Lesson 1

Interaction of Heredity & the Environment

Environment Effects on Genes

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

Nature Nurture debate

Epigenetics

Interaction of Heredity and the Environment

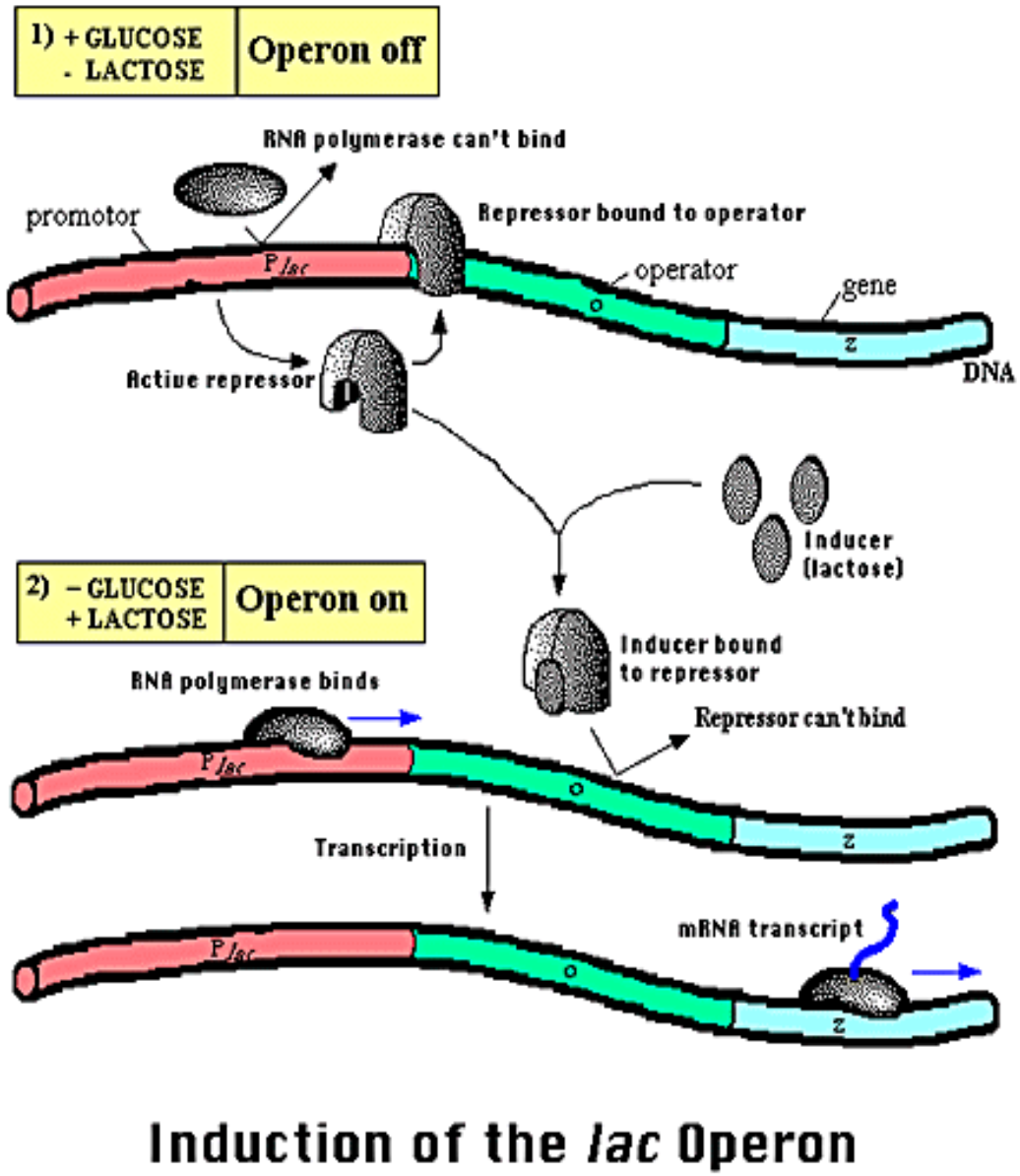
Environmental Effects on Gene Expression

Gene Regulation

- when factors in the environment can “turn a gene on or off”
- can affect the production of a protein

Video: The Lac Operon (gene expression)

Video - Gene Expression & Order of Operon (Amoeba Sisters animation)



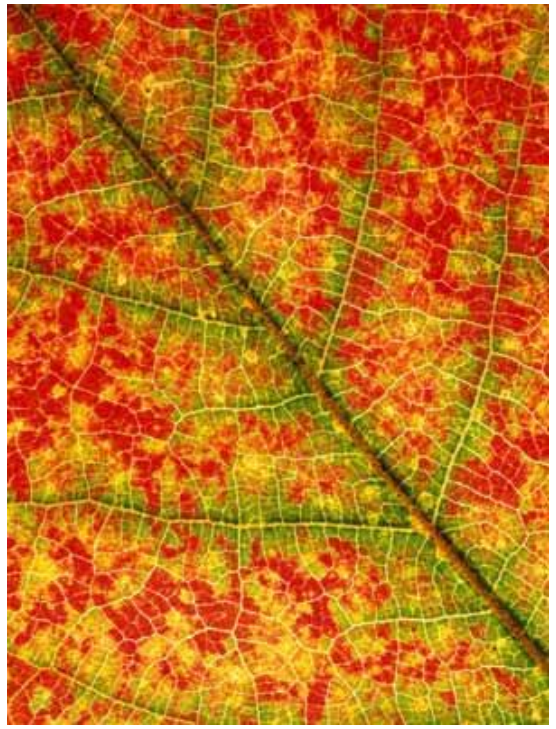
Induction of the *lac* Operon

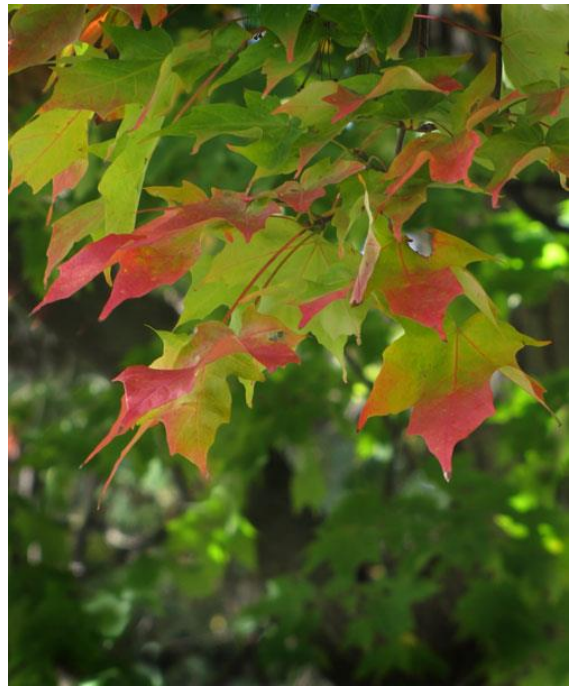
Example 1: Sunlight on Skin Color

- 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 (pigment chlorophyll is produced)





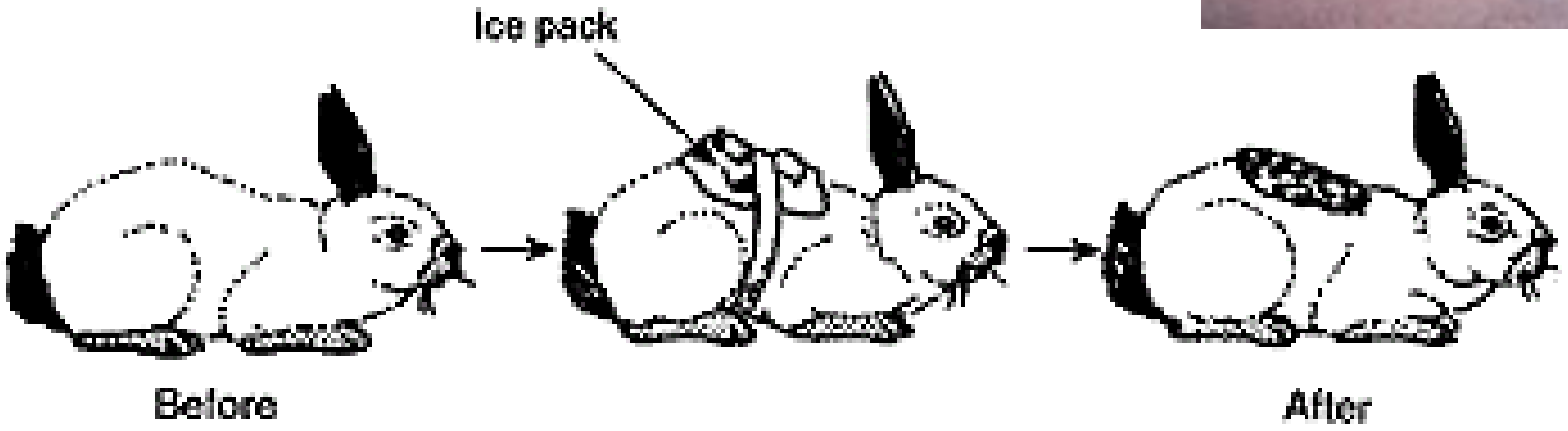
Example 3: Sex determination

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

Video (3:10)

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

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



Example 5: Identical Twin Studies

- identical twins may have variations in height, weight, intelligence
- due to diet, exposure, altitude, etc.

Video: Identical Twins Raised Apart

James Arthur Springer and his identical twin, James Edward Lewis reunited at age 39 after being given up by their mother and separately adopted as 1-month-olds

- Daphne Goodship and Barbara Herbert first met when they were 40. Debbie was raised Jewish and Sharon was raised Catholic. *We discovered we had a miscarriage the same year, followed by two boys and a girl in that order," says Barbara.*
- *They admit that they've also cooked the same meal from the same recipe book on the same day, without knowing it.*
- *Segal called Daphne and Barbara the "giggle twins" because they laugh and fold their arms the same way.*

- *Identical twins Tom Patterson and Steve Tazumi met four years ago.*
- *Tom is from rural Kansas, he was raised Christian and his parents were janitors. Steve, raised as a Buddhist, lives in Philadelphia. His father was a pharmacist.*
- *However, Tom and Steve chose the same careers. “It’s phenomenal,” says Steve. “He owned a body building gym and I owned a body building gym. We’re both 100 percent into fitness.”*
- *But there are differences in these twins, too. Steve says he’s more party oriented while Tom is more family oriented.*

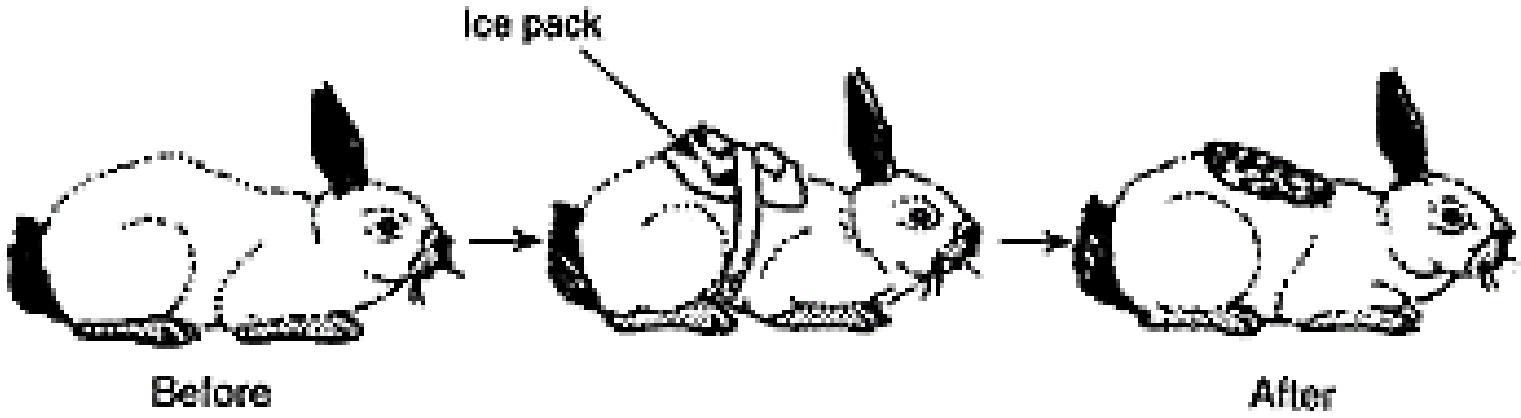
Heredity & the Environment Practice

1) Identical twins were born with genes for a genetic disorder that can be controlled by diet. Both twins were placed on this diet, which excludes a certain amino acid. However, one twin chose not to follow the diet and developed the genetic disorder. The other twin followed the diet and did not develop the disorder. This difference between the twins illustrates that

1. gene expression is not influenced by biochemical factors
2. gene expression is influenced by the environment
3. identical twins do not always have the same genotype
4. the genetic disorder is inherited by identical twins, only

2) The diagram below illustrates what happens to the fur coloration of a Himalayan hare after exposure to a low temperature. This change in fur coloration is most likely due to

1. the effect of heredity on gene expression
2. environmental influences on gene action
3. the arrangement of genes on homologous chromosomes
4. mutations resulting from a change in the environment



3) Scientists conducted a study of identical twins who were separated at birth and raised in different homes. They found that in some sets of twins the individuals showed a marked difference in intelligence. The most likely explanation for this difference is that

1. expression of inherited traits can modify the environment
2. environment can influence the development and expression of inherited traits
3. intelligence is a sex-linked trait
4. nondisjunction occurred in the autosomes of one twin but not the other twin

4) A garden hose that had been lying on a green lawn for several days was removed. Which statement best explains the presence of yellow grass in the area where the hose had been?

1. The lack of sunlight under the hose altered the genotype of the grass.
2. The hose altered genes in the grass, causing the grass to switch from autotrophic to heterotrophic nutrition.
3. Gene expression is not affected by the environment.
4. The lack of sunlight under the hose affected chlorophyll production.

5) In fruit flies with the curly wing mutation, the wings will be straight if the flies are kept at 16°C, but curly if they are kept at 25°C. The most probable explanation for this is that

1. fruit flies with curly wings cannot survive at high temperatures
2. high temperatures increase the rate of mutations
3. the environment influences wing phenotype in these fruit flies
4. wing length in these fruit flies is directly proportional to temperature

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

Video - Epigenetics (Bozeman Science)

Lesson 2

Selective Breeding

Selective Breeding/Artificial Selection

- allowing reproduction between individual organisms with desired characteristics
- May result in new varieties of plants and animals
- Methods include:
  - Inbreeding
  - Cross-breeding / hybridization
  - Vegetative propagation

How does selective breeding work?

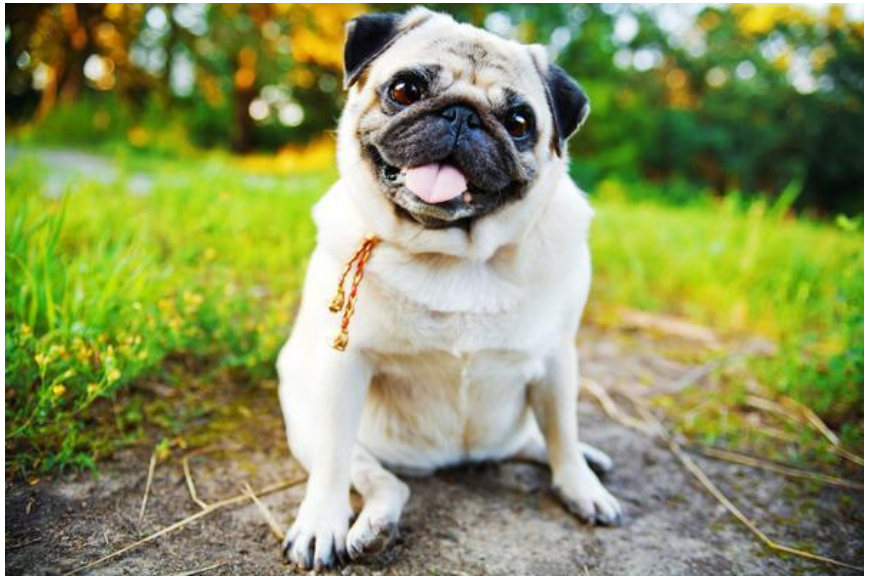
If you want a variety of cow that produces a lot of milk, you could…

1. Select the cows in your herd that produce the most milk
2. Only let these cows reproduce
3. Select the offspring that produce the most milk
4. Only let these offspring reproduce
5. Keep repeating the process of selection and breeding until you achieve your goal.

