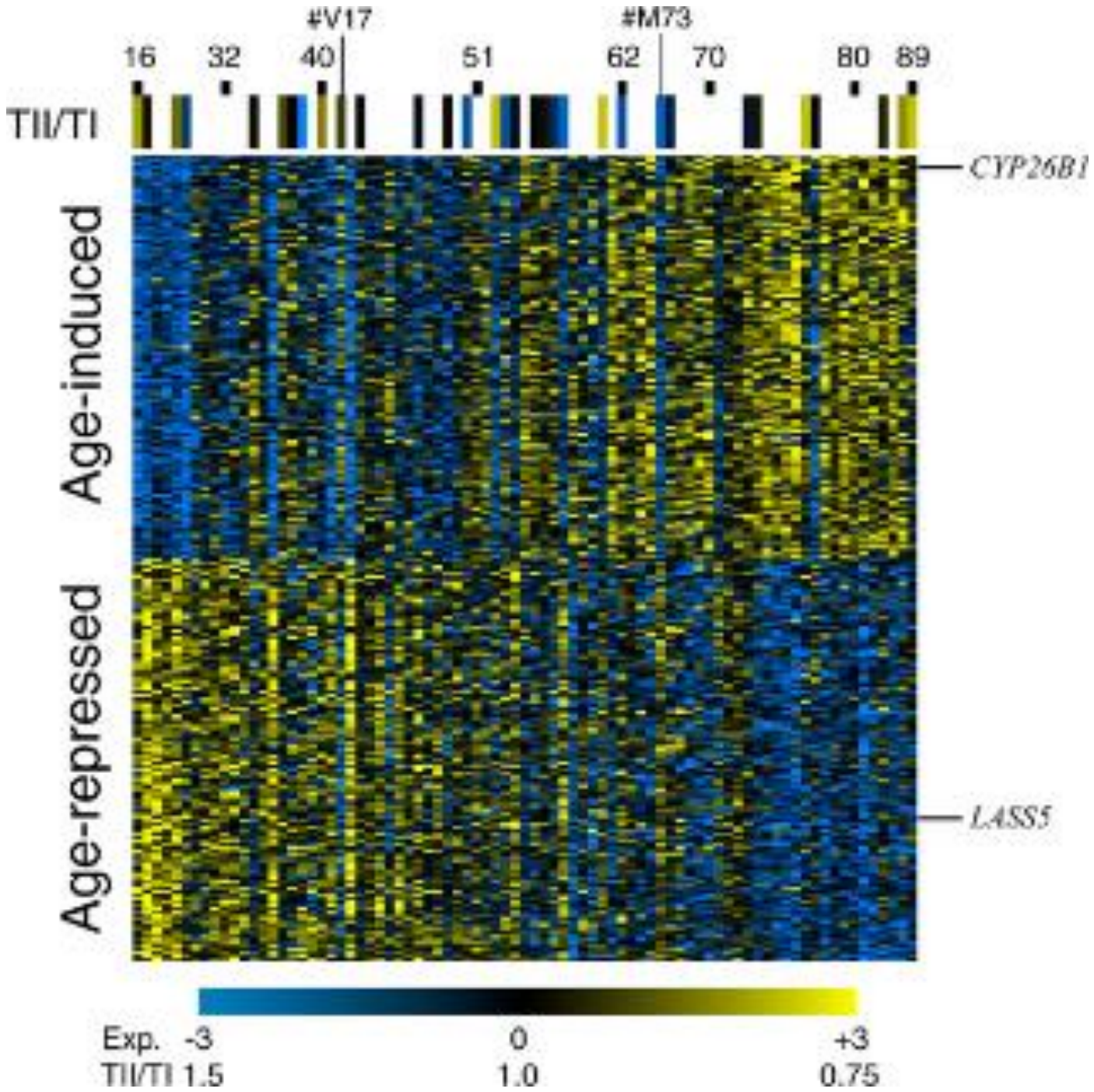


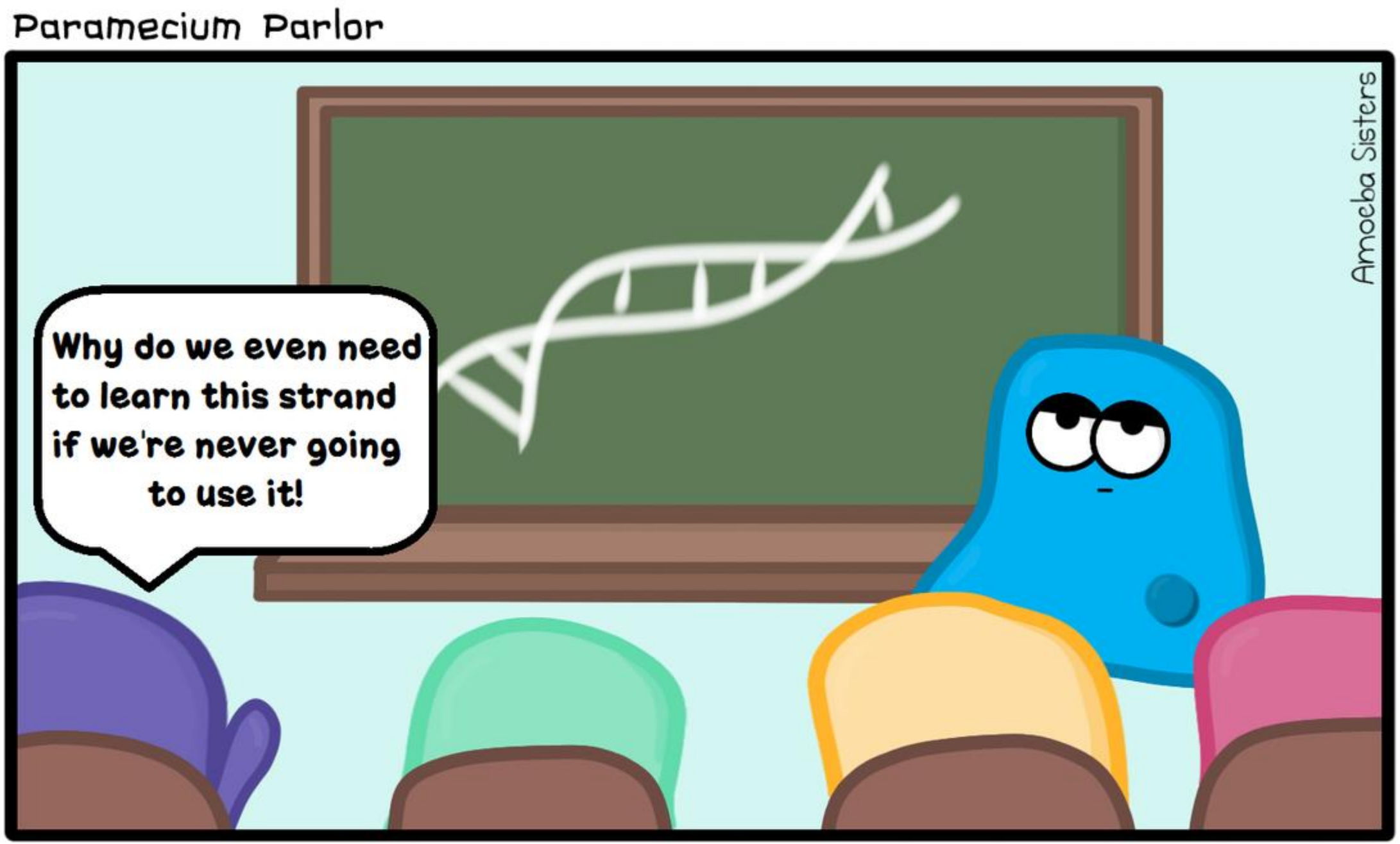
- When a gene is “on” and its protein is being made, scientists say that the gene is being EXPRESSED.
- The on and off states of a cell’s genes is known as a GENE EXPRESSION PROFILE.
- Each cell type has a unique gene expression profile.

Gene Expression Profile of Macrophages (white blood cells)