Ex. Breeding Dogs: humans have selectively bred dogs over time to create varieties with specific characteristics that serve a certain purpose (hunting, hairless, intelligence, etc.)

From left to right - Beagle, Wheaten Terrier, Rhodesian Ridgeback, Red Siberian Husky, Irish Setter, Golden Retriever, Boxer, Sheltie

Pugs have been bred for their cuteness but not without some negative ramifications.



[Video - Pug Nose health problems]

Ex. Fruits and Vegetables

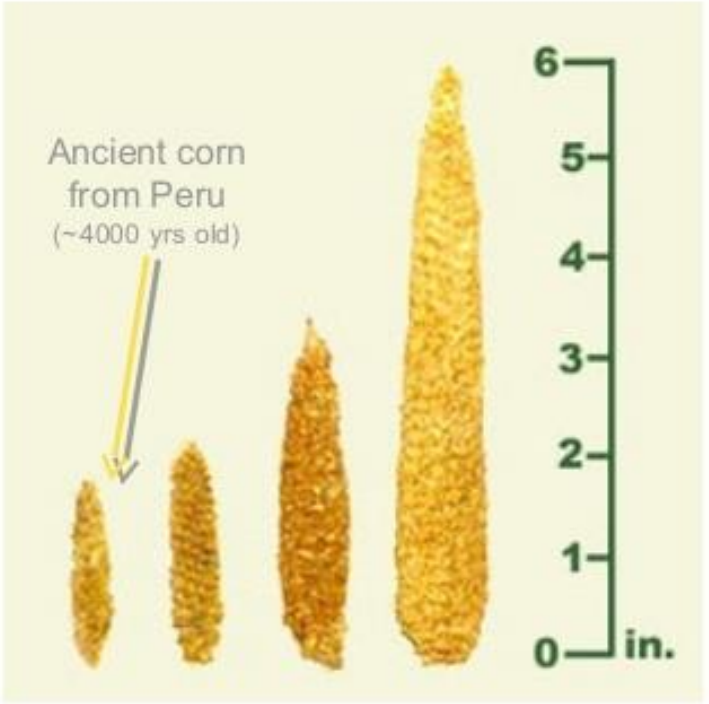
- Are bred for less cracking, splitting, bruising, longer shelf life, tolerance to disease, etc.

- The Dunne tomato is a cross between the varieties 'San Marzano' and 'Dattero' and has a salty aromatic taste and a strong and crispy pulp. Dunne has a copper color and has more than ten to fifteen tomatoes per bunch with a fruit weight of forty grams.
- The most important properties of Dunne are its drought resistance, high tolerance for disease and its suitability for transport. In addition the tomato remains on the vine after harvesting and can be prepared in various ways.

Ex. Other Crops (corn, rice)

- Bred to increase the amount of edible material produced

The artificial breeding of crops over many centuries has led to humans using only a few strains of each of the major crops, such as corn, worldwide. This has raised concerns because if an epidemic passed through a certain strain or group of strains for one of mankind's major crops, such as rice or corn, it could destroy a huge portion of the world's food supply. As a result, many scientists stress the usage of a variety of crop species and the cultivation and preservation of the closest living relative to our food crops' ancestor.



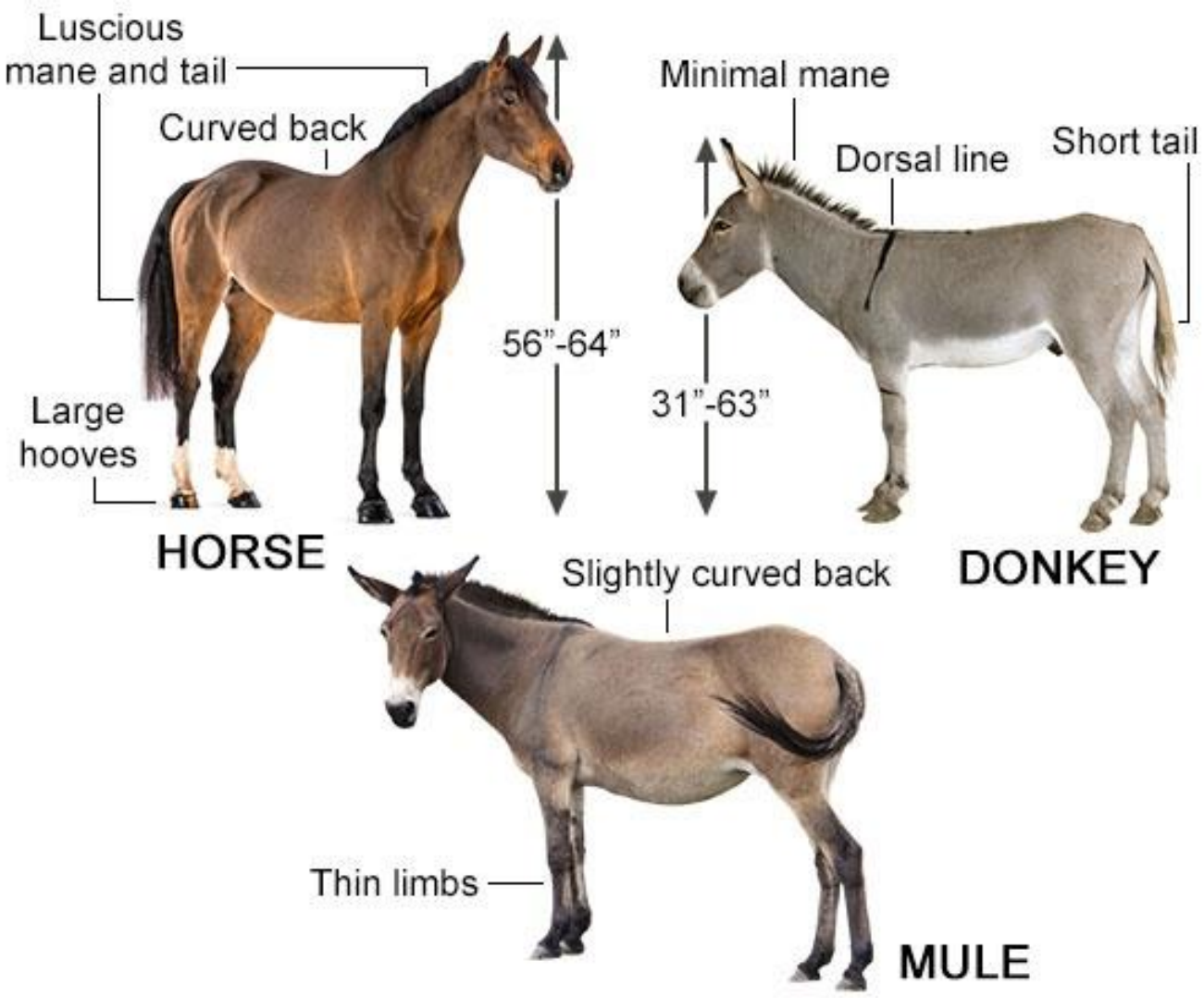
Choosing only the best corn plants for seeds results in better crops over a long time.

Ex. Cattle and Livestock

- Animals are selectively bred to produce the most desirable characteristics (most meat, thick wool, etc.)
- Belgian Blue Cattle

Mule – a cross between a donkey and horse

- The mule is valued because, while it has the size and ground-covering ability of a horse, it is stronger than a horse of similar size and inherits the endurance and disposition of the donkey, tending to require less food than a horse of similar size. Mules also tend to be more independent than most domesticated equines other than the donkey.



Ex. Species Conservation

- endangered species may be cross-bred with a related species

Liger

Lonesome George:
Galapagos Island Tortoise
RIP June 24, 2012
(the last of his species)

Drawbacks of Selective Breeding

- Desired traits are **NOT** guaranteed in offspring because:
  - Sexual reproduction allows for random recombination of traits (possible to get undesired traits from both parents)
  - Hidden recessive alleles may appear in offspring
  - Random mutations may occur
- Some types (inbreeding) decreases the genetic diversity of a species, increasing vulnerability to disease

Selective Breeding Practice Questions

1. Artificial selection is illustrated by
    1. random mating taking place in a population
    2. gardeners producing a hybrid by cross-pollinating plants
    3. the appearance of a new species on a remote island
    4. wind assisting the pollination of grass in a field

2. Breeders have developed a variety of chicken that has no feathers. Which methods were most likely used to produce this variety?

1. artificial selection and inbreeding
2. regeneration and incubation
3. grafting and hybridization
4. vegetative propagation and binary fission

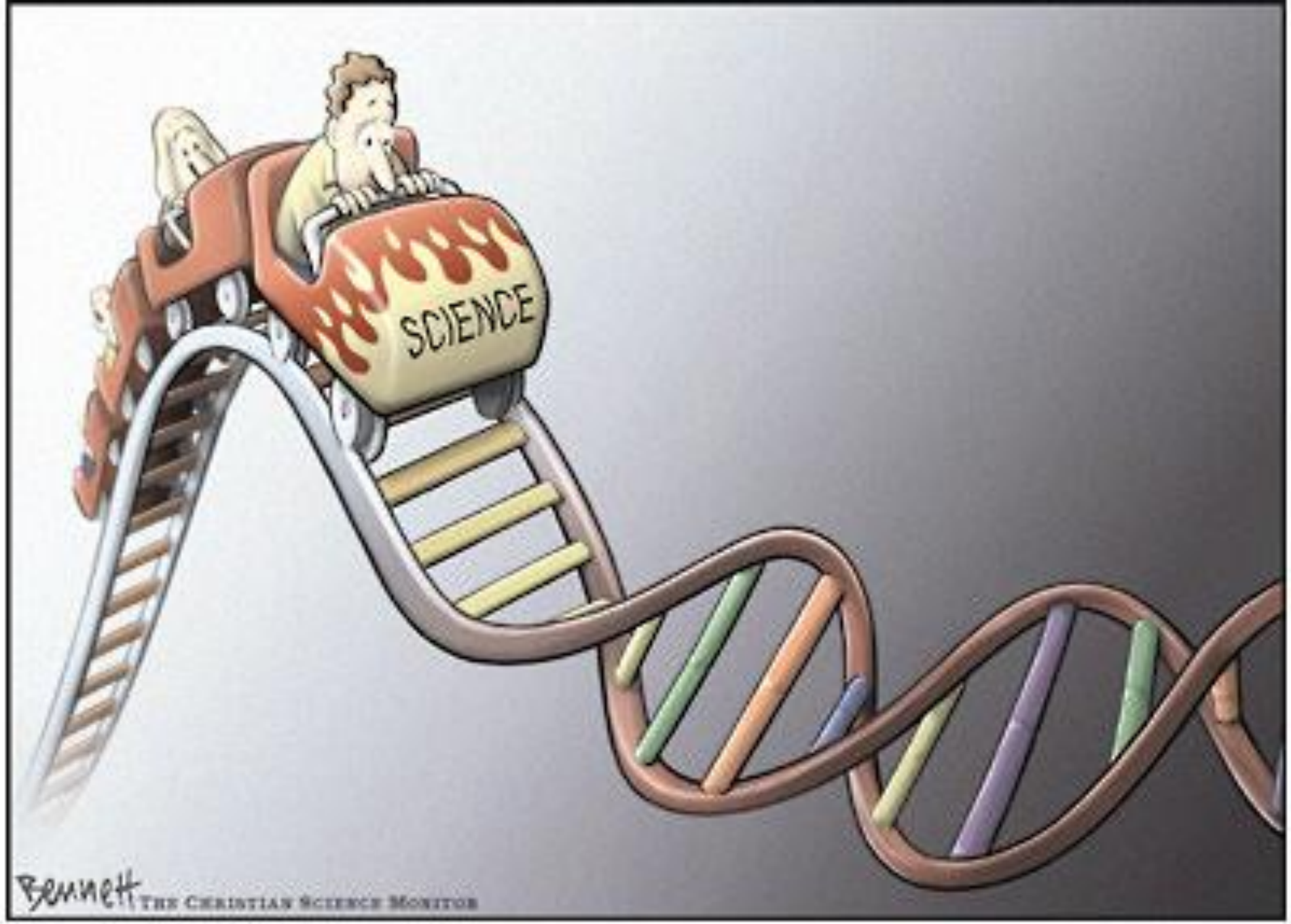
3. A cattle breeder wished to develop a variety of cattle that would produce large quantities of meat per animal. He chose a bull and a cow that most nearly met his goals for breed size. From their calves, he again chose the male and female offspring that most nearly met his goals. After several generations of this style of breeding, the breeder developed a herd of high-yield cattle. In order to maintain this herd of high-yield cattle, which technique should the cattle breeder use?

    1. vegetative propagation
    2. genetic recombination
    3. hybridization
    4. inbreeding

Lesson 3

Biotechnology

- Genetic Engineering
  - Recombinant DNA
  - Gene therapy


SCIENCE
Bennett
The Christian Science Monitor


FROZEN FOODS
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Uncle Ben's
Mrs. Paul's
DR. JEKYLL'S
GENETICALLY ALTERED FOOD


PATENT
PENDING
THE CHRISTIAN SCIENCE MONITOR

Biotechnology

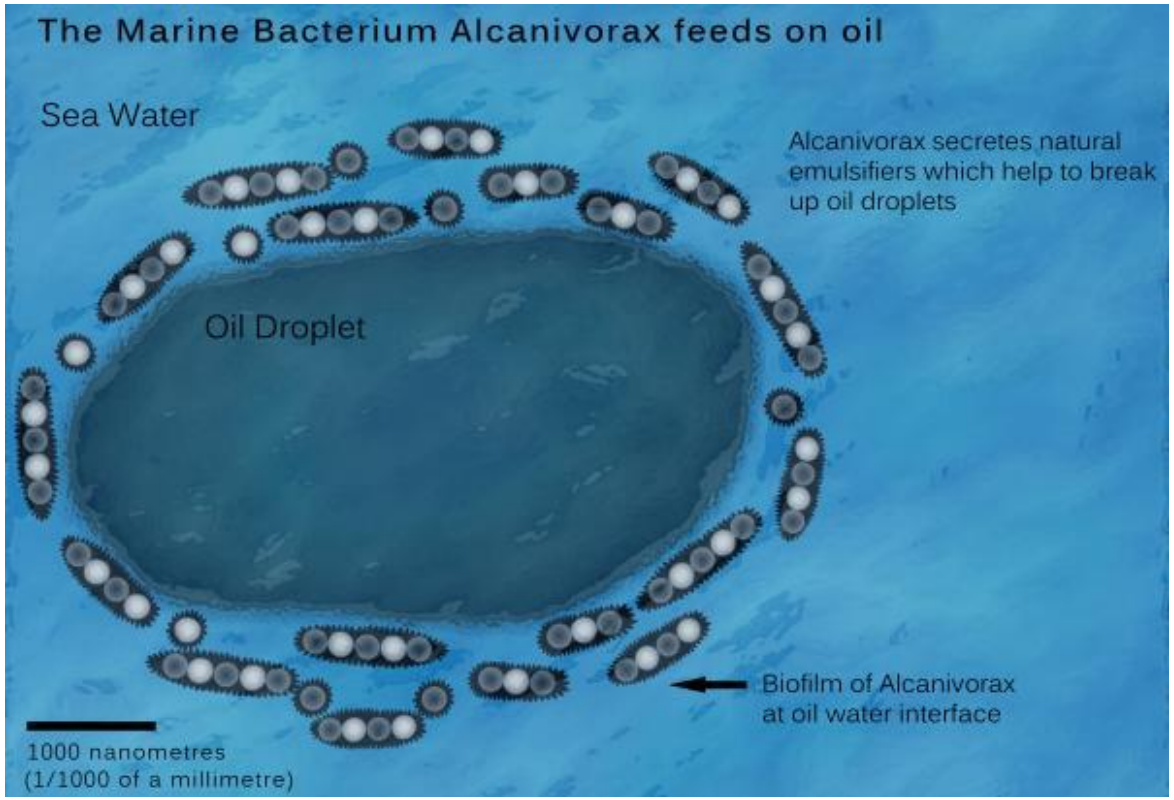
Genetic Engineering (G.E.)