Gene Expression Profile of aging in human muscle cells

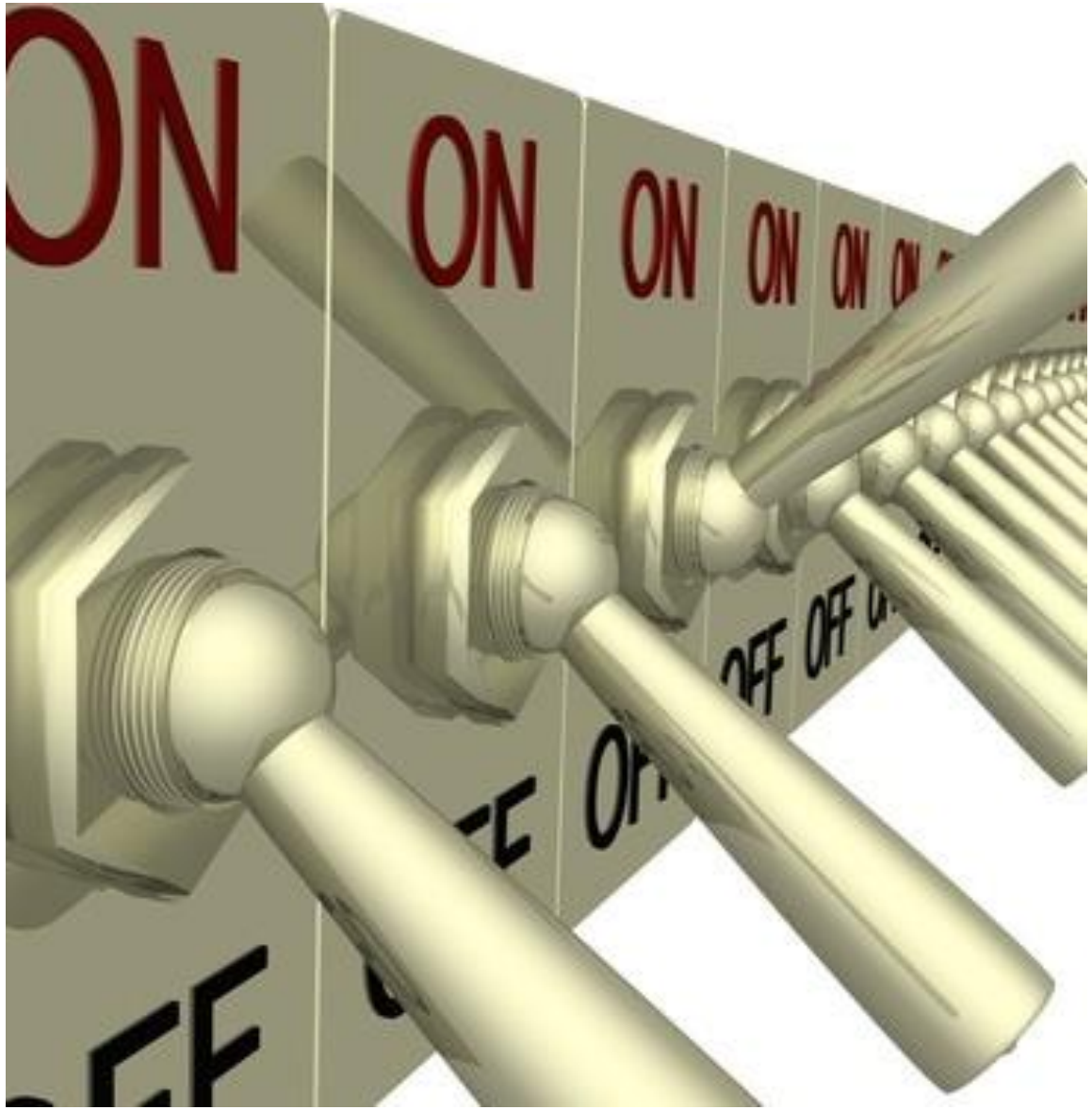




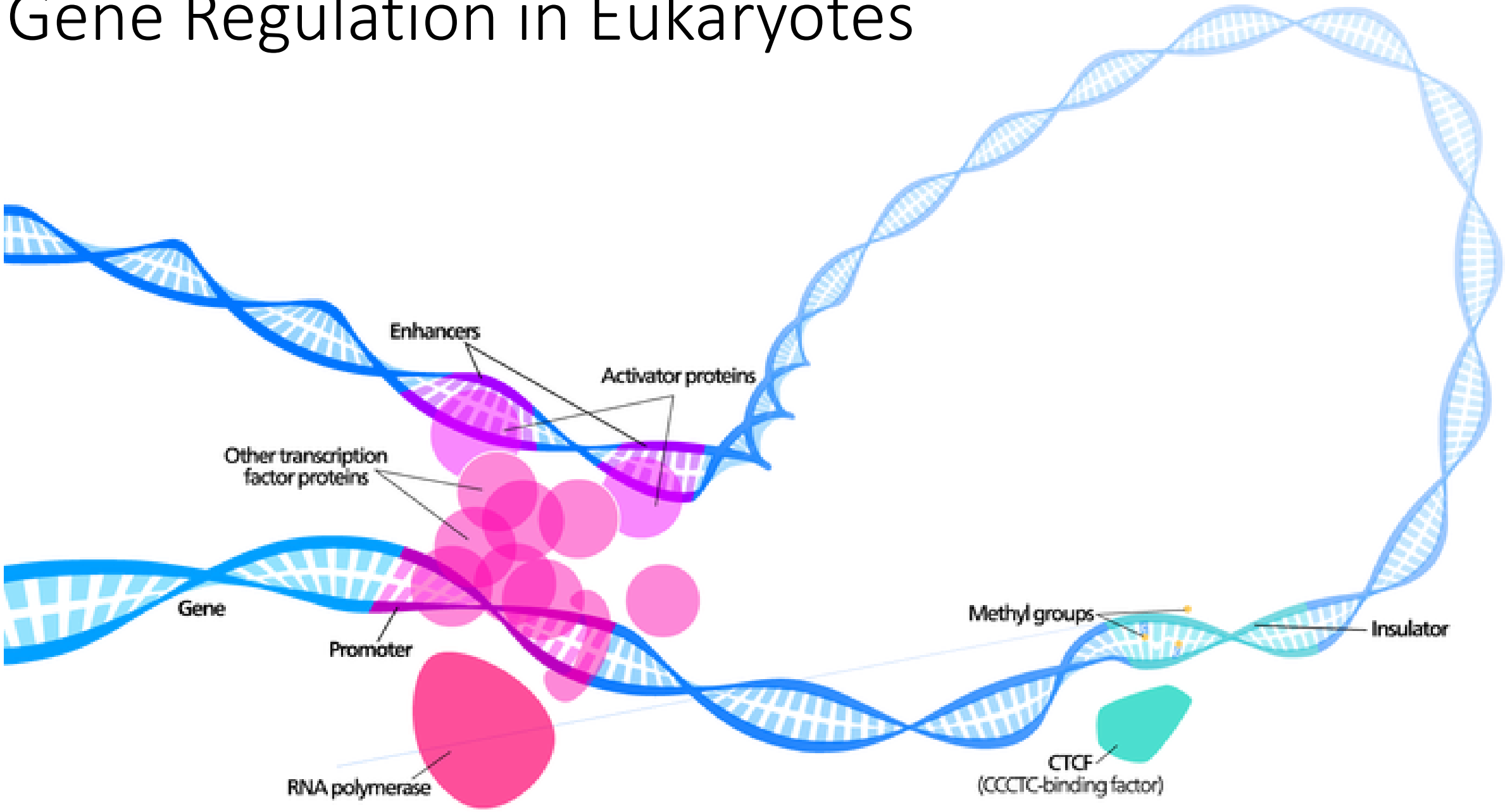
[Amoeba Sisters - Gene Regulation & Order of the Operon]

How do cells know what protein to make when?

<u>Gene Regulation:</u> ability of an organism to control which genes are transcribed.



Gene Regulation in Eukaryotes



Gene Regulation Vocab

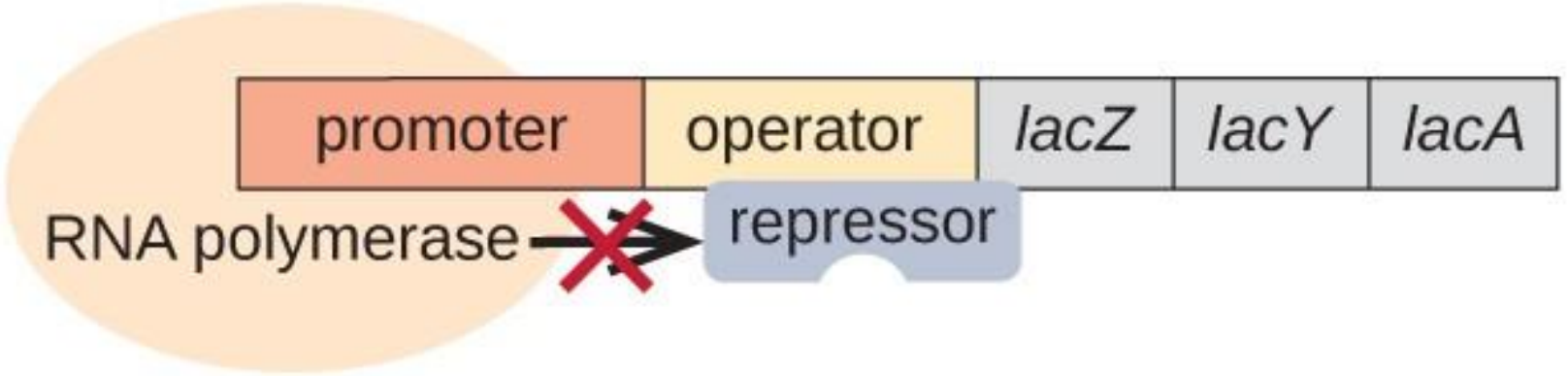
- **Regulatory gene** – gene (DNA sequence) that regulates another gene
- **Promotor** – regulatory sequence of DNA where RNA polymerase binds to initiate transcription of the gene (Ex. TATA box)
- **Transcription Factors** – regulatory proteins that increase or decrease the chance that a gene will be transcribed into RNA
  - Activator – increases transcription
  - Repressor – decreases transcription
- **RNA Polymerase** – enzyme that transcribes a gene (DNA) to form mRNA

Gene Regulation in an Operon (prokaryotes)

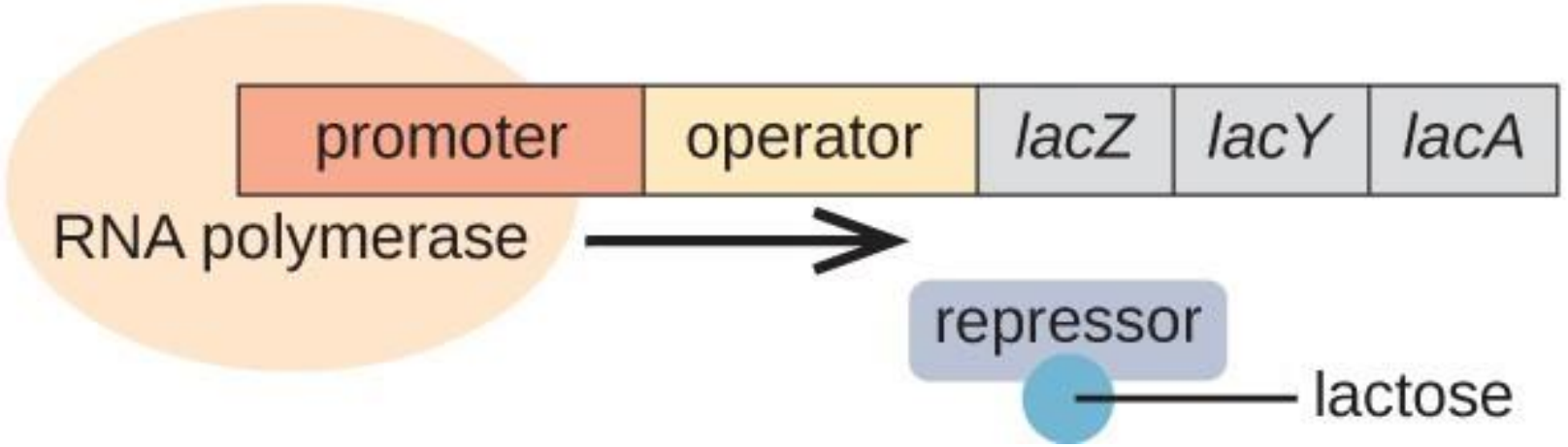
- **Operator** – between promotor and gene, like an on/off switch
- **Repressor** – protein that binds to the operator, blocking transcription
- **Lac Operon** – positive control (ON in the presence of lactose)
  - lactose binds to repressor, changing its shape, detaching it so that RNA polymerase can transcribe the lac genes to make lactose digesting enzymes
- **Trp Operon** – negative control (OFF in presence of tryptophan)
  - Tryptophan fits into the repressor, keeping it attached to the operator, blocking RNA polymerase from transcribing the trp genes when tryptophan is present

Lac Operon (positive control)

In the absence of lactose, the *lac* repressor binds the operator, and transcription is blocked.

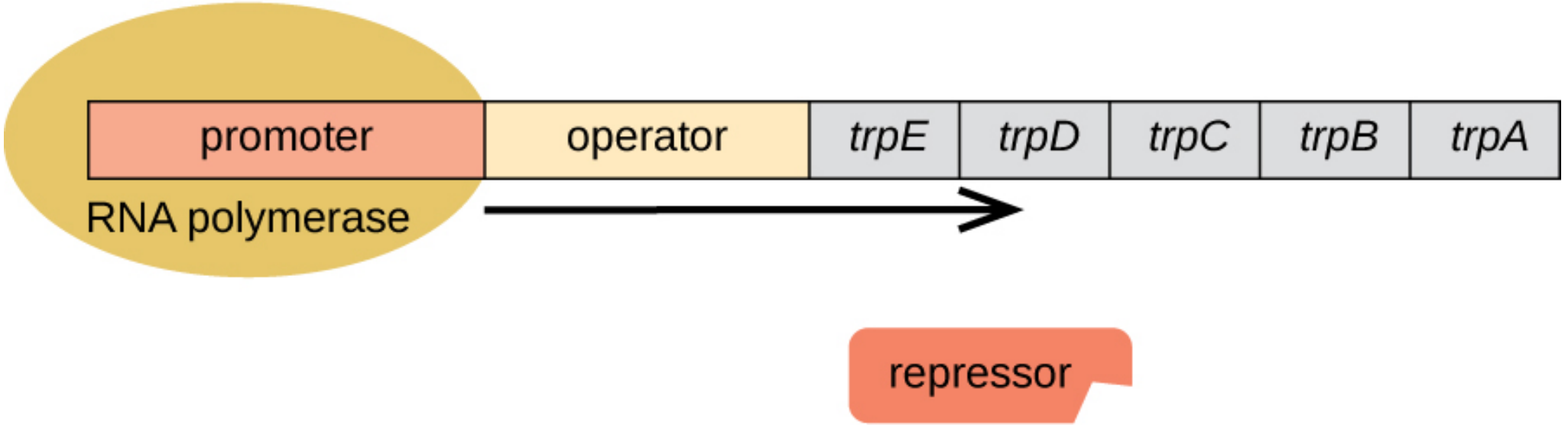


In the presence of lactose, the *lac* repressor is released from the operator, and transcription proceeds at a slow rate.

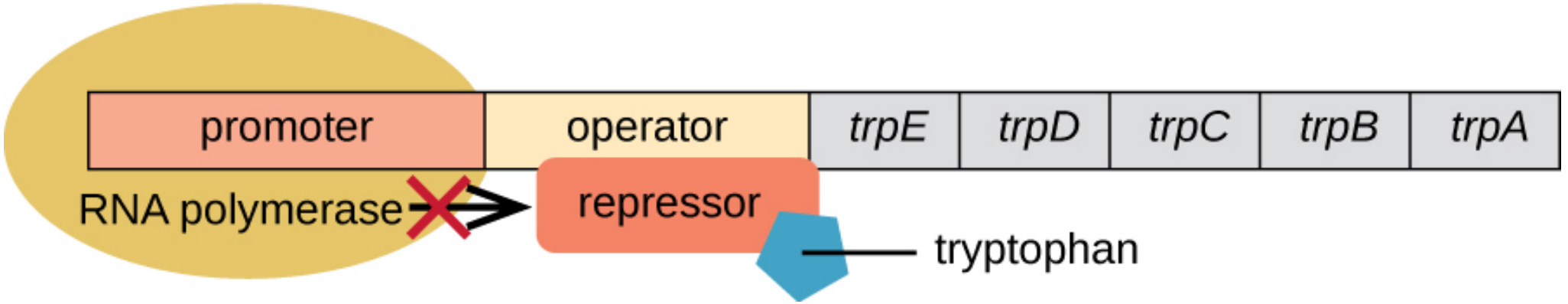


Trp Operon (negative control)

In the absence of tryptophan, the *trp* repressor dissociates from the operator, and RNA synthesis proceeds.



When tryptophan is present, the *trp* repressor binds the operator, and RNA synthesis is blocked.



Lesson

Interaction of Heredity & the Environment

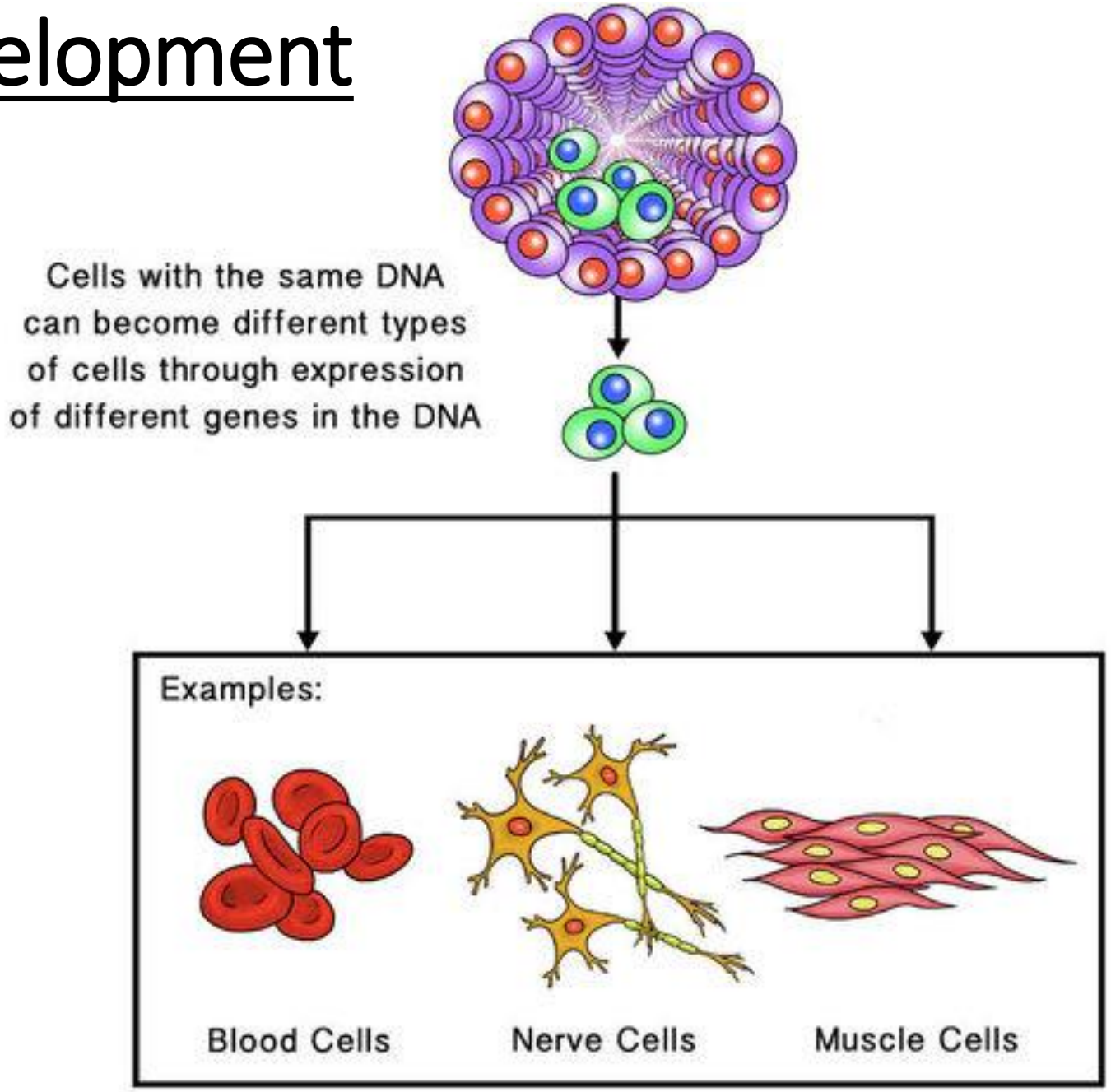
Environment Effects on Genes

- sunlight on skin
- light on chlorophyll production in plants
- temperature on rabbit hair color