- laboratory techniques used to alter (change) an organism's genetic makeup
- Produces genetically modified organisms (GMOs)

Applications of Genetic Engineering

1) G.E. bacteria can:

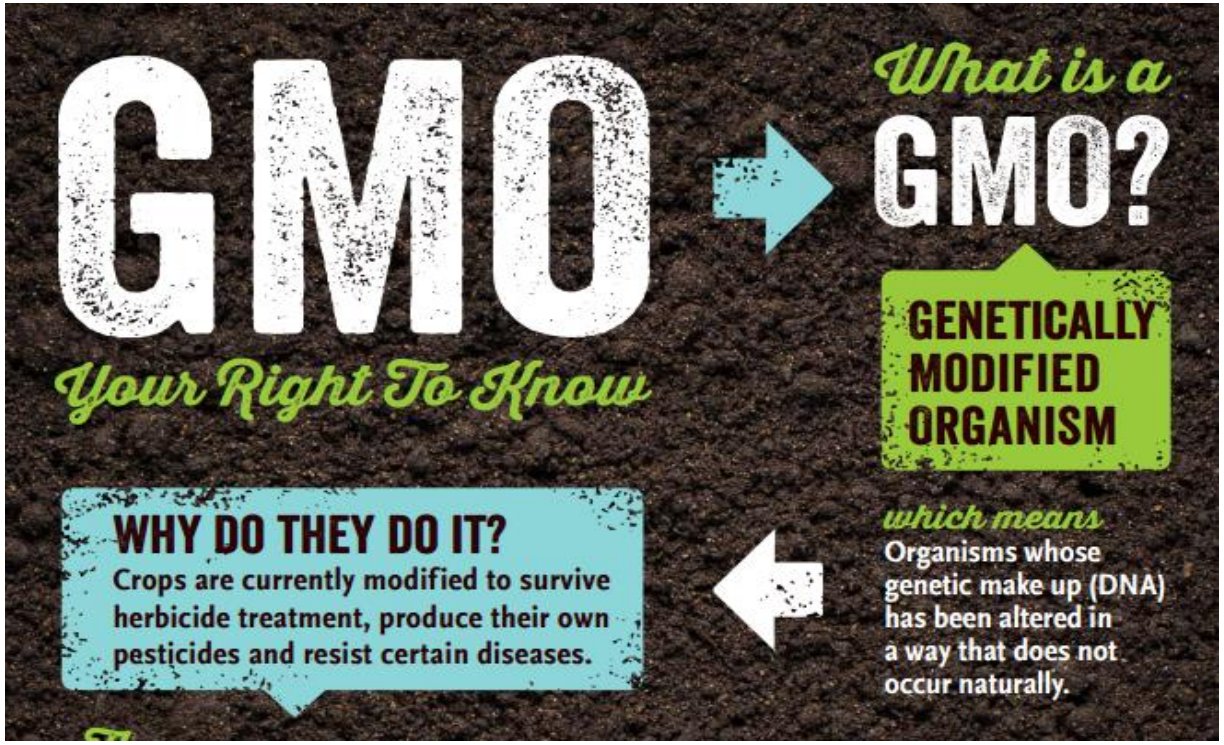
- treat human disorders by producing human hormones
- clean oil spills from the environment



Applications of Genetic Engineering (cont.)

2) G.E. plants/crops can:

- produce their own pesticide to resist insects
- survive herbicide treatments or frost

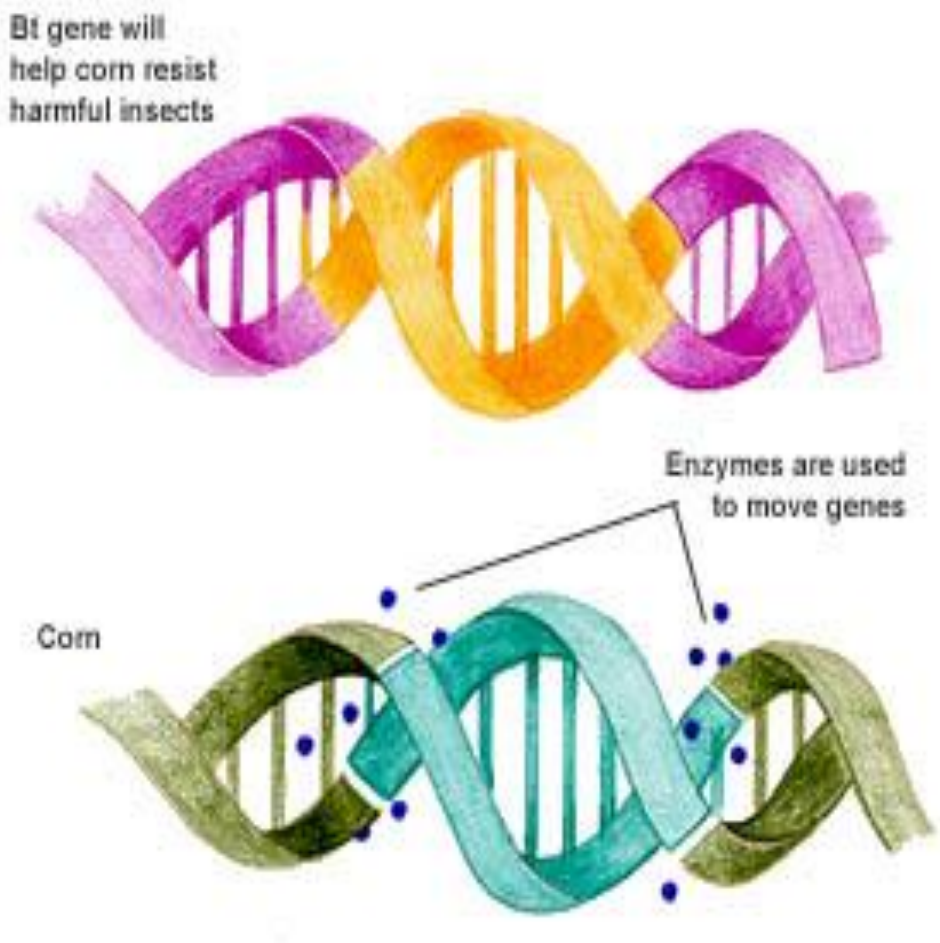


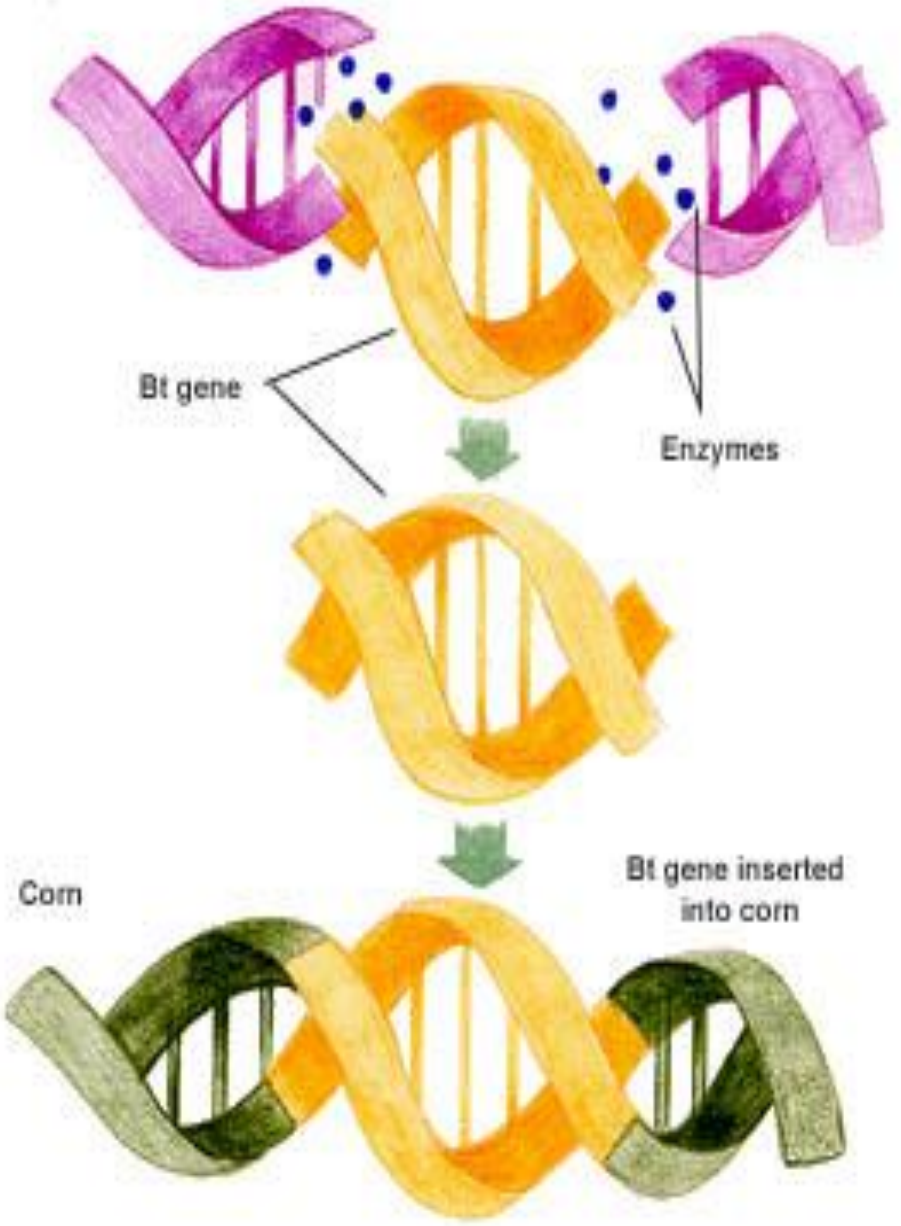
Example - Bt toxin targeting the corn borer (insect that eats corn crops)

Advantages?

Disadvantages?

Gene Splicing – “cutting” & “pasting” of a gene





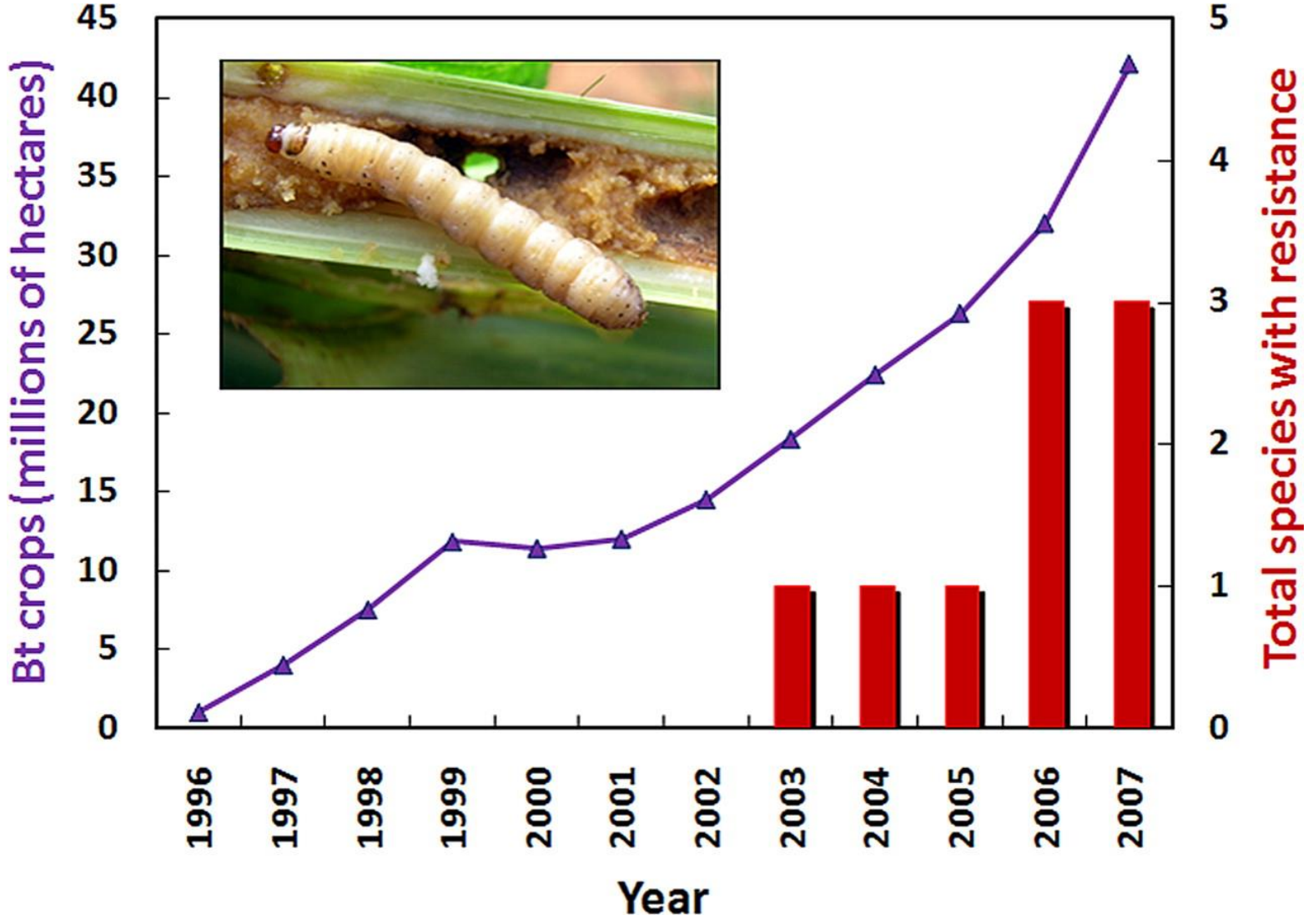
The Bt toxin gene from a type of soil bacteria is <u>spliced</u> into corn DNA to improve crops resistance to insects (caterpillars)

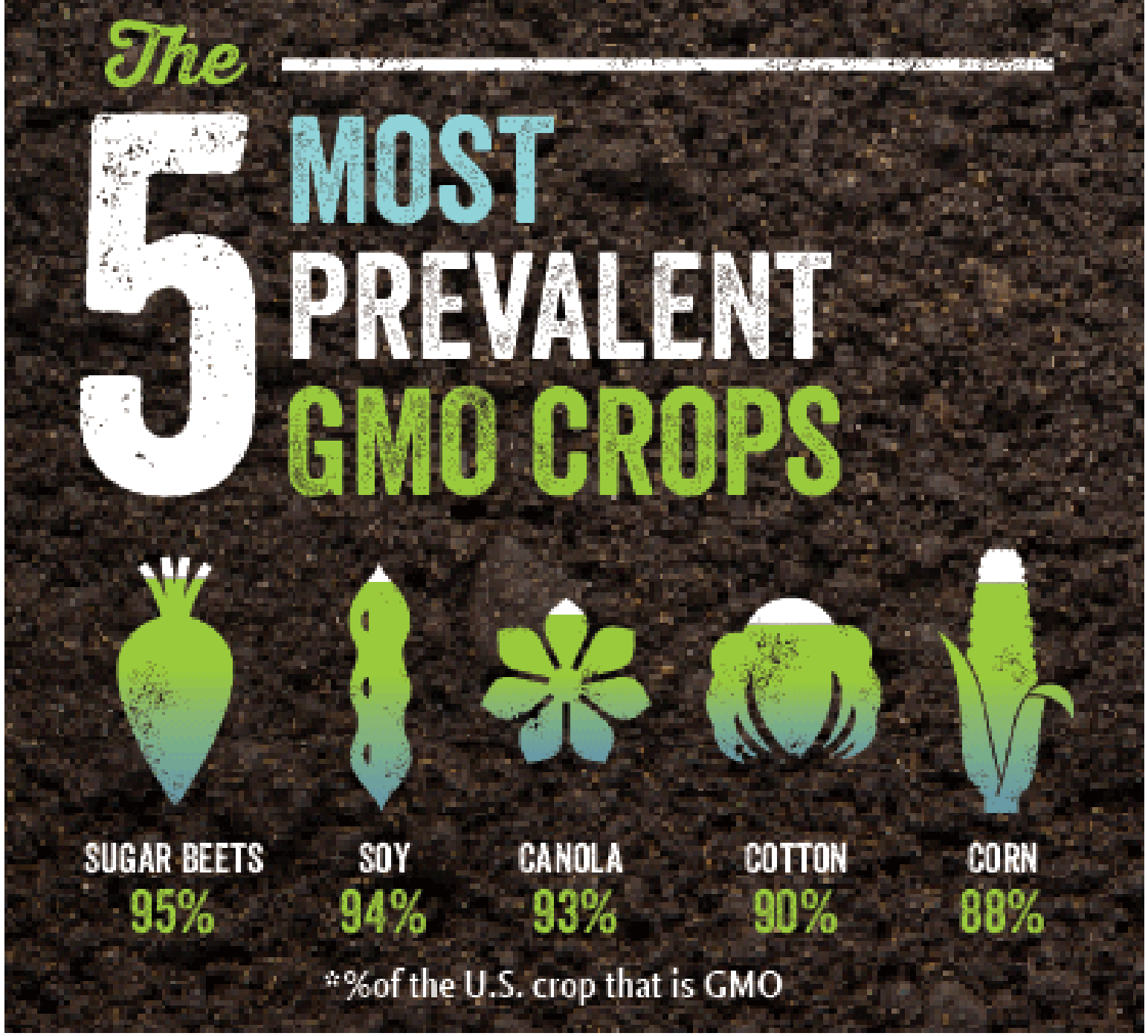
Advantages of Bt gene

- Farmers spray less pesticides (less risk to water supply & other organisms)
- Less crop loss = more profit
- *Bt* protected cotton, the United States was able to save approximately $92 million

Disadvantages of Bt gene

- Insects may develop a resistance to the toxin
- Loss of insects may affect the food chain harming other organisms in the area




The
5 MOST PREVALENT GMO CROPS
SUGAR BEETS
95%
SOY
94%
CANOLA
93%
COTTON
90%
CORN
88%
*%of the U.S. crop that is GMO

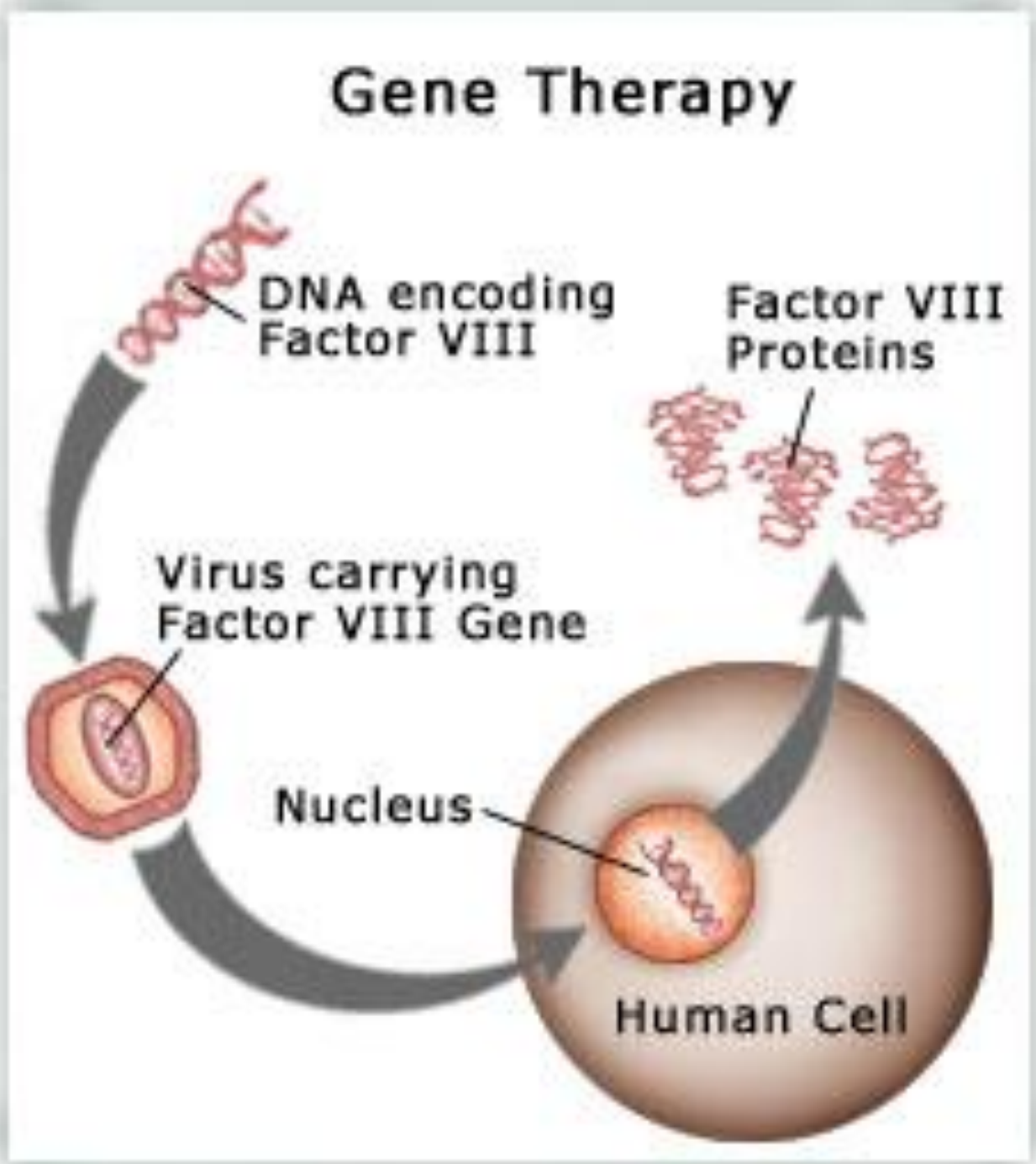
Applications of Genetic Engineering (cont.)

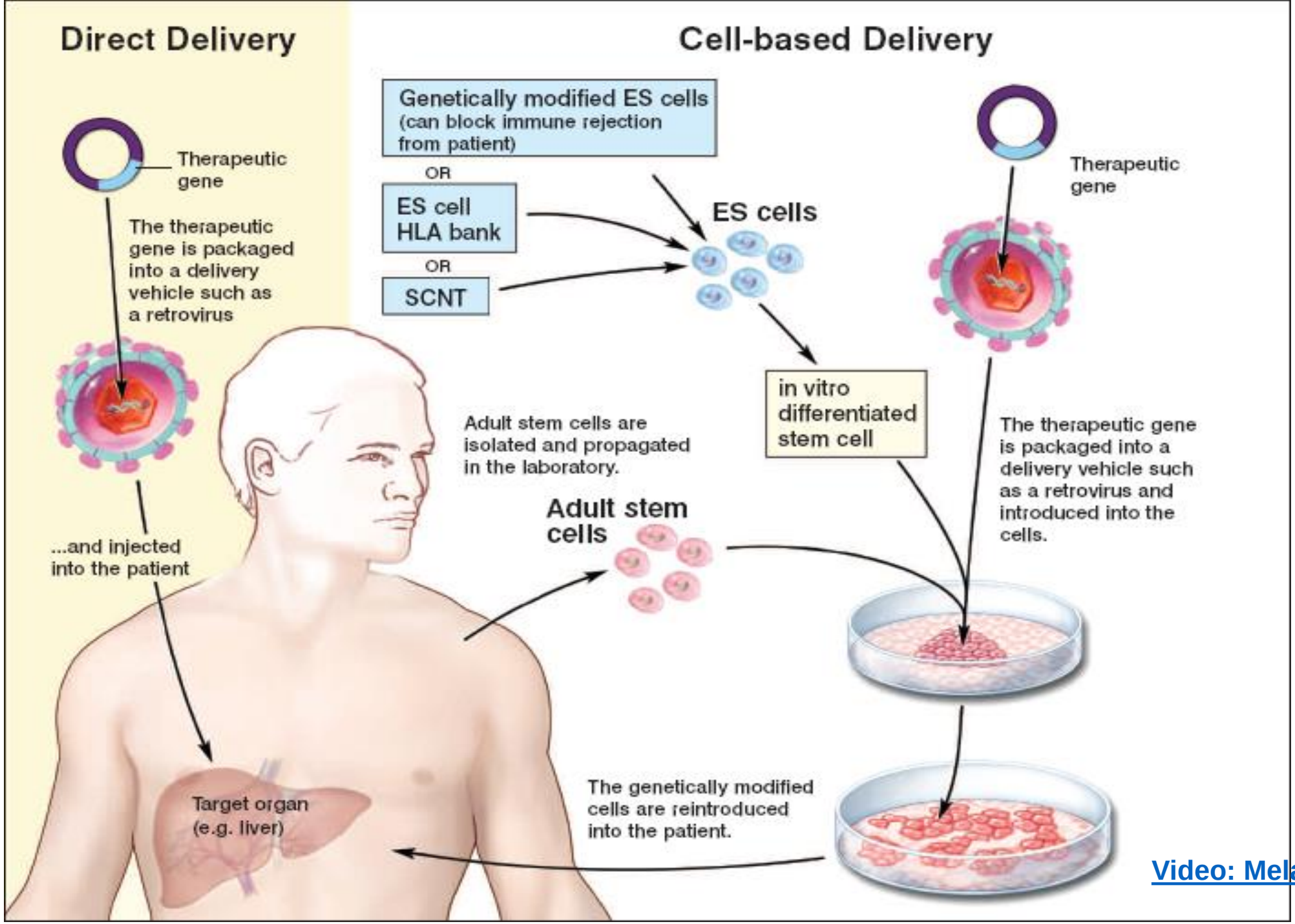
3) G.E. viruses may treat/cure genetic diseases and/or cancer via Gene Therapy

- Replacement of defective gene for a trait with a functional gene using a G.E. virus as a vector (delivers the gene)
- trials on cystic fibrosis and immune disorders
- High risk, experimental procedure
  - Gene may be spliced in the wrong location
  - Therapy may affect non-target cells
  - May trigger an unwanted immune response

Ex. Hemophilia

[Video - What is Gene Therapy (1:45)]

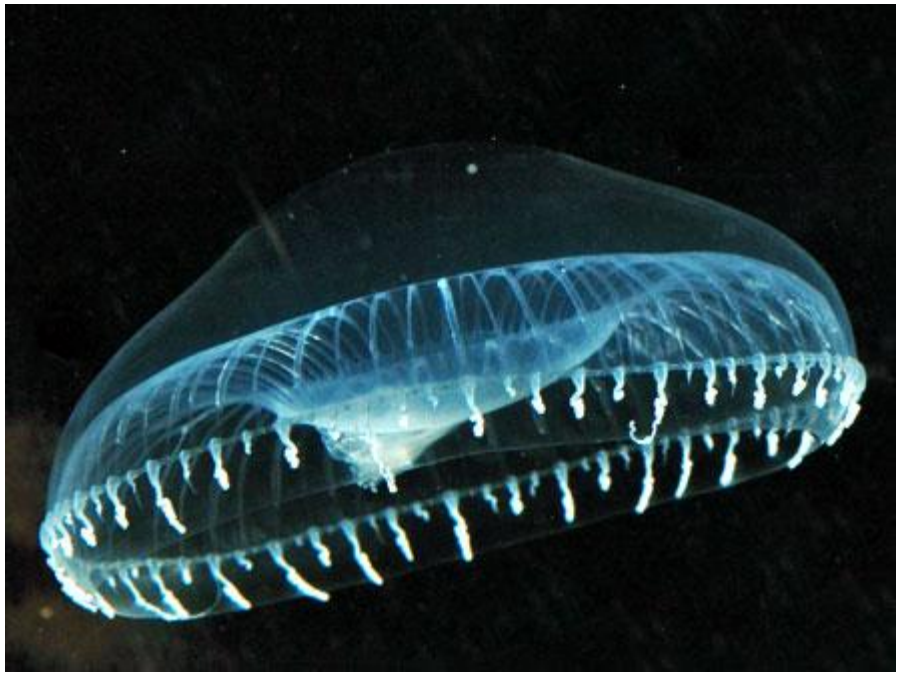


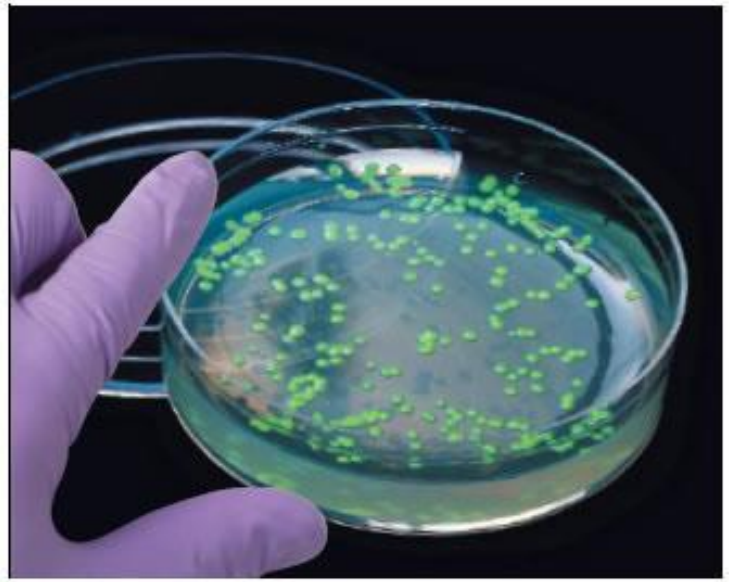


[Video: Melanoma Cure]

pGLO gene

AKA GFP (green fluorescent protein)