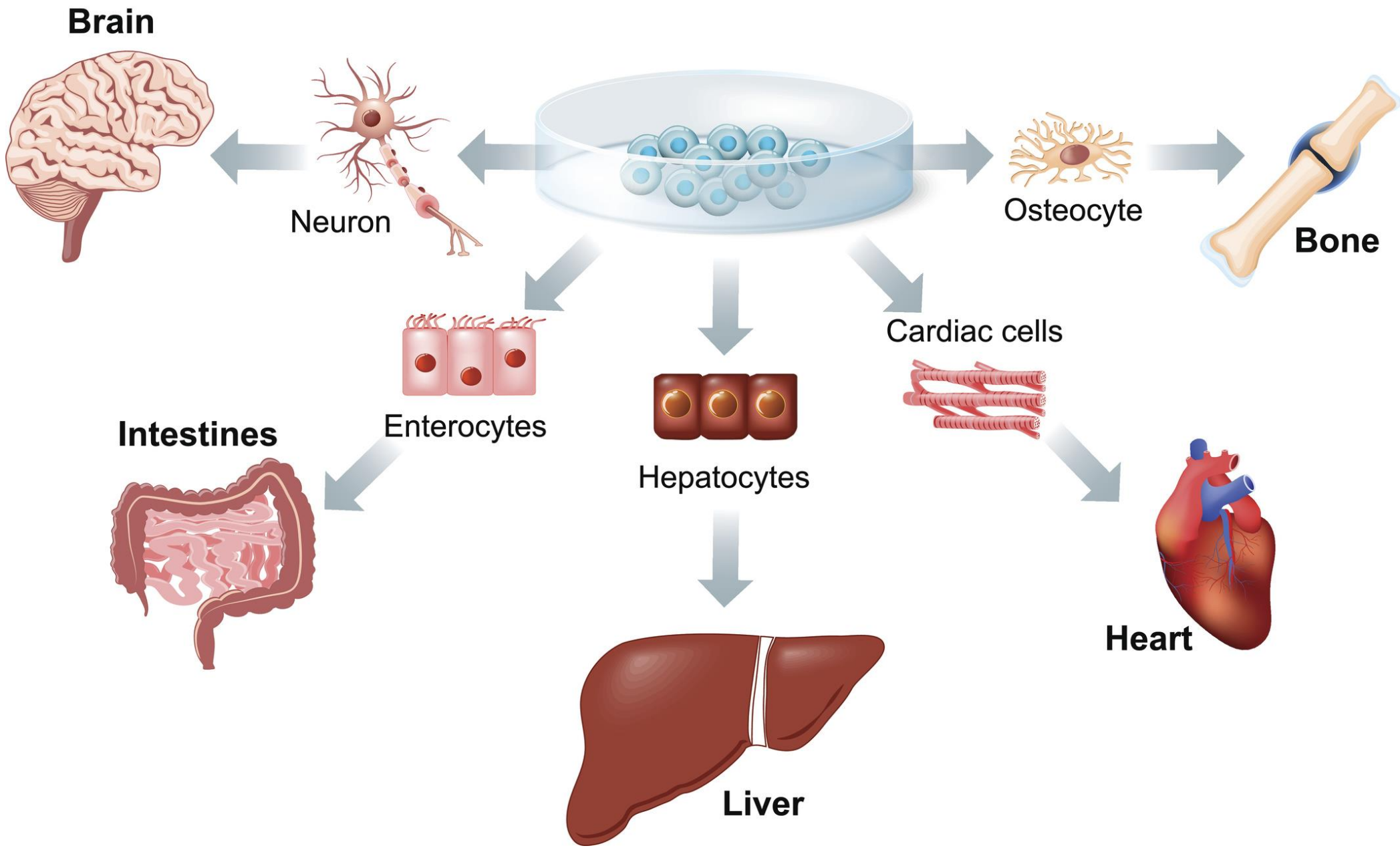
Epigenetics

Differentiation and Development

- Everyone develops from a zygote that undergoes mitosis
- **Cell differentiation:** cells become specialized
- Certain gene sequences determine cell differentiation

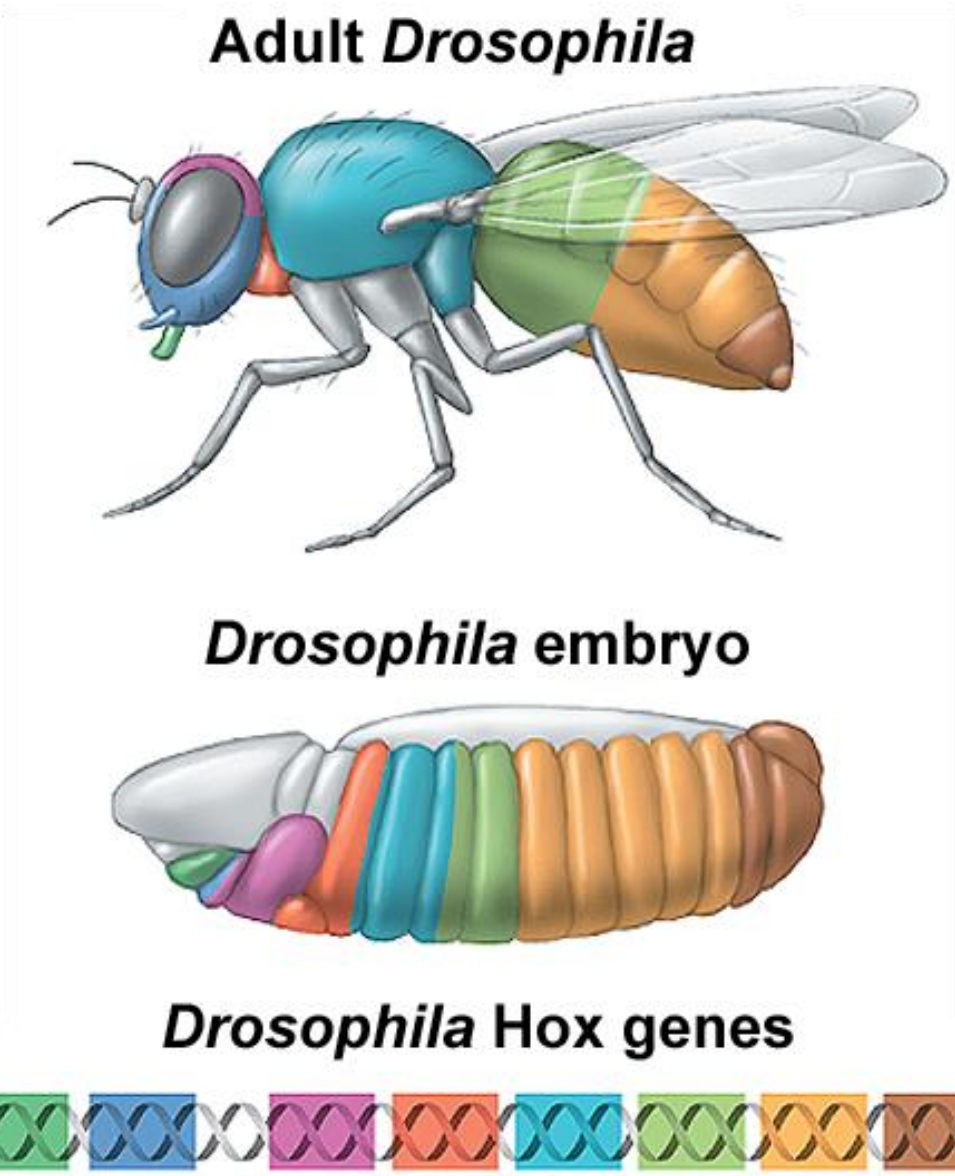


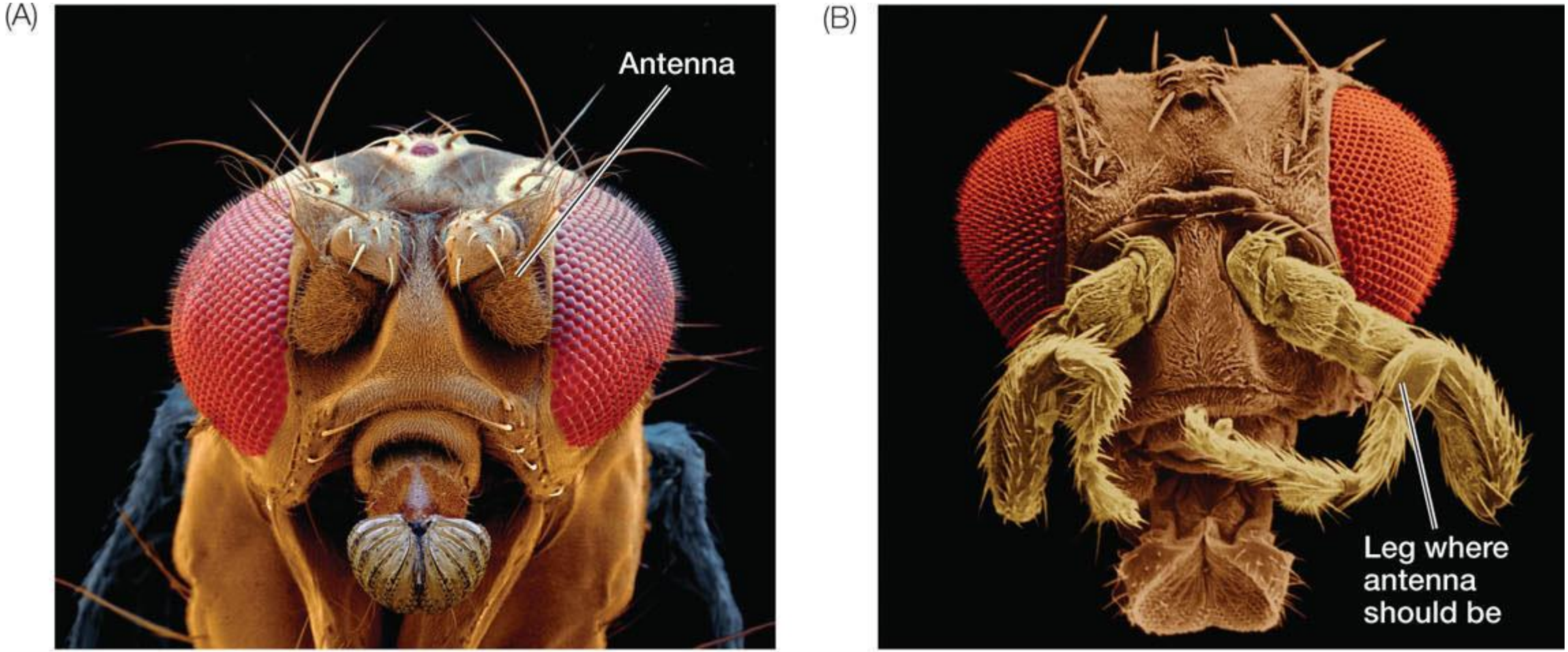
STEM CELL


Brain
Neuron
Osteocyte
Bone
Enterocytes
Cardiac cells
Intestines
Hepatocytes
Heart
Liver