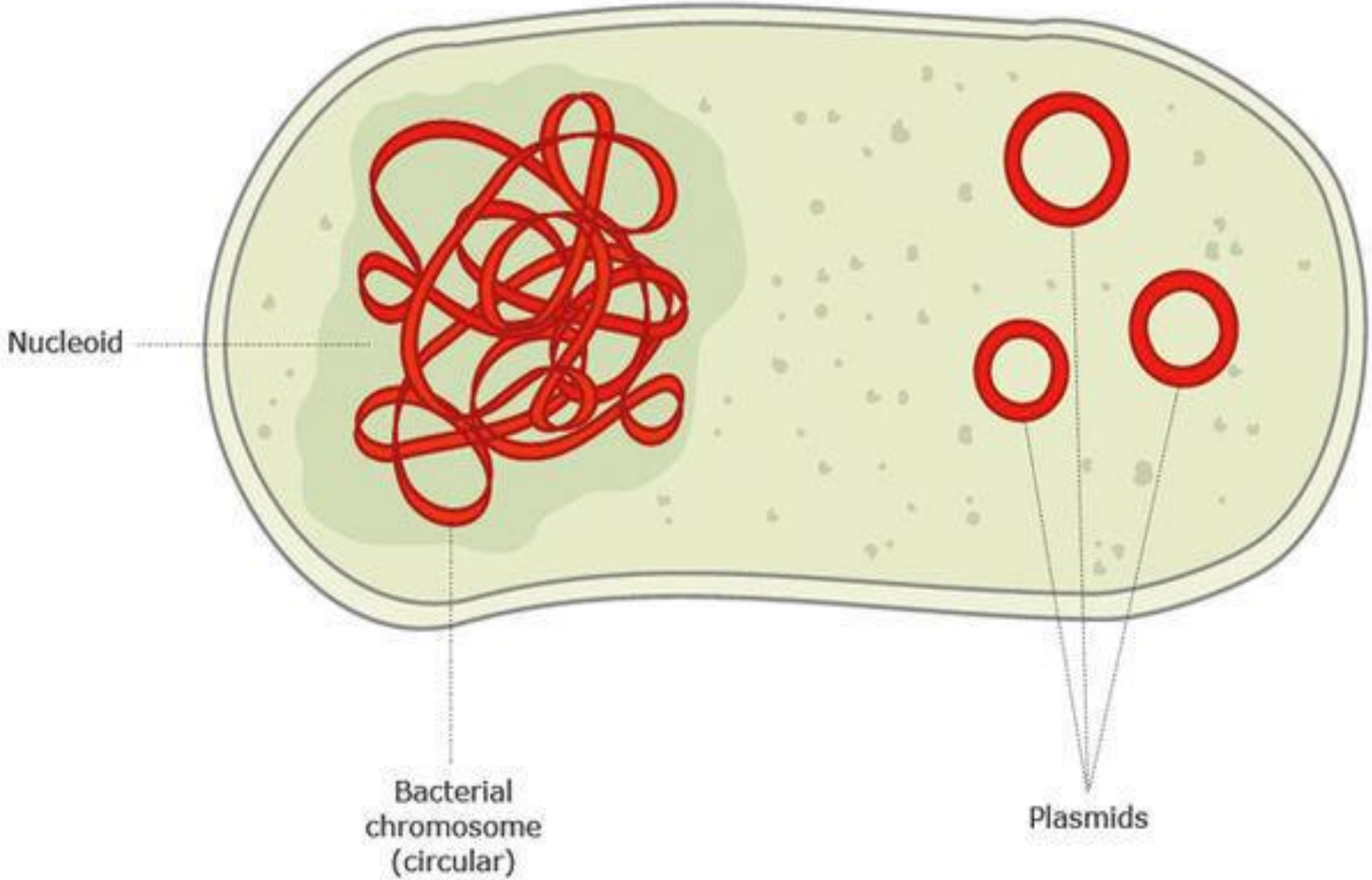




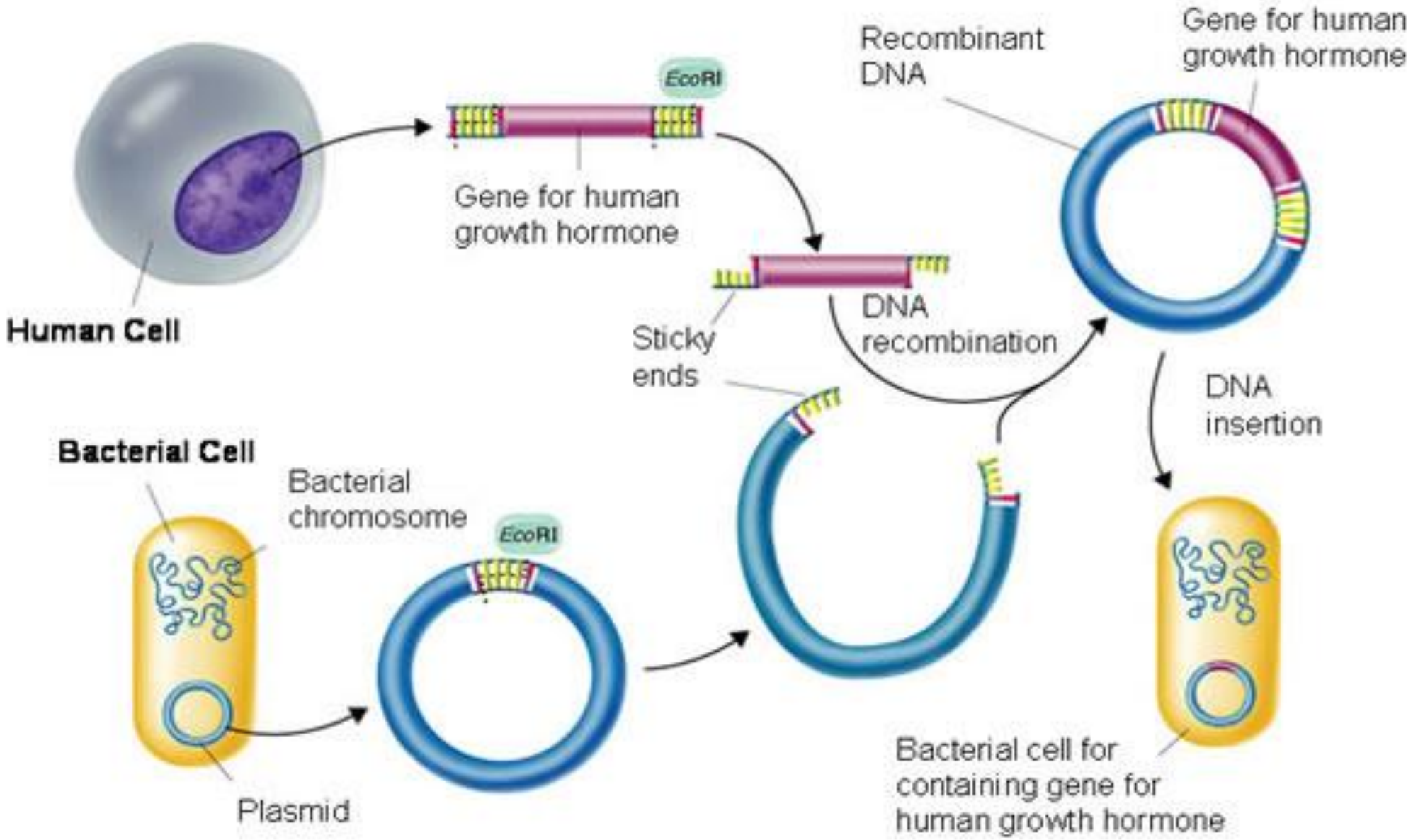
How is G.E. done?

1. Recombinant DNA Technology / Cell Transformation
   - gene of interest is “cut” from a cell using **restriction enzymes** (enzymes that can cut specific regions of DNA)
   - is then spliced (inserted) into bacterial DNA (a plasmid) using **restriction enzymes**
   - Reproduces offspring which all will contain the new Recombinant DNA
   - The new gene is expressed, producing the desired protein
   - Protein is then extracted from the bacteria

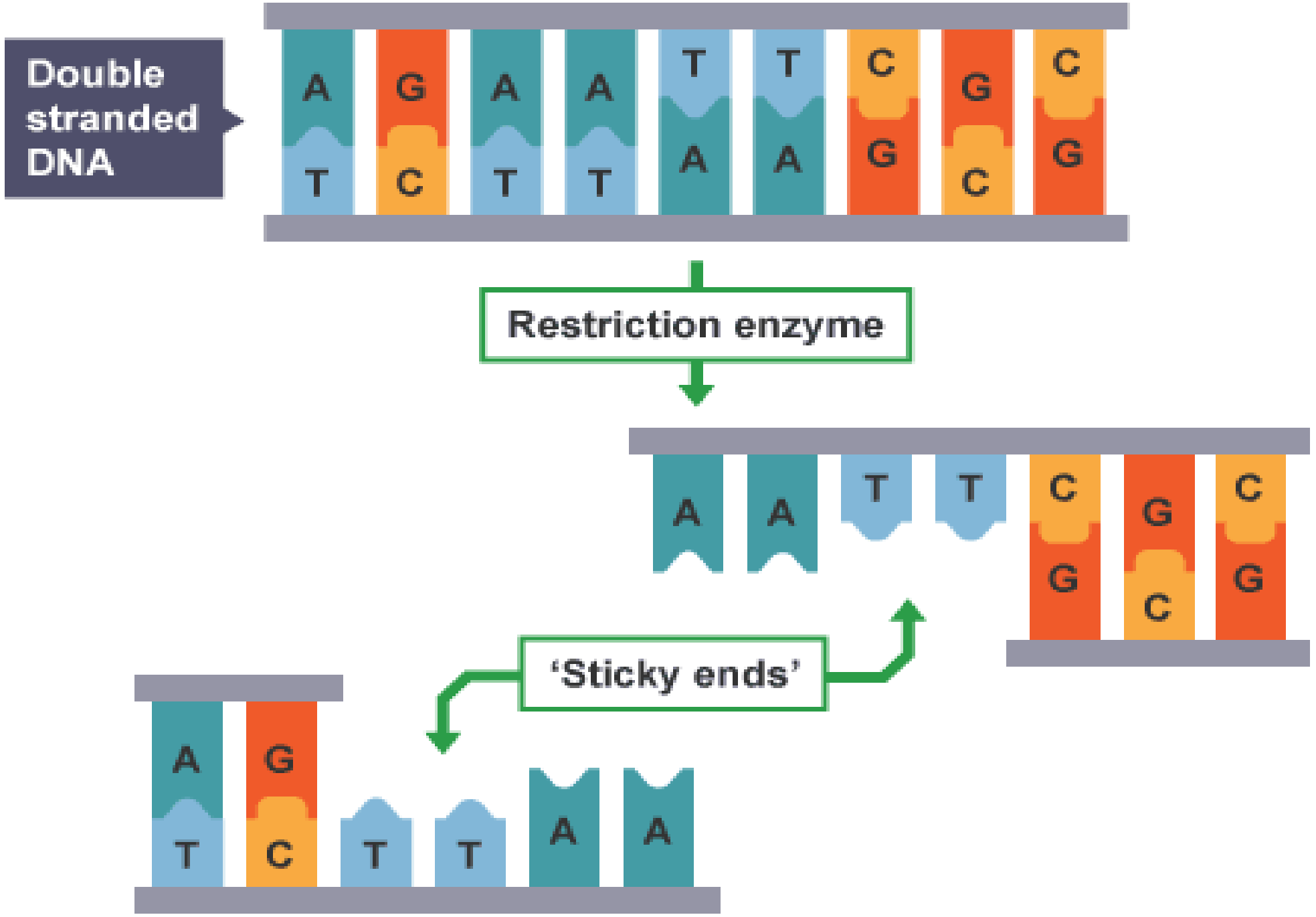
Bacterial Cell



Bacterial (cell) Transformation



[Recombinant DNA & Restriction Enzymes (short clip)]


Double stranded DNA
A G A A T T C G C
T C T T A A G C G
Restriction enzyme
A A T T C G C
G C G
'Sticky ends'
A G
T C
T T A A

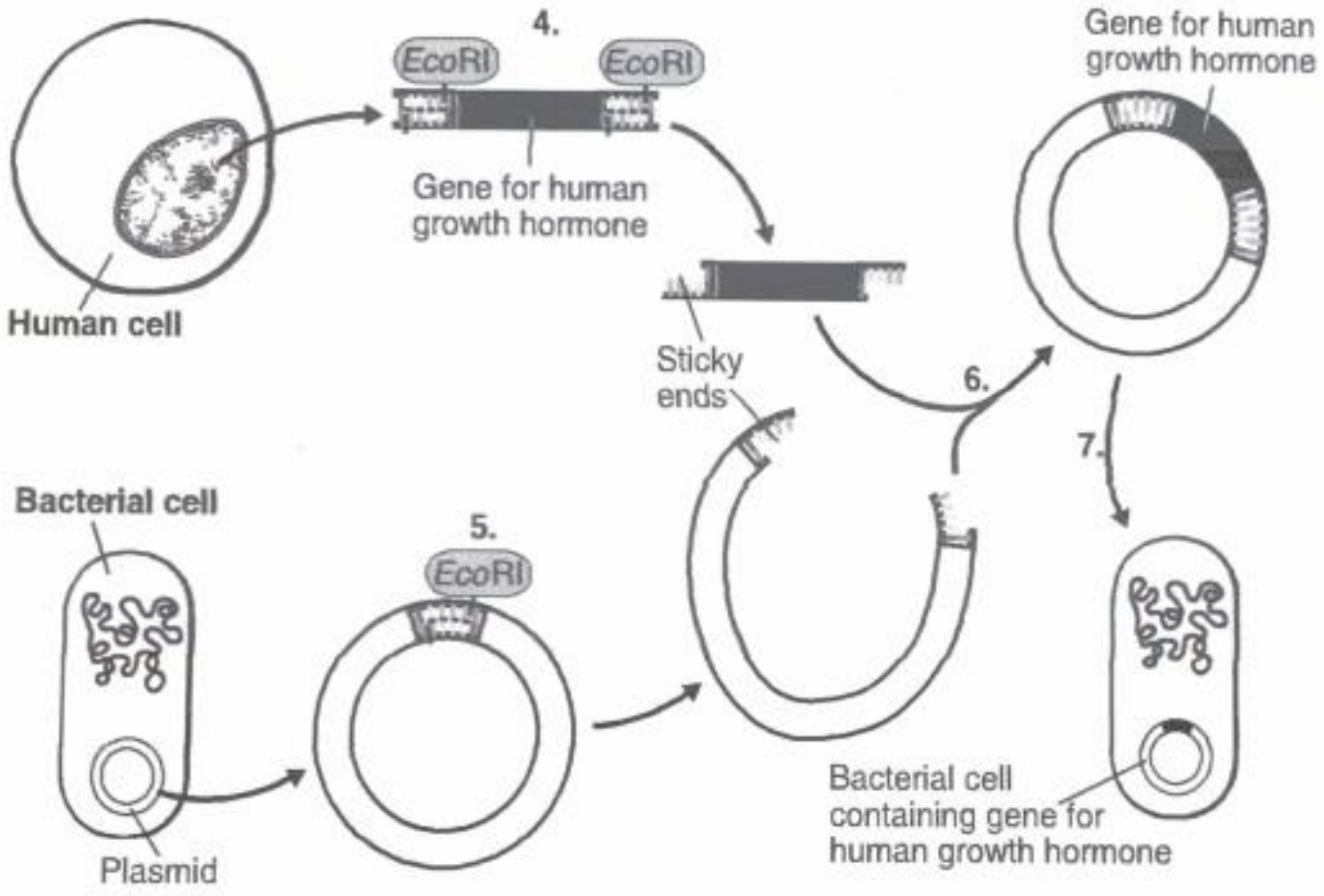
Example of Restriction Enzyme Cut

Reviewing Key Concepts

Completion *On the lines provided, complete the following sentence using three of the following words:* inside, outside, DNA, RNA, replication, transformation.

During transformation (1.) a cell takes DNA from outside (2.) the cell, which becomes part of the cell's DNA (3.).

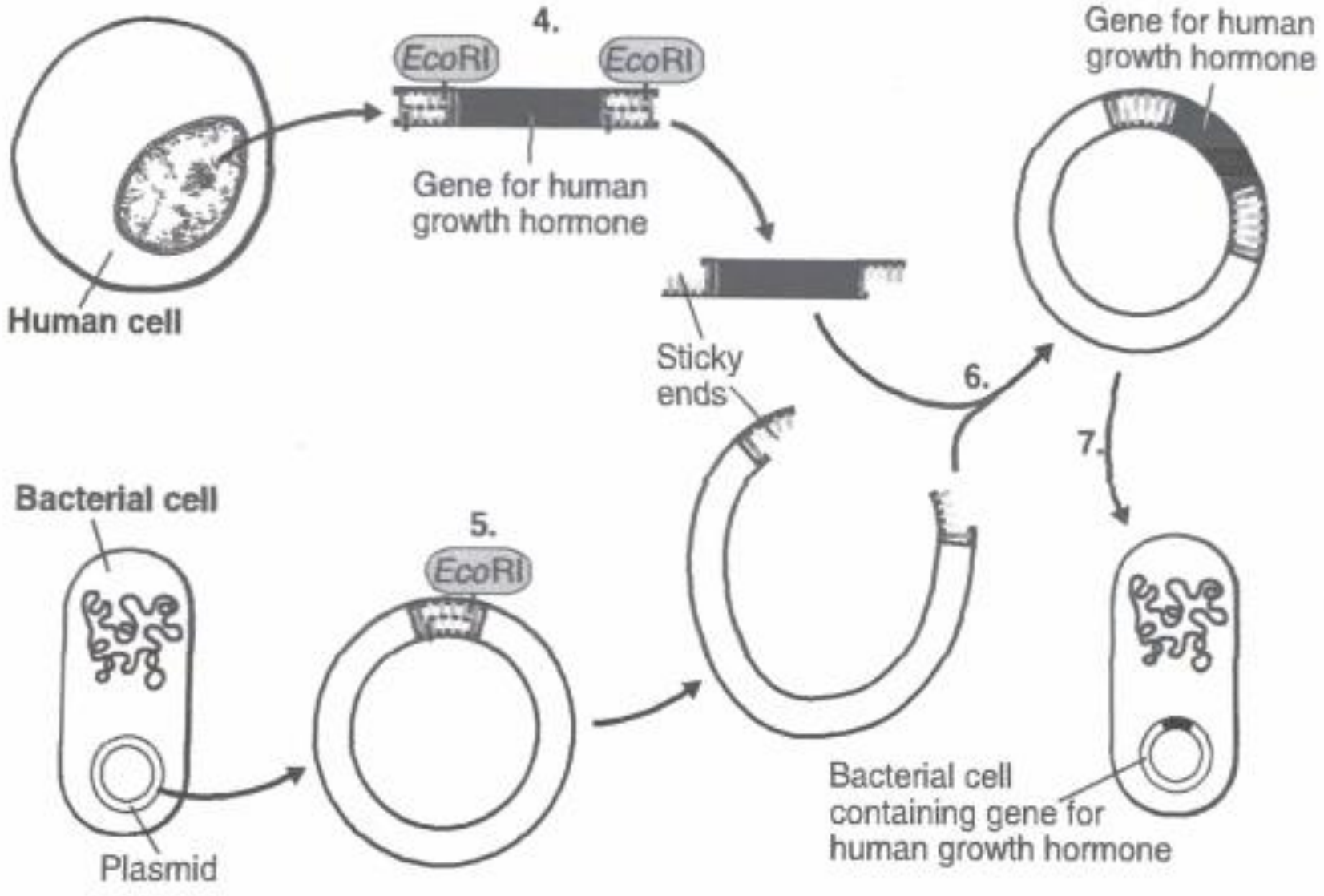
Identifying Processes *On the lines provided, describe the steps in the transformation of bacteria shown here.*



4.

The gene for human growth hormone is cut out of human DNA using restriction enzymes (EcoRI).

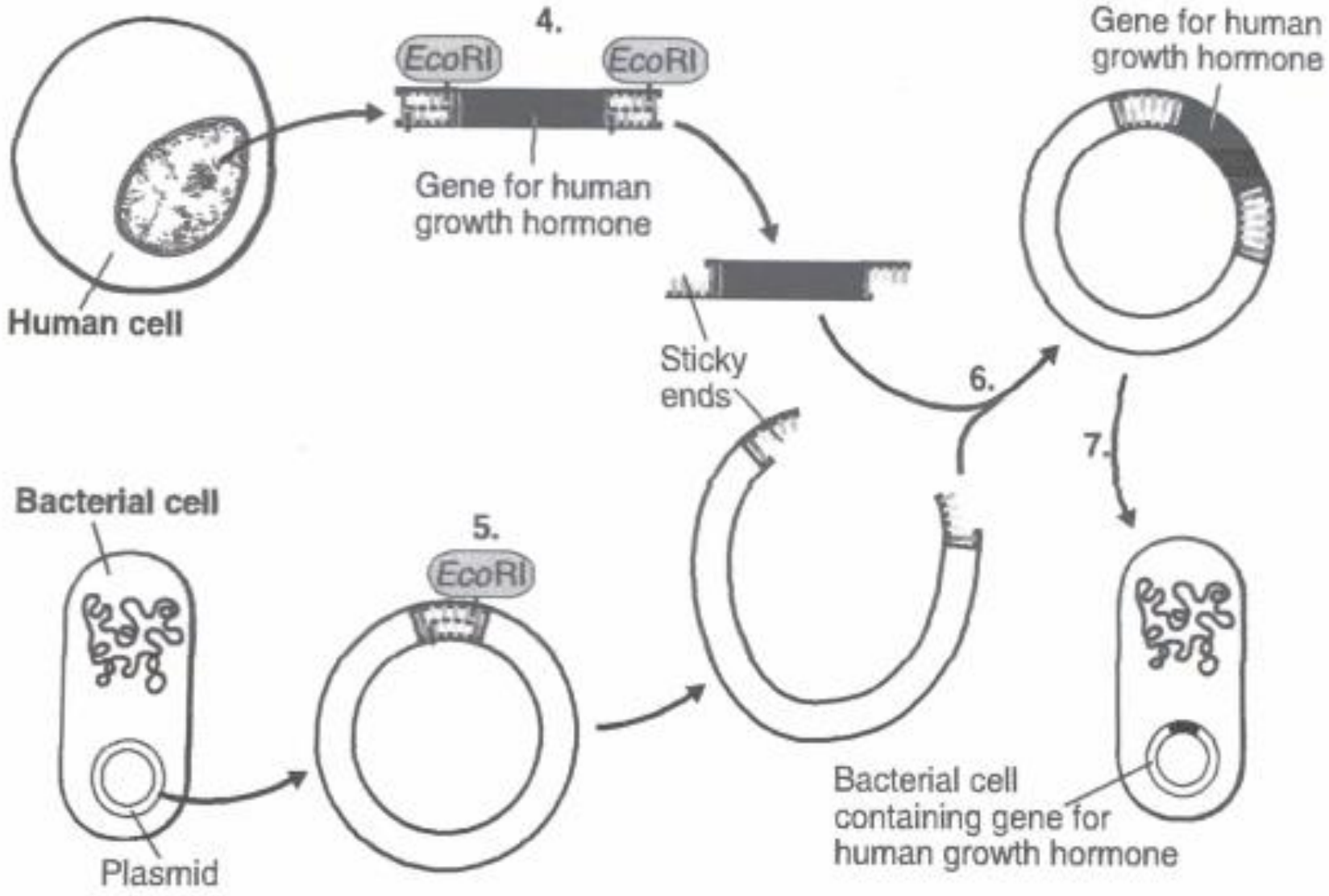
Identifying Processes *On the lines provided, describe the steps in the transformation of bacteria shown here.*



5.

A plasmid (DNA) is removed from a bacterial cell and cut open.

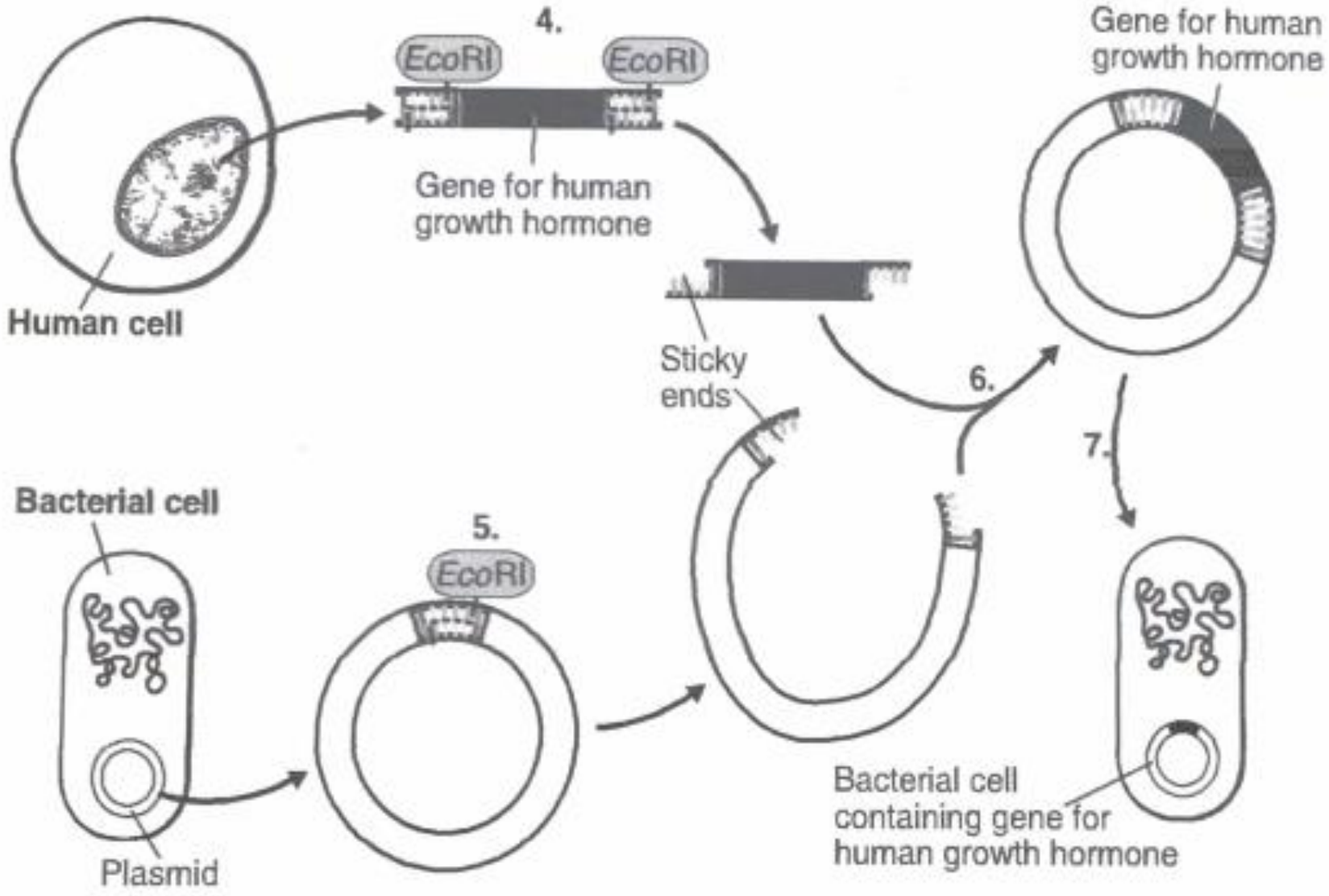
Identifying Processes *On the lines provided, describe the steps in the transformation of bacteria shown here.*



6.

The human gene is spliced (inserted) into the plasmid, forming new recombinant DNA.

Identifying Processes *On the lines provided, describe the steps in the transformation of bacteria shown here.*



7.

The recombinant DNA is inserted into the bacterial cell.

8. What happens to the recombinant DNA during a successful cell transformation?

It is integrated into the cell and is used to make proteins

Reviewing Key Skills

9. **Applying Concepts** How might a plasmid be used to alter the characteristics of an organism?

A foreign gene can be inserted into a plasmid of a bacterial cell which will then produce the protein/trait the gene codes for.

Lesson 4

Biotechnology

- Cloning

DOCTOR PANDORA'S BOX

Misconceptions (Myth or Truth?)

? Cloning produces a full grown individual ?

(MYTH!)

- **<u>Truth</u>: Cloning produces an embryo, <u>NOT</u> a full grown individual!**

? Clone will be exactly like the original organism?

(MYTH!)

- **<u>Truth</u>: Clone will not have exact personality and appearance, development influenced by environment!**

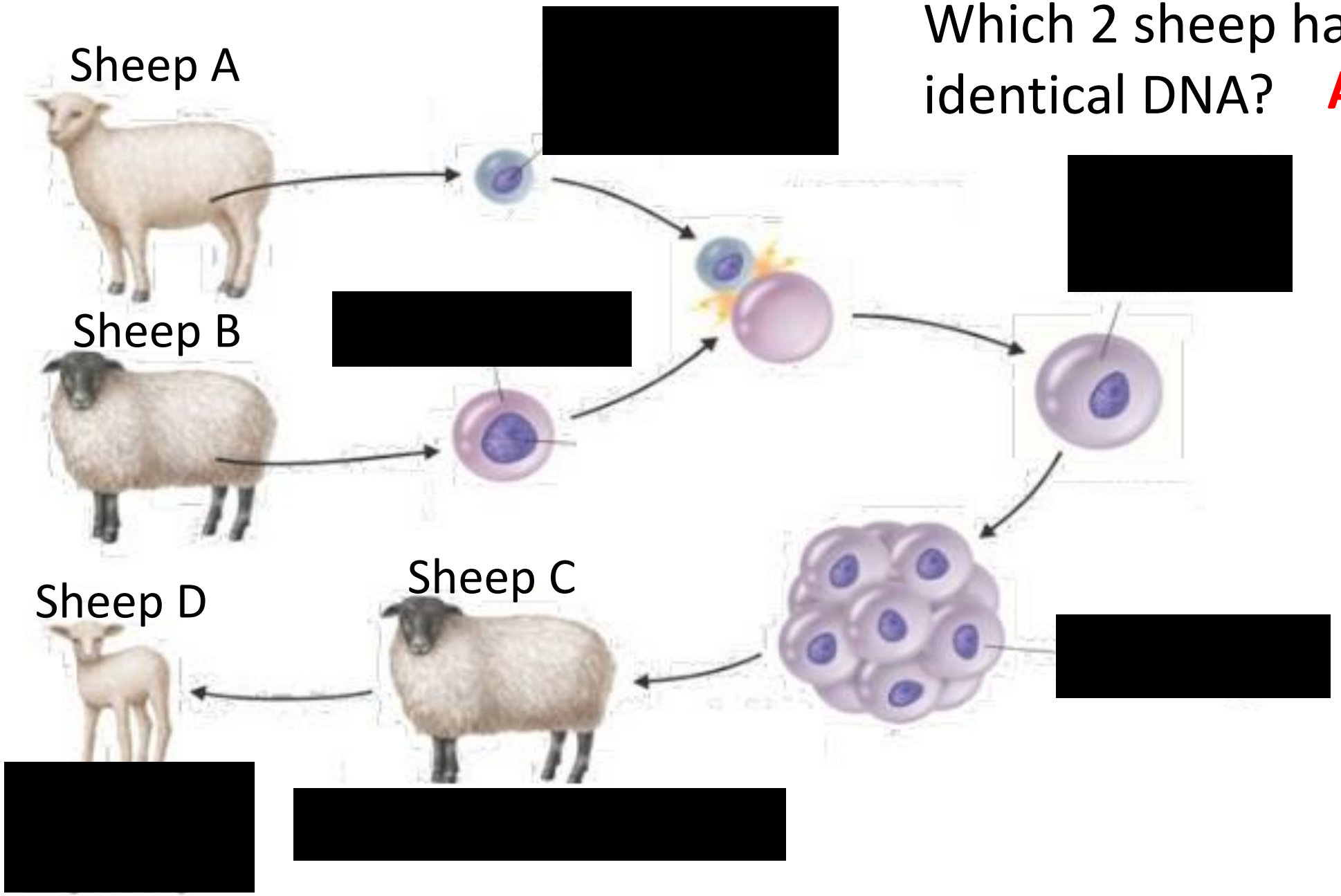
Cloning

- production of genetically identical offspring from the cells of an organism
- Ex. Identical twins (natural clones) or asexual mitotic cell divisions
- Done by somatic cell nuclear transfer

Video - Somatic Cell Nuclear Transfer

Which Animals Have been Cloned?

“Dolly” the sheep – first cloned mammal, 1997



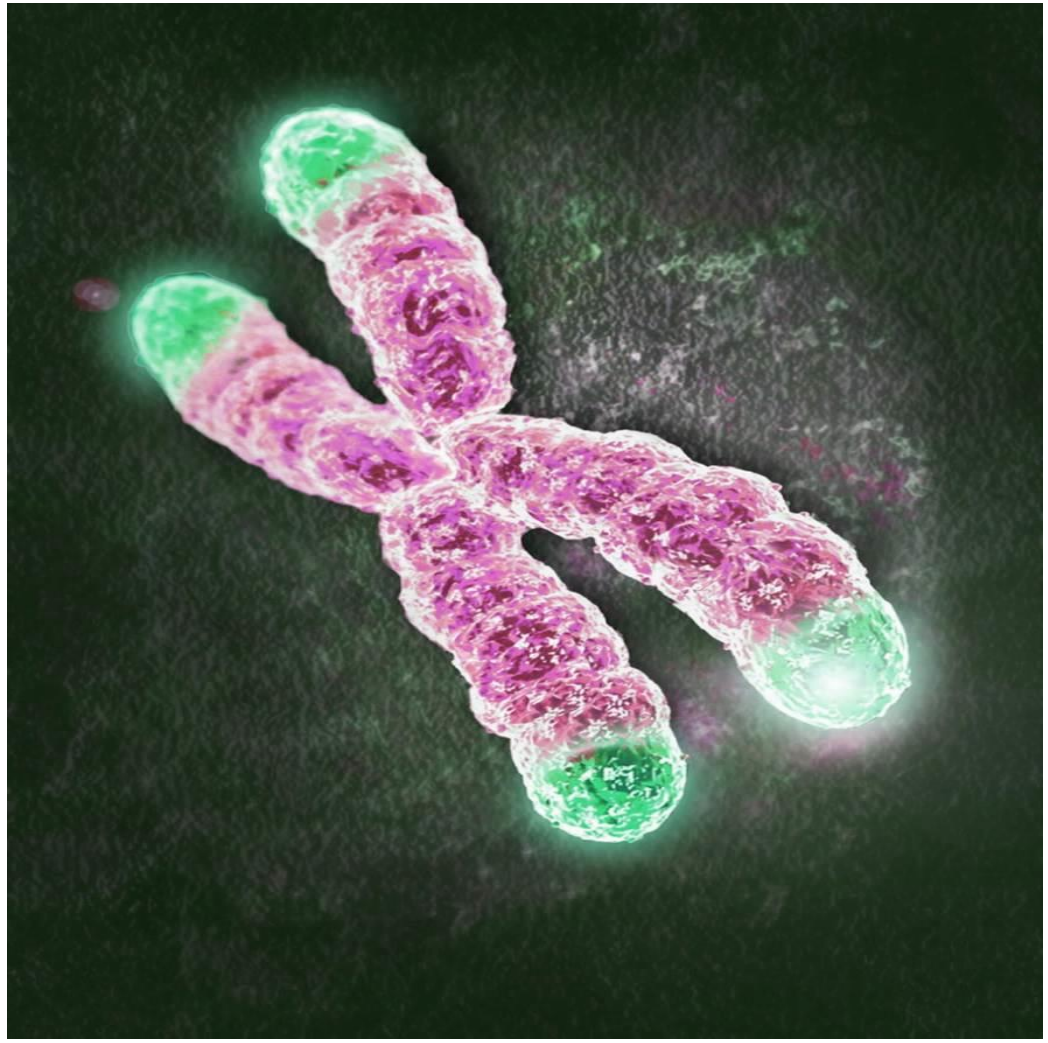
Which 2 sheep have identical DNA? **A and D**