HOX Genes (Homeobox genes)

- Developmental regulatory genes responsible for the general body pattern of most animals
- are transcribed at specific times, and located in specific places on the genome
- Evolutionary Developmental Biology (Evo-Devo) studies genetic influences of development and its similarities between species





14.14A: © Eye of Science/ Science Source. 14.14B: © Science VU/ Dr. F. Rudolph Turner/Visuals Unlimited, Inc.

[Evolutionary Development - Chicken Teeth Crash Course Biology (11min)]

[Video - Evo Devo song by A Capella Science (3:45)]

Environmental Effects on Gene Expression

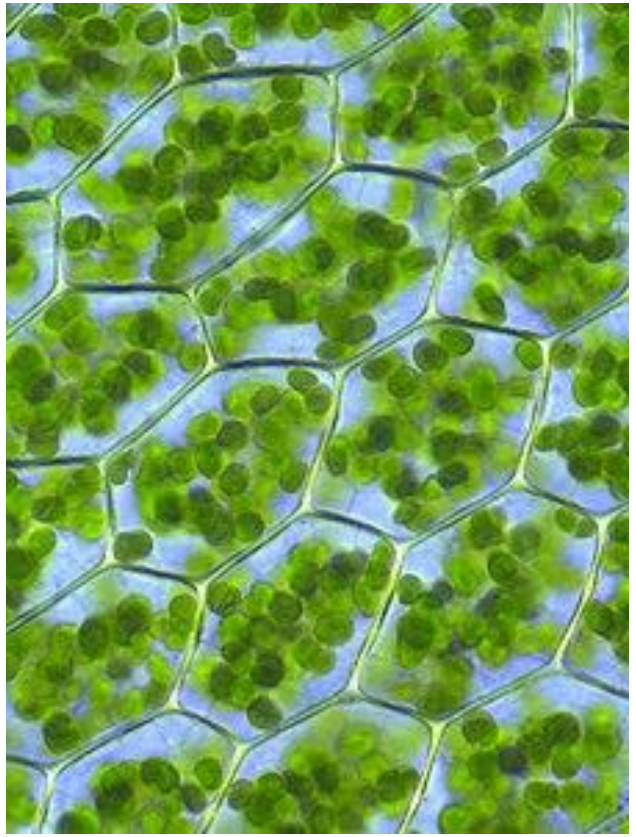
Environmental Effects on Gene Expression

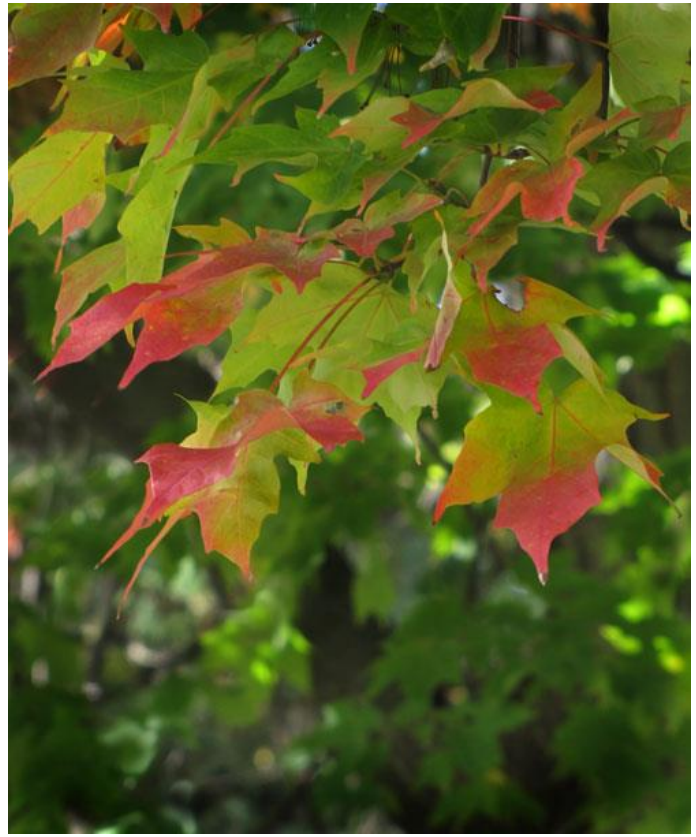
Example 1: Sunlight (UV rays) on Skin Color

- Increased exposure to sunlight (UV rays) increases production of skin pigment melanin

Example 2: Effect of Light on Chlorophyll Production

- With more light available, plants turn green because more chlorophyll is produced





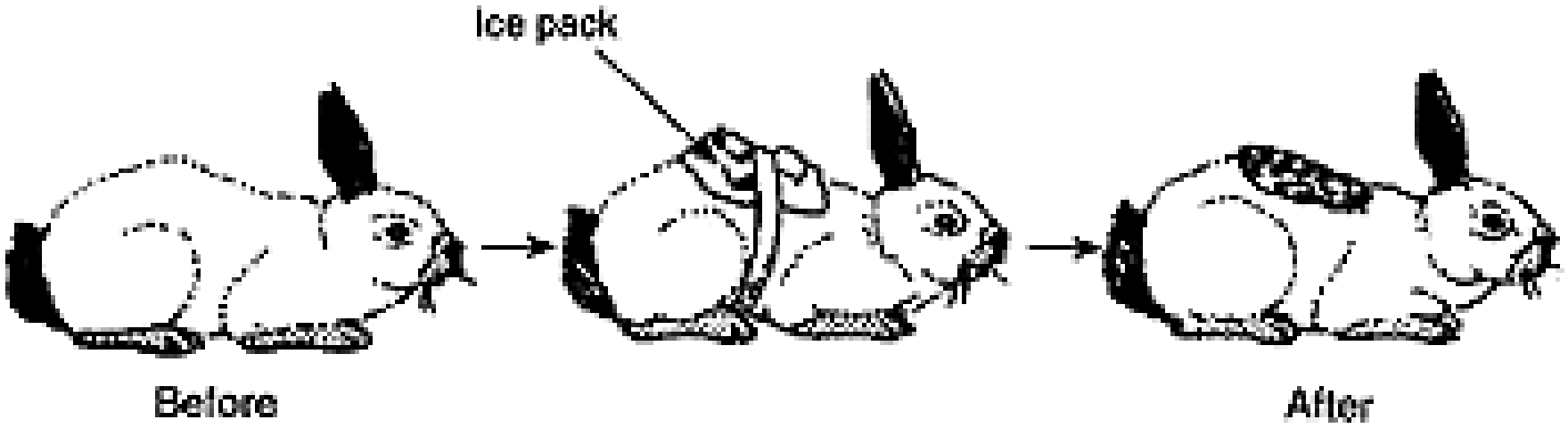
Example 3: Sex Determination in some organisms

- Temperature, weather, or location is the determining factor in some organisms

Video (start at 3:10)

Example 4: Effect of Temperature on hair color in the Himalayan rabbit

- Ice applied to white-haired area causes it to grow black



Example 5: Identical Twin Studies

- identical twins may have differences in height, weight, intelligence due to:
  - diet
  - altitude
  - exposure to chemicals, radiation, education, gravity, etc.