Cloning

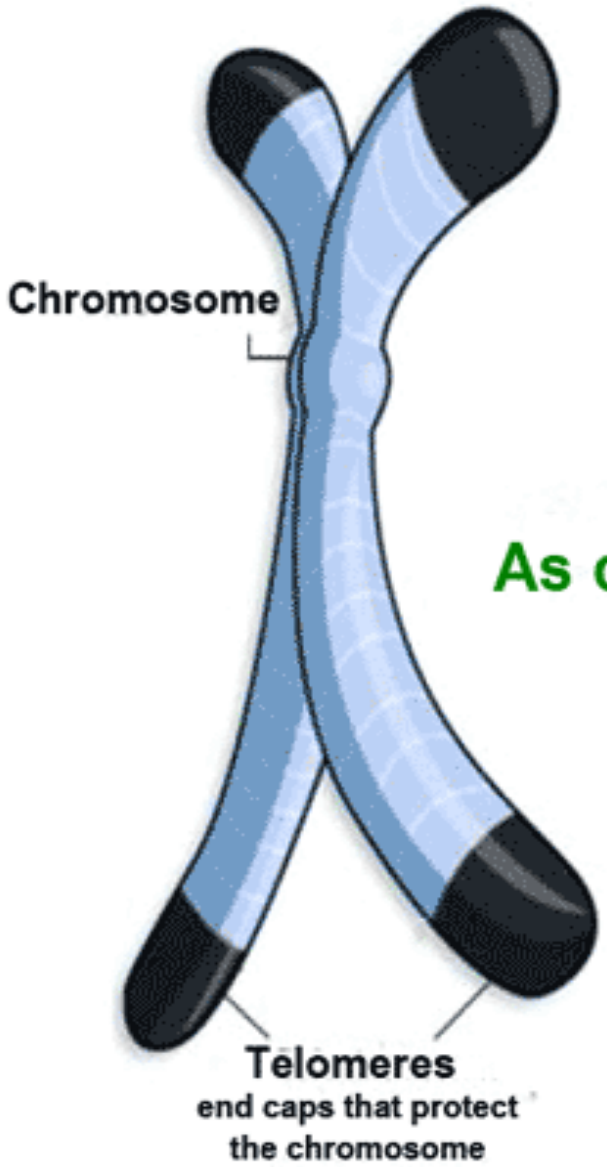
- A body cell is taken from a donor animal
- An **egg** cell is taken from a different animal
- The **nucleus** is removed from the egg
- The body cell and egg are fused by **electric shock**
- The fused cell begins dividing, becoming an **embryo**
- The embryo is implanted into the uterus of a **foster** mother
- The embryo develops into cloned animal

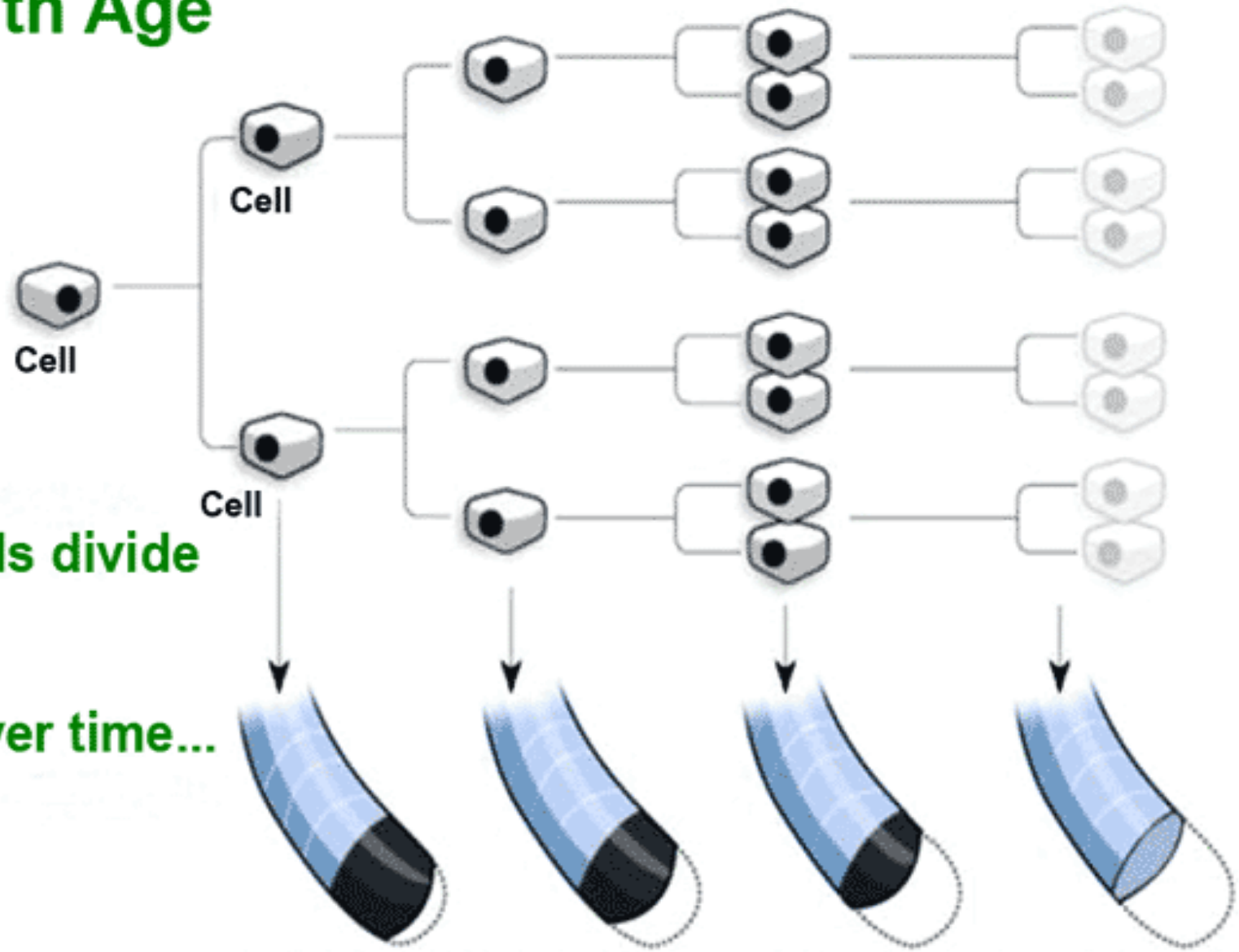
Limitations of Cloning

- high loss in resulting cells
- mitochondrial DNA is not transferred from donor nucleus, so the clone is not a perfect copy
- Telomeres (tips of chromosomes protecting DNA from fraying) are shorter



What We Lose With Age





As cells divide

over time...

...telomeres shorten, and eventually
cell division stops

Advantages of Cloning

- organisms with desirable qualities can be mass produced (the best livestock and crops)
- Can increase endangered species populations
- possibilities of creating donor organs, curing disease, bringing back extinct animals

Disadvantages of Cloning

- clones lack genetic diversity (may be wiped out by virus/disease)
- tend to develop diseases and age rapidly, early death
- ethical controversies:
  - use of embryonic stem cells
  - implications for human cloning

Cloning Regents Questions

1. Cloning an individual usually produces organisms that
   1) Contain dangerous mutations
   2) Contain identical genes
   3) Are identical in appearance and behavior
   4) Produce enzymes different from the parent

2. Which phrase does not describe cells cloned from a carrot?

1) They are genetically identical
2) They are produced sexually
3) They have the same DNA codes
4) They have identical chromosomes

3. From a single monkey, an animal breeder claims that he has successfully cloned two monkeys. He displays the two monkeys, a male and a female, to the public. The claim of the breeder should be rejected because the monkeys

1) Are twins
2) Have the same parents
3) Are of two different sexes
4) Developed from more than one sperm cell

4. “Dolly” is a sheep developed from an egg cell of her mother that had its nucleus replaced by a nucleus from a body cell of her mother. As a result of this technique, Dolly is

1) No longer able to reproduce
2) Genetically identical to her mother
3) Able to have a longer lifespan
4) Unable to mate

5. Which statement concerning an organism produced by cloning is correct?

1) The clone is identical to its parent.
2) The clone has the combined genes of both of its parents.
3) The genotype of the clone will be somewhat different from that of its parents.
4) The phenotype of the clone will be entirely different from that of its parents.

Lesson 5

Biotechnology

- DNA Profiling
  - Gel Electrophoresis
  - PCR

Scenario:

Mr. I.M. Megabucks, the wealthiest man in the world, recently died. Since his death, three women have come forward. Each woman claims to have a child by Megabucks and demands a substantial share of his estate for her child.

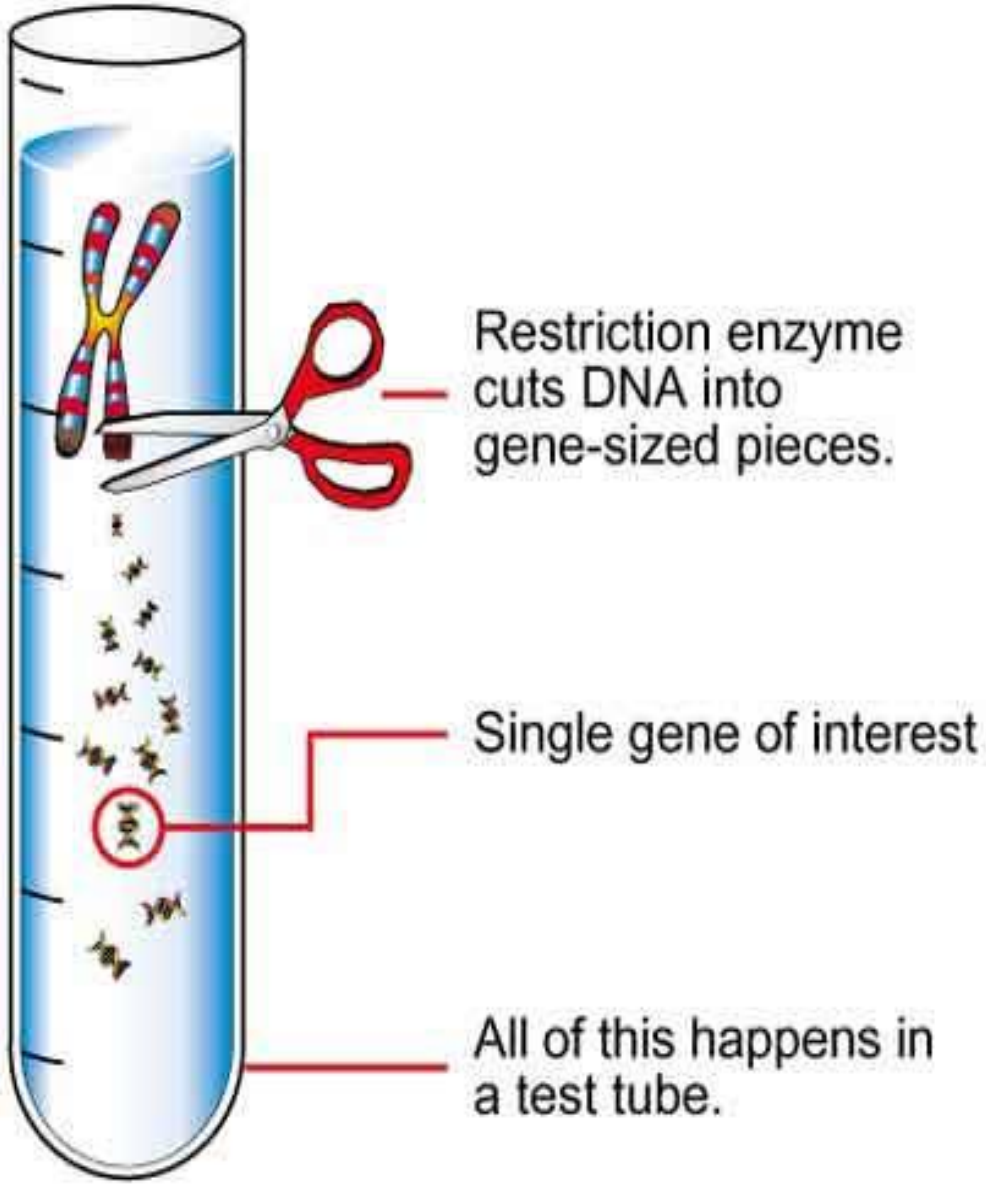
How can we find out if they are telling the truth?

DNA Profiling (aka DNA “fingerprinting”)

- Certain segments of DNA are unique to each person
- Identification can be done by analyzing DNA samples
  - Skin
  - Blood
  - Hair
  - Saliva
  - Semen

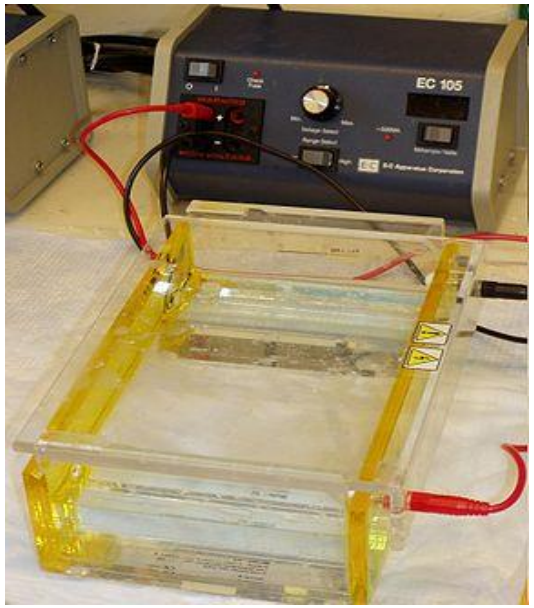
Restriction Enzymes

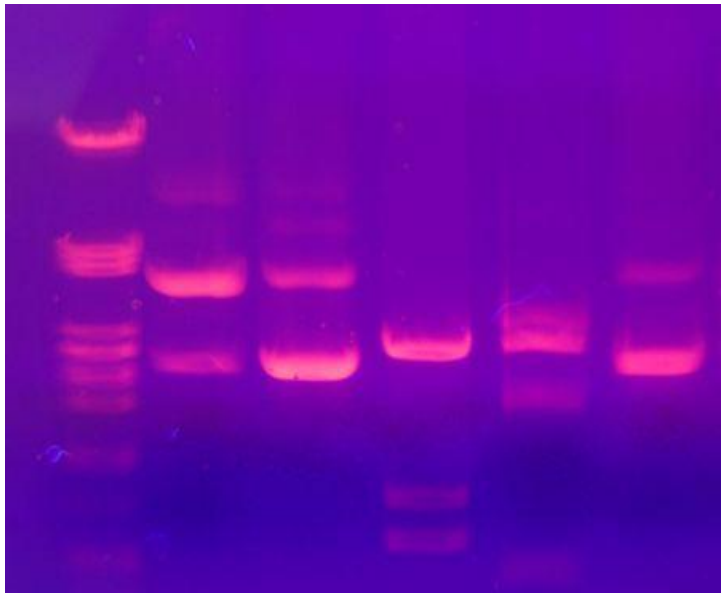
- cut DNA at a specific nucleotide sequence, producing different sized fragments
- DNA fragments are then separated by a process called gel electrophoresis



Gel Electrophoresis

- lab technique used to analyze DNA for purpose of:
  - solving a crime
  - determining family relationships (ex. parent/child)
  - determining relationships among species