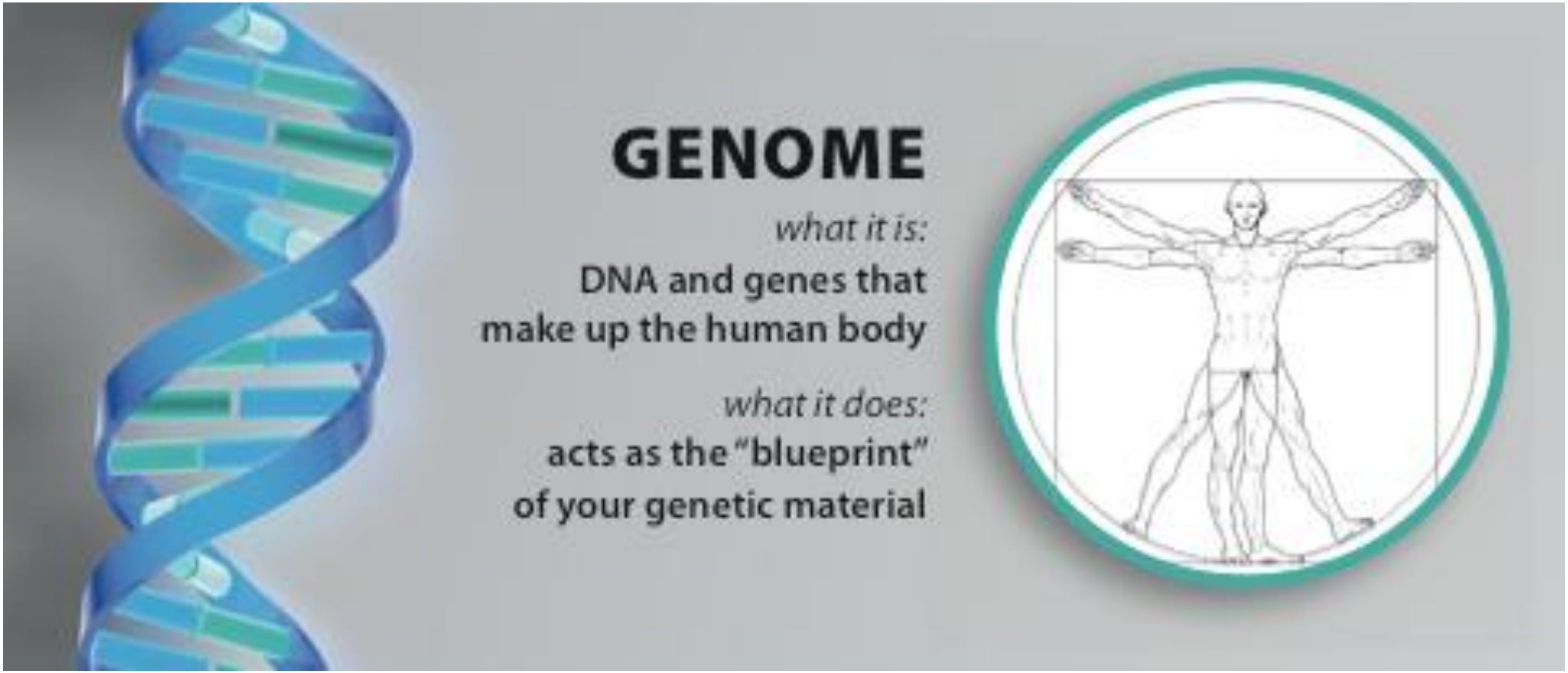
Video - Astronaut Twins news by Inside Edition

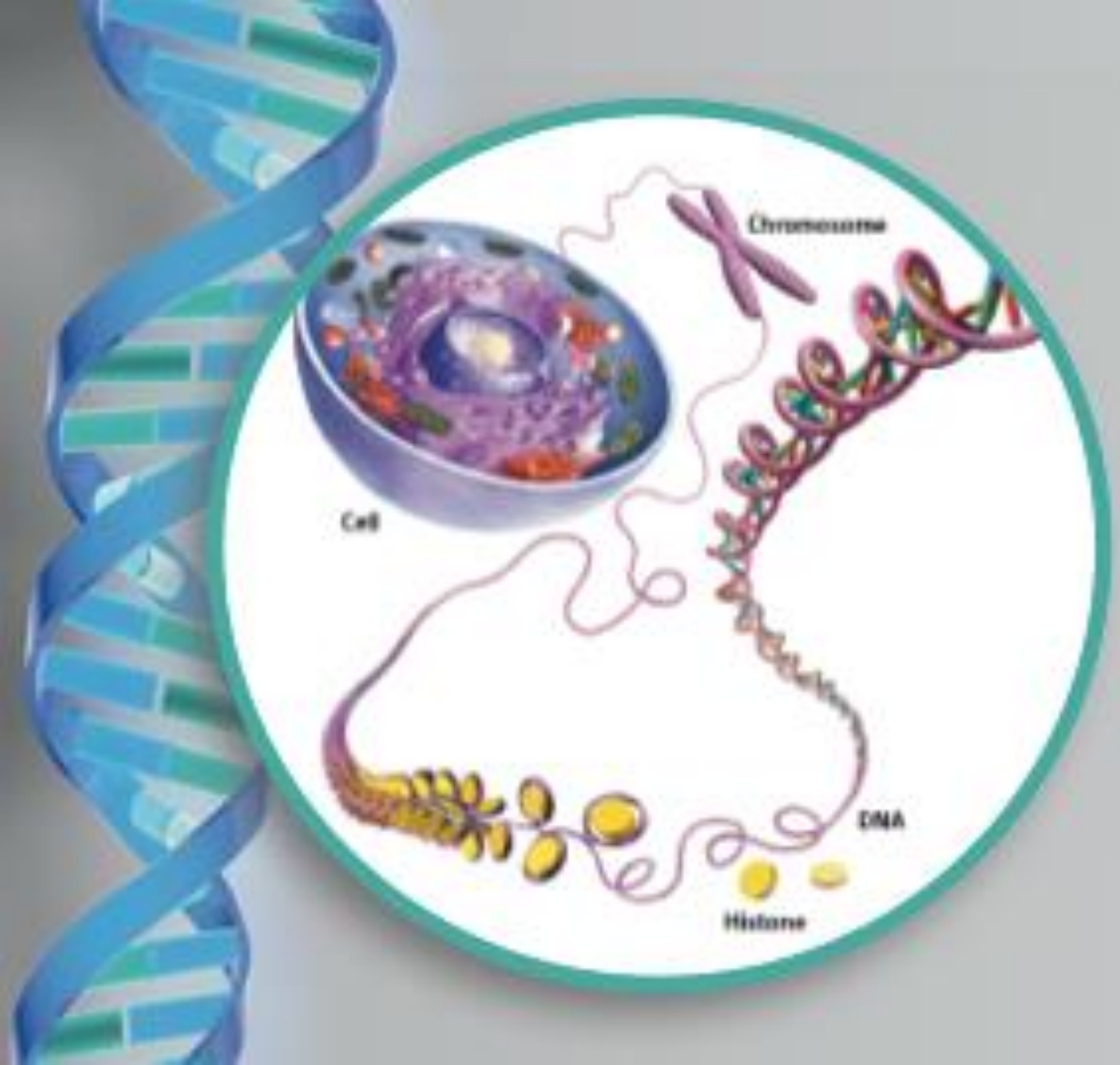
Epigenetics

- the study of potentially heritable changes in gene expression
- does NOT involve changes to the DNA sequence
- a change in phenotype without a change in genotype
- affects how cells read the genes

Video - Epigenetics (brief animated explanation)

Video - Epigenetics Ted Talk


GENOME
what it is:
DNA and genes that
make up the human body
what it does:
acts as the "blueprint"
of your genetic material



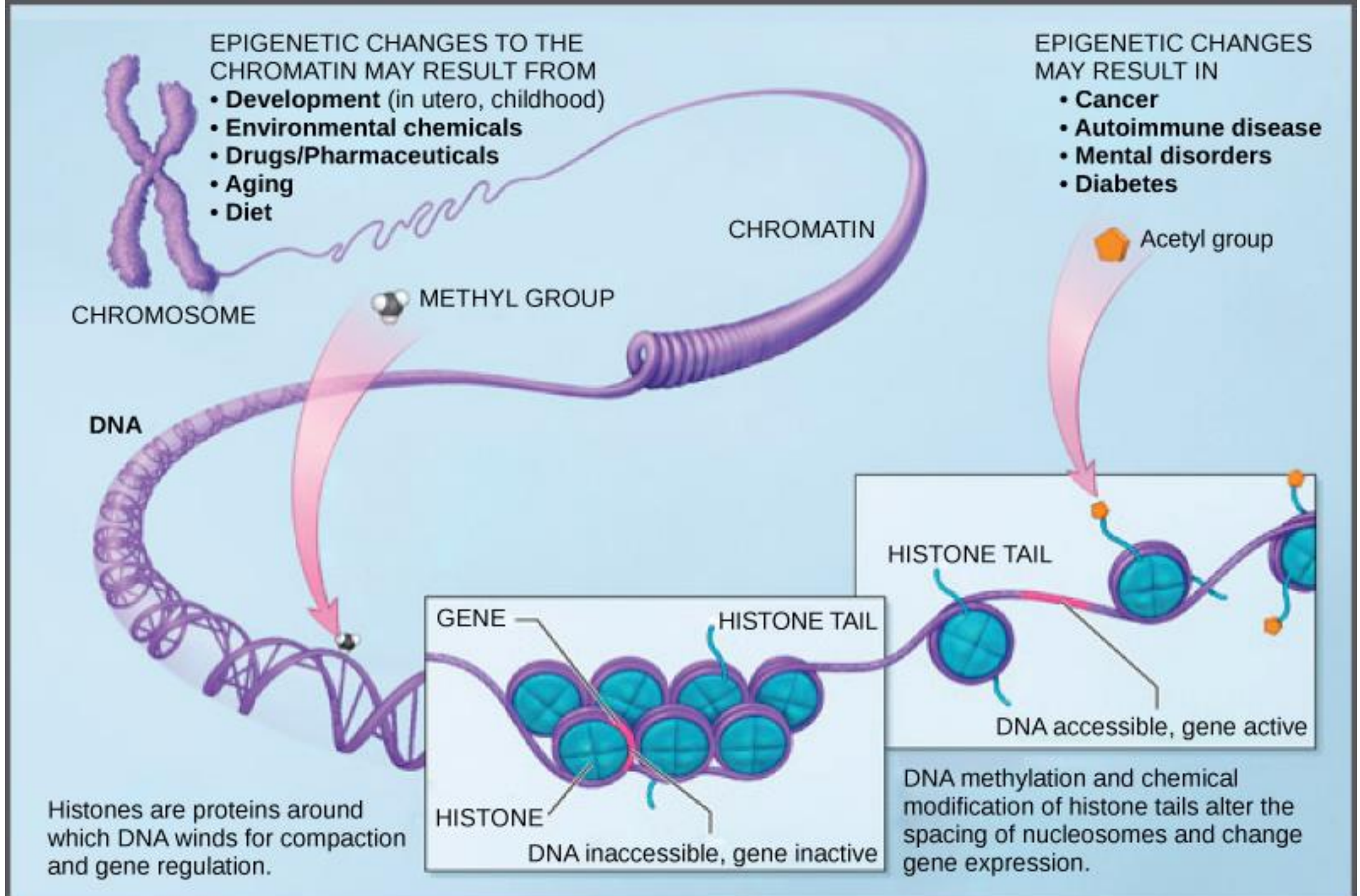
EPIGENOME

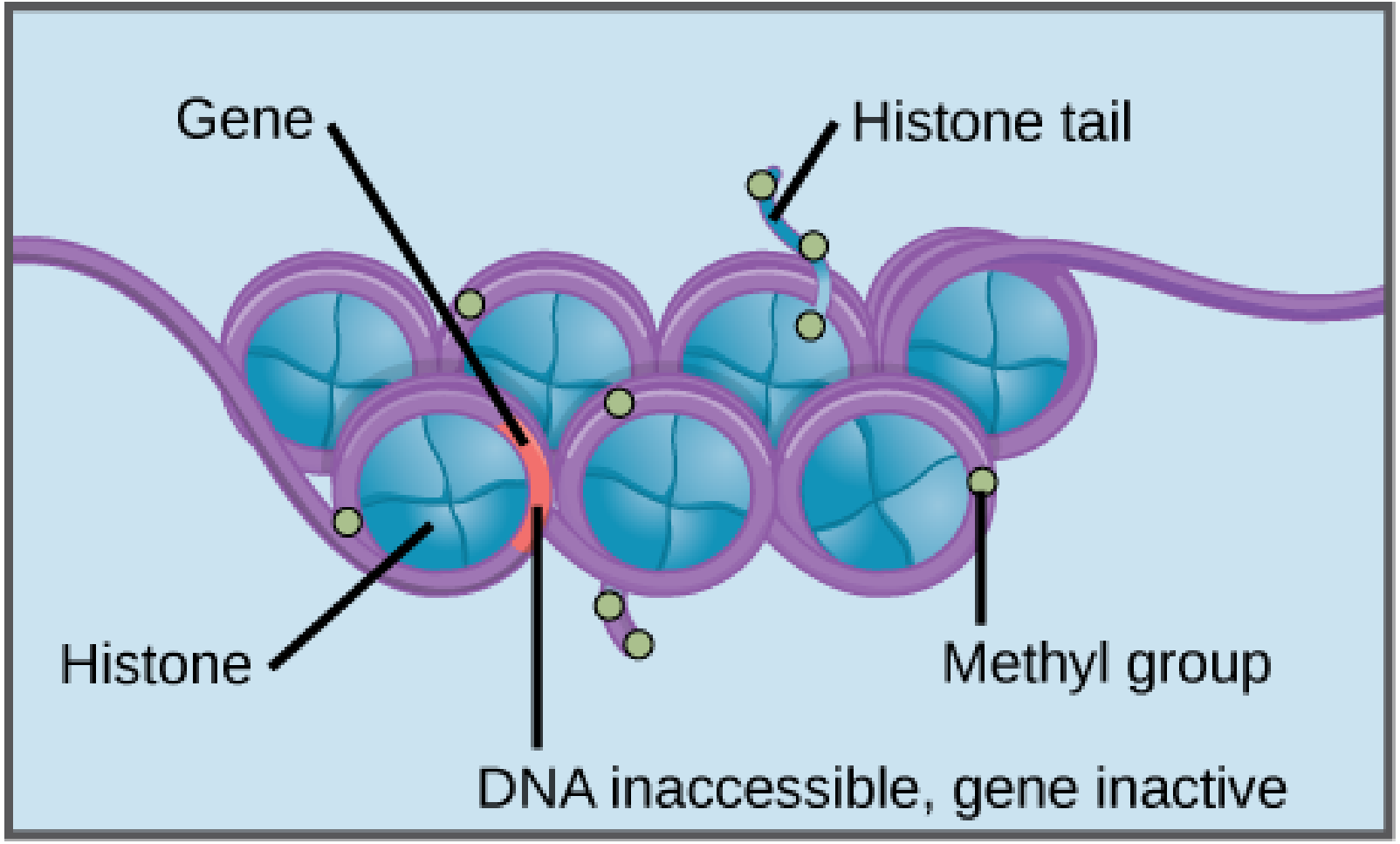
what it is:

histones – DNA packaging material; and methyl – chemical compounds formed by the nutrition you consume

what it does:

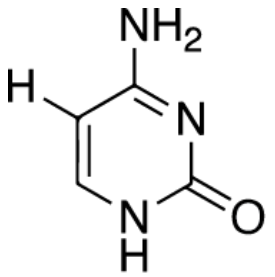
tells the DNA which genes to turn off and on and how to create different types of cells (skin cells, liver cells, etc.) through the epigenetic processes of methylation and histone modification


EPIGENETIC CHANGES TO THE CHROMATIN MAY RESULT FROM
• Development (in utero, childhood)
• Environmental chemicals
• Drugs/Pharmaceuticals
• Aging
• Diet
EPIGENETIC CHANGES MAY RESULT IN
• Cancer
• Autoimmune disease
• Mental disorders
• Diabetes
CHROMOSOME
CHROMATIN
METHYL GROUP
Acetyl group
DNA
HISTONE TAIL
GENE
HISTONE TAIL
HISTONE
DNA inaccessible, gene inactive
DNA accessible, gene active
Histones are proteins around which DNA winds for compaction and gene regulation.
DNA methylation and chemical modification of histone tails alter the spacing of nucleosomes and change gene expression.

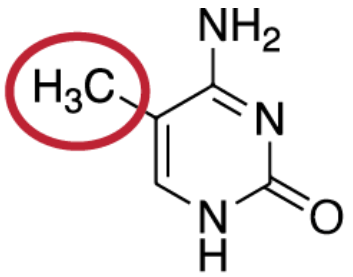


Methylation

Methylation of DNA and histones causes nucleosomes to pack tightly together. Transcription factors cannot bind the DNA, and genes are not expressed.



Cytosine

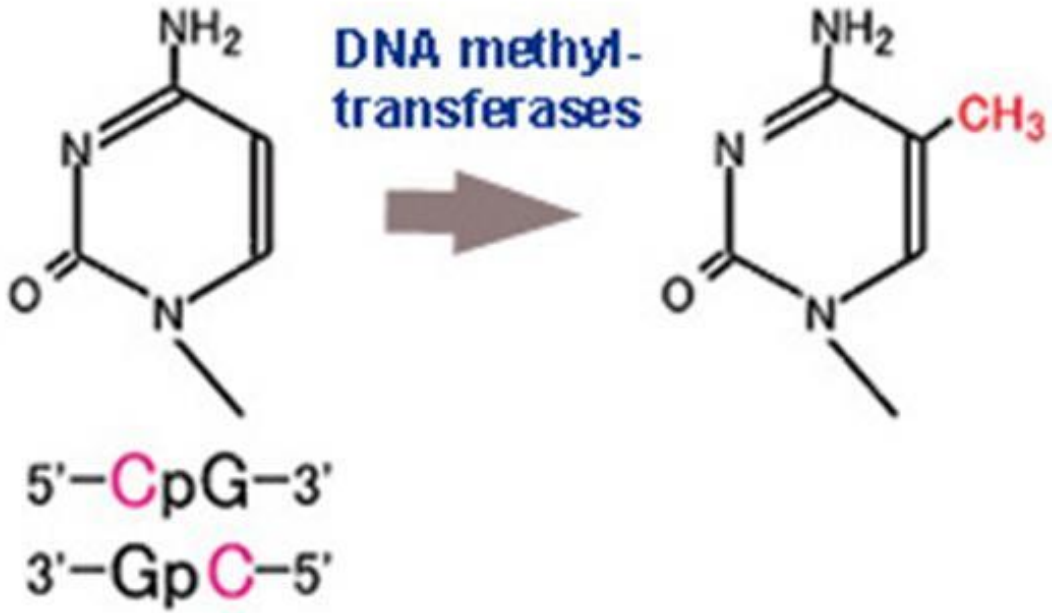


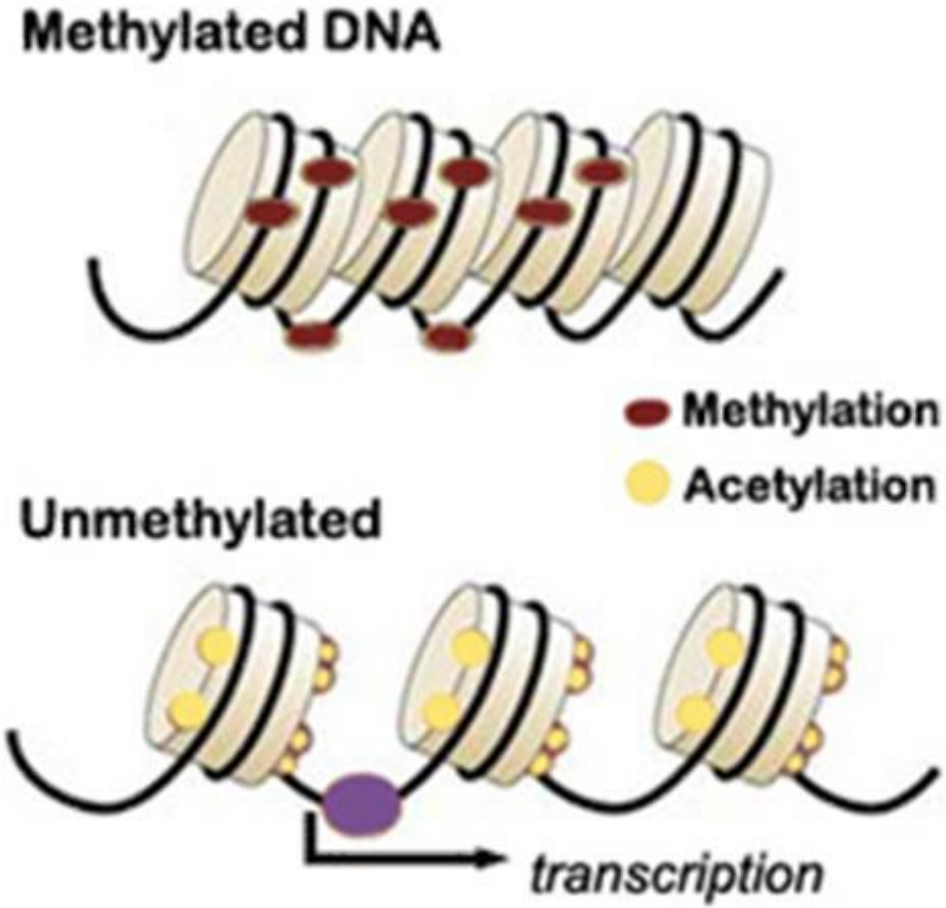
methylated Cytosine

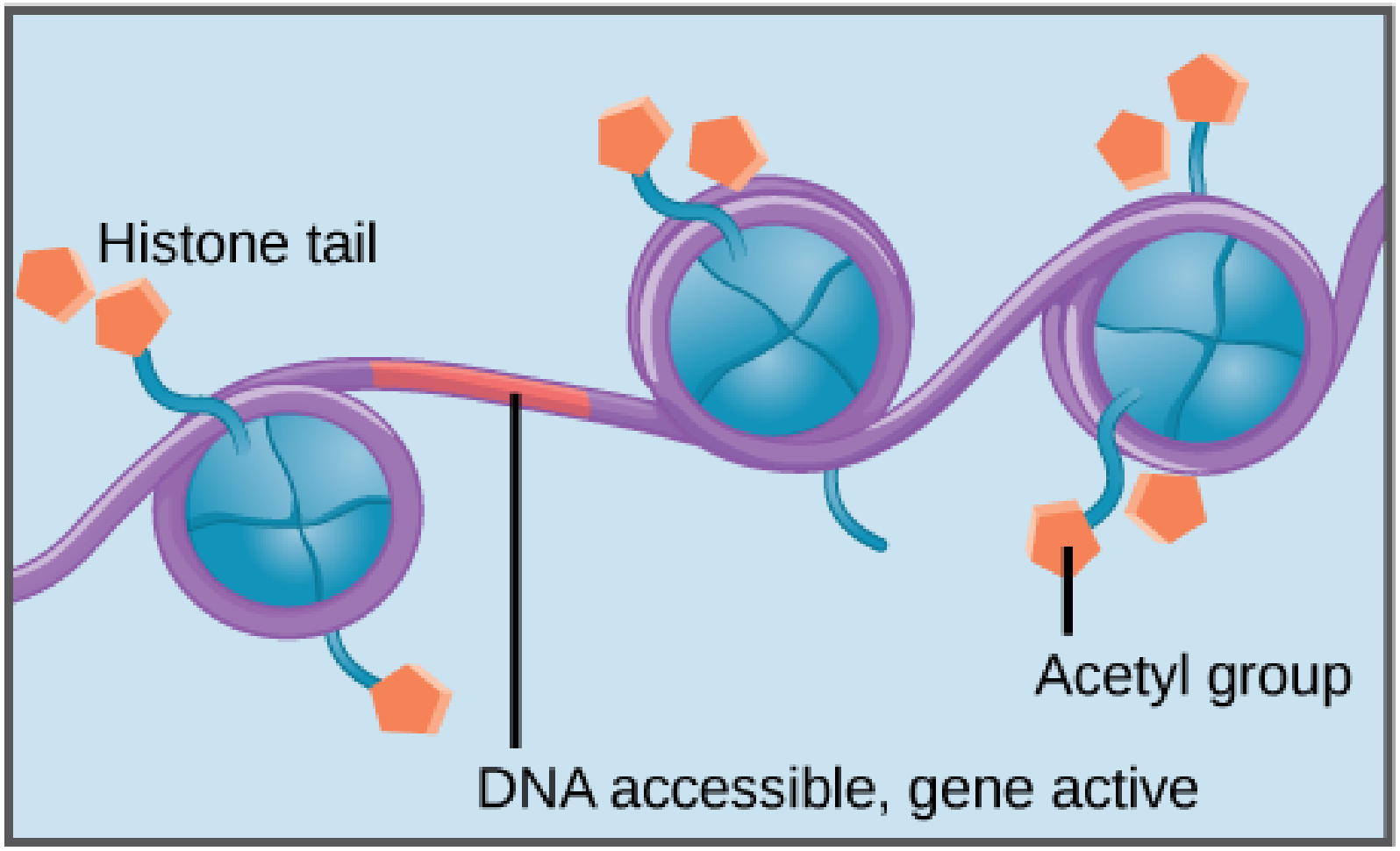
[Video - Epigenetics (Bozeman Science)]

Methylation – adding a methyl group tightens DNA packaging, blocking transcription, switching "off" gene expression

Demethylation – removing methyl groups allows gene transcription

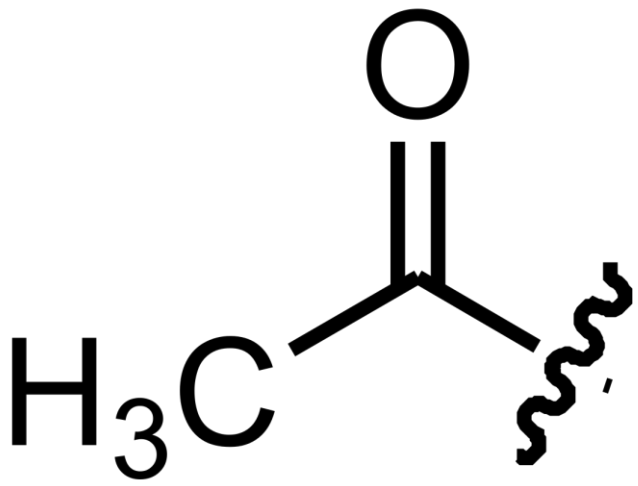






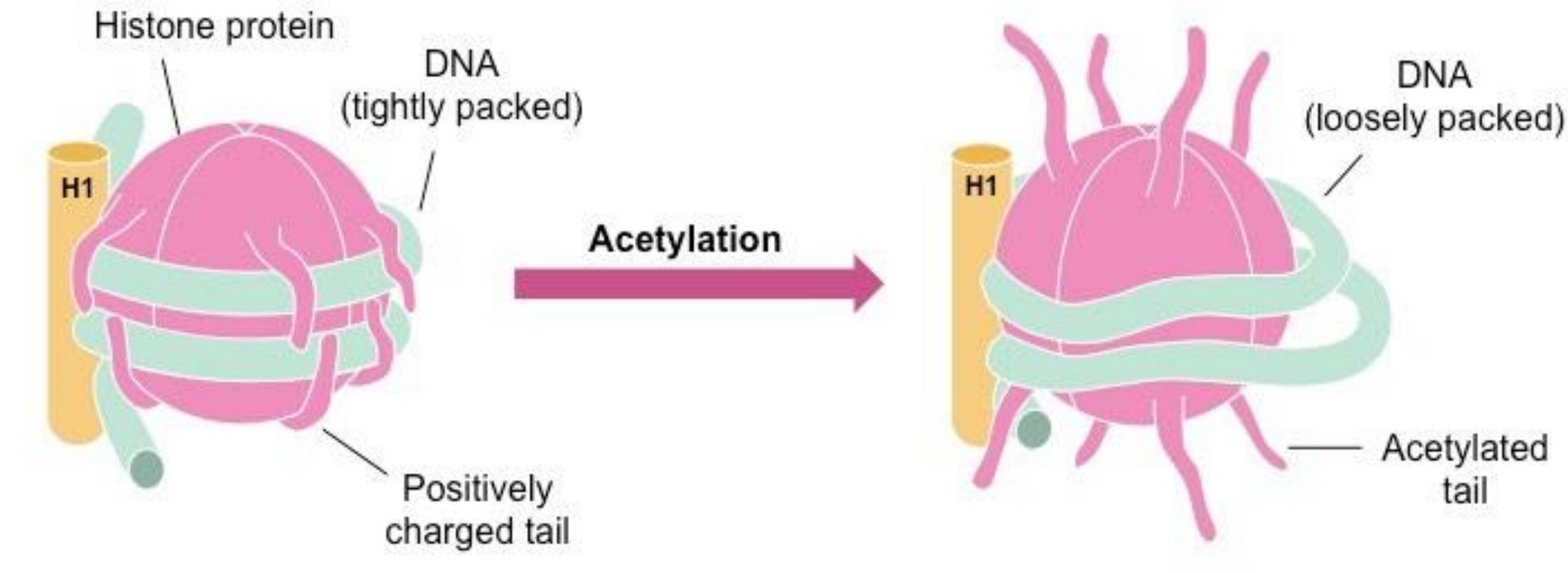
Acetylation

Histone acetylation results in loose packing of nucleo-somes. Transcription factors can bind the DNA and genes are expressed.



Acetylation – addition of acetyl group loosens packaging of DNA, turning "on" gene expression

Deacetylation – removal of acetyl group tightens DNA packaging, turning "off" gene expression



Why study epigenetics?

- Can help us to better understand and possibly treat diseases like
  - Cancer
  - Autoimmune disease
  - Mental disorders
  - Diabetes

SciShow Epigenetics (9:30)

Video - Epigenetics and Influence of Our Genes (long)