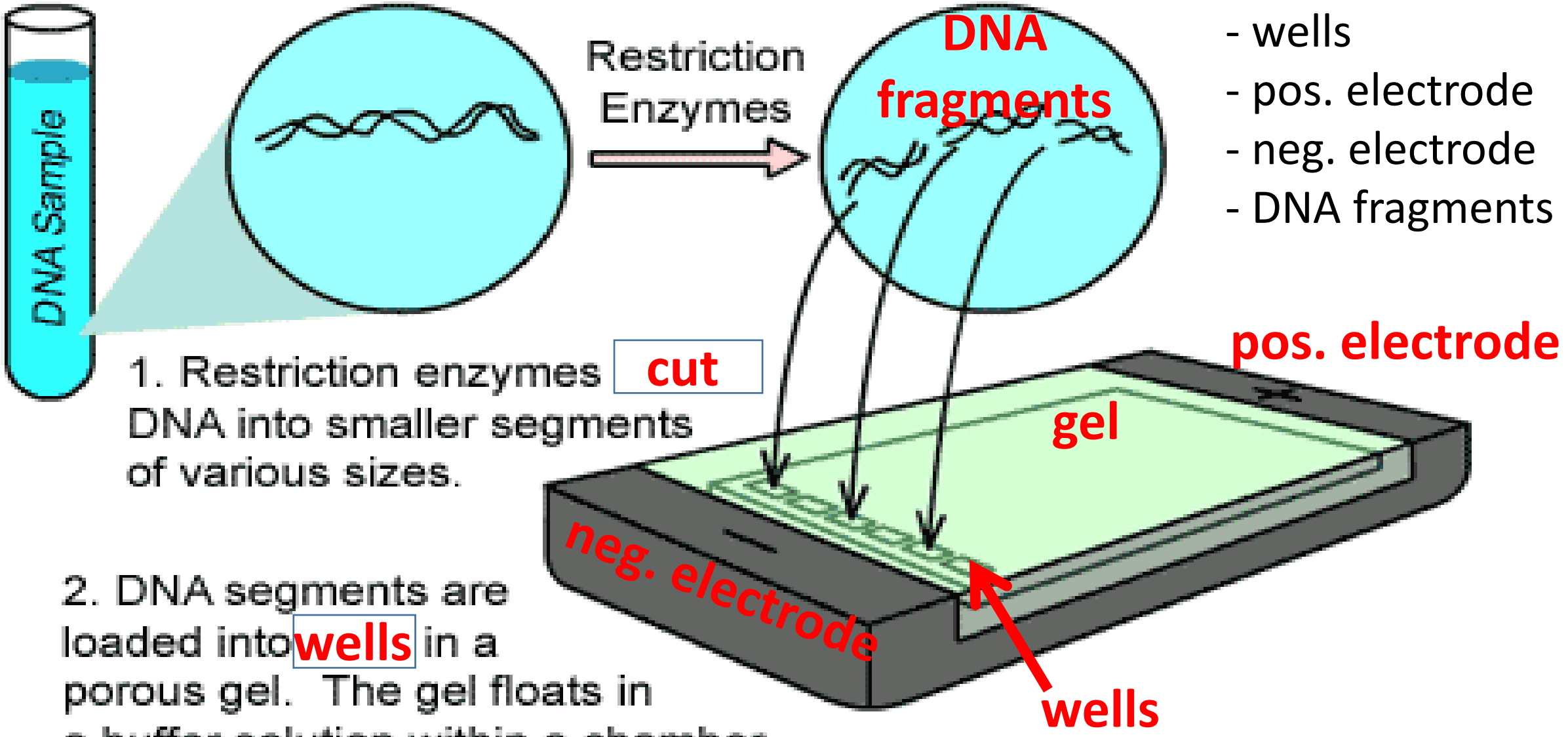


Gel Electrophoresis lab demo

Virtual Lab (Gel Electrophoresis)

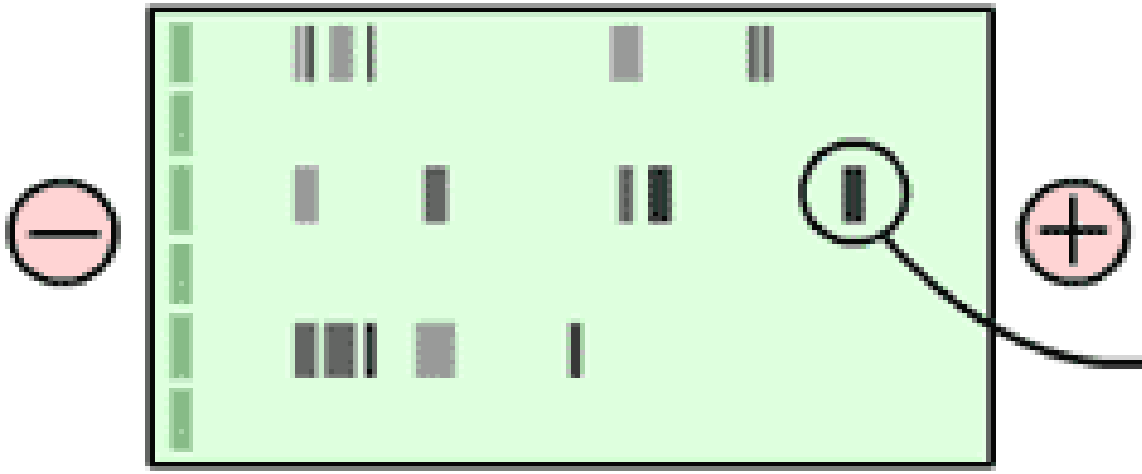
Figure S-2: Gel Electrophoresis

Label:
- gel
- wells
- pos. electrode
- neg. electrode
- DNA fragments



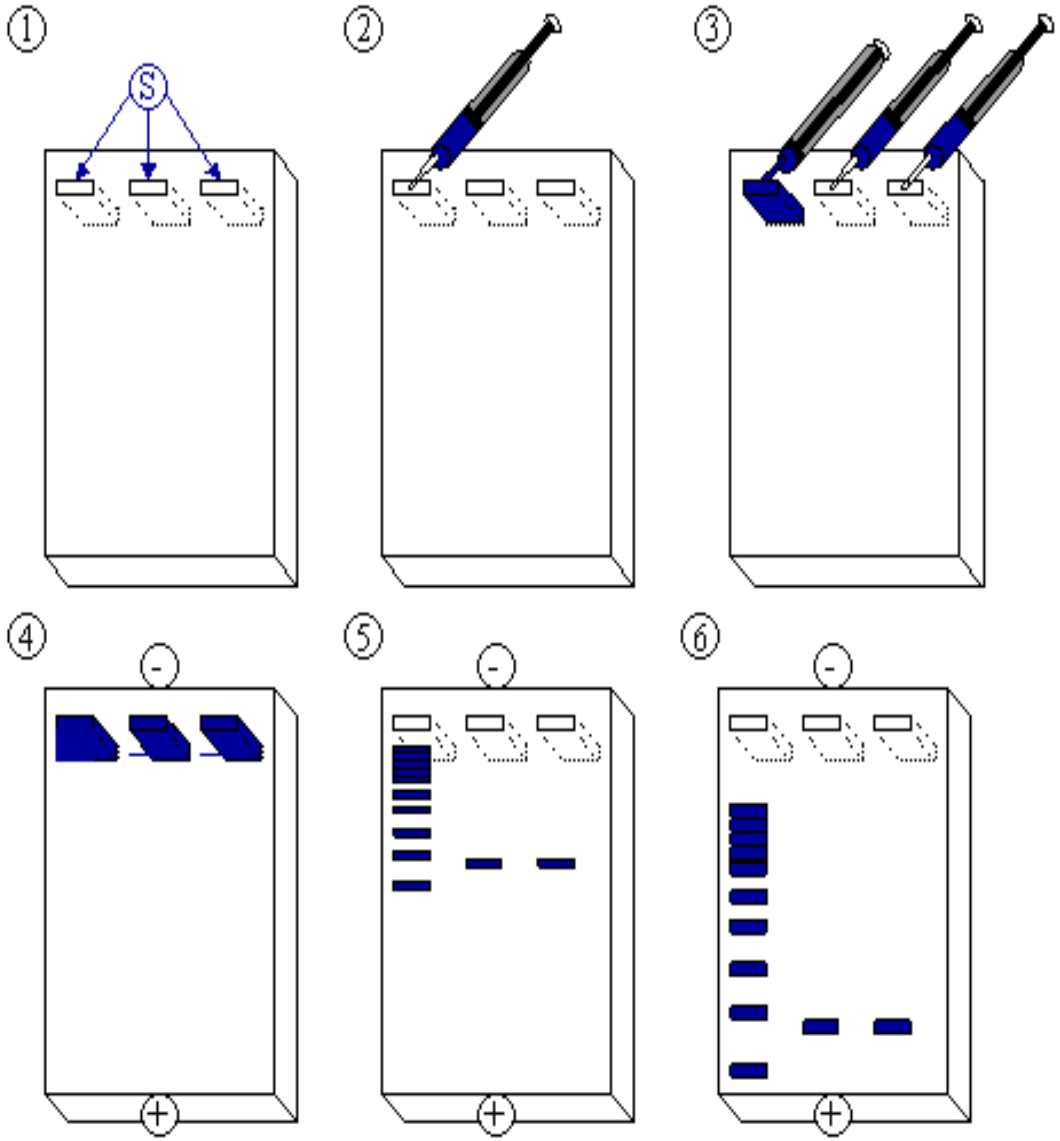
1. Restriction enzymes **cut** DNA into smaller segments of various sizes.

2. DNA segments are loaded into **wells** in a porous gel. The gel floats in a buffer solution within a chamber between two electrodes.



3. When **electricity** is passed through the chamber, DNA fragments move toward the positively-charged cathode because DNA has a **negative** charge.

4. Smaller DNA segments move faster and **farther** than larger DNA segments.



Pictures 1 – 3 show:

Loading of DNA fragments into the gel.

Pictures 4 – 6 show:

Movement of fragments through the gel.

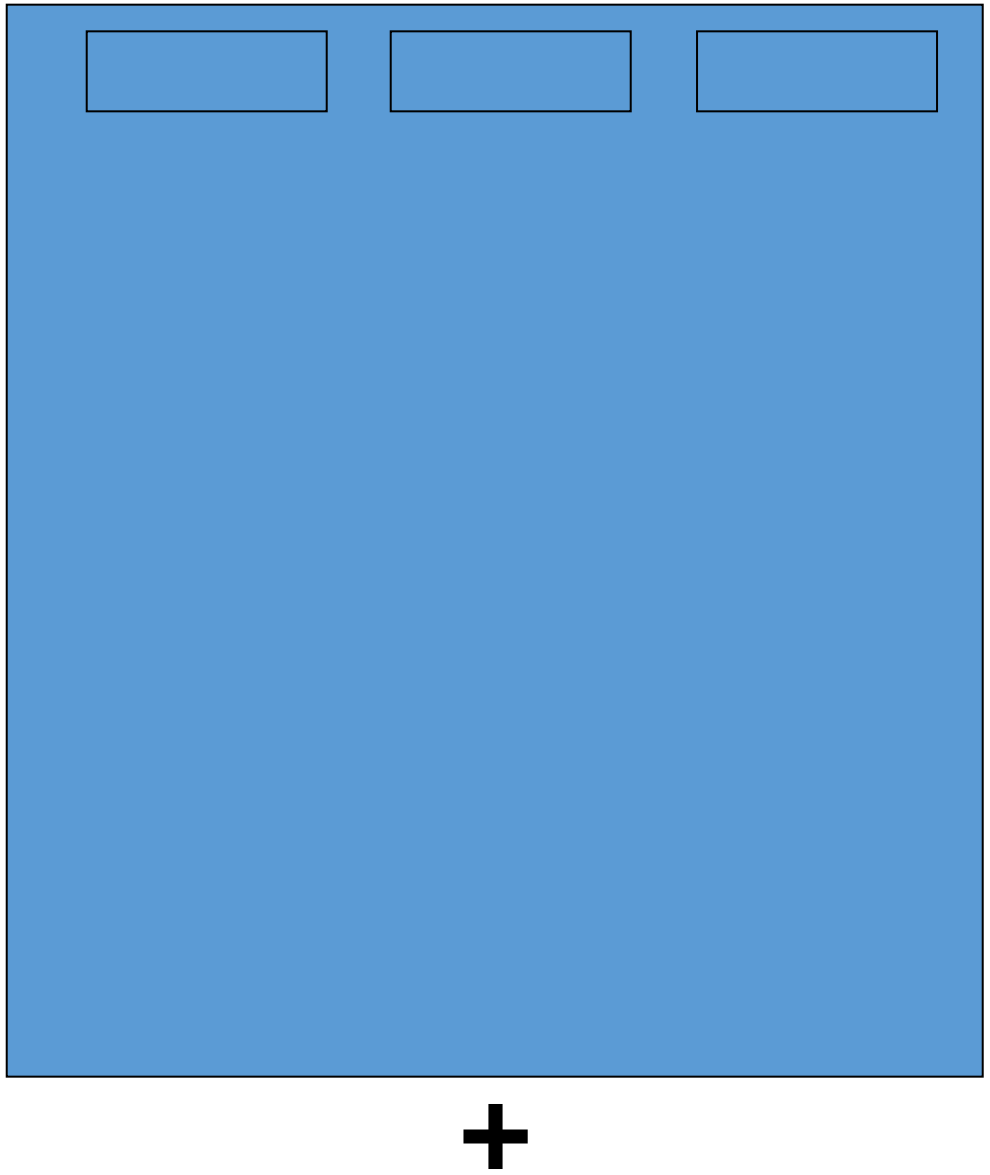
DNA samples produce unique **banding patterns** that can be compared for analysis of similarities and differences.

Highlights of Gel Electrophoresis

The distance that the molecules move is based on their <u>SIZE</u>

Molecules move farther if they are <u>SMALLER</u>

<u>ELECTRIC CURRENT</u> makes the DNA move toward the <u>POSITIVE</u> end!



Restriction Enzymes Practice Problem

A restriction enzyme is used to cut the DNA from species A & B. The enzyme binds to the sequence G G G A T T and cuts between G and A. State how many cuts will be made in the DNA sequences of each species when this enzyme is used, how many fragments are produced, and how many bases long is the size of each band?

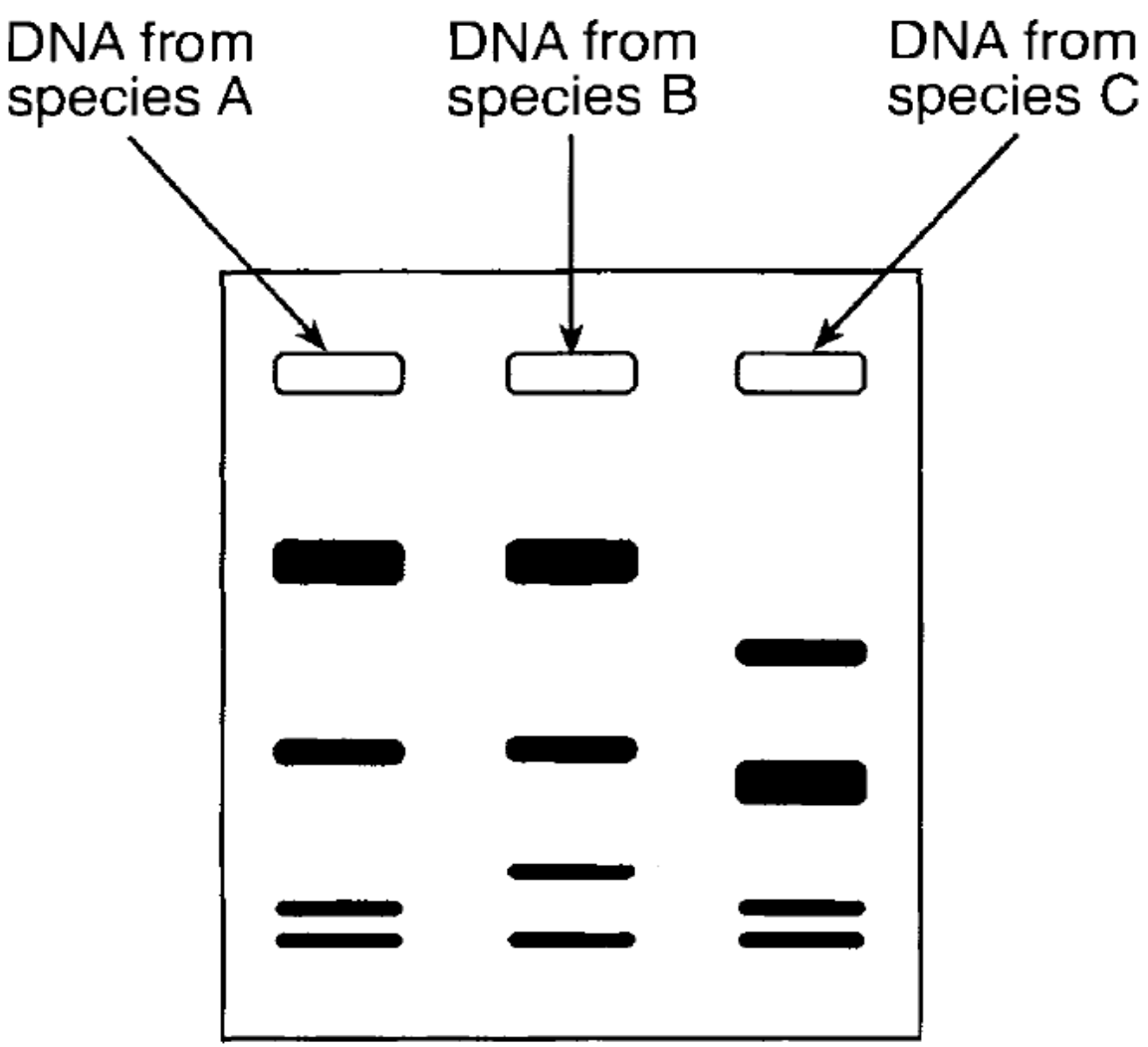
Plant Species A: A C C G C A G G G | A T T C G C

Plant Species B: A C C G G A G C G A T T C G C

Correct Answer:

Plant A – 1 cut, 2 fragments, (9 bases, 6 bases)

Plant B – 0 cuts, 1 fragment (15 bases)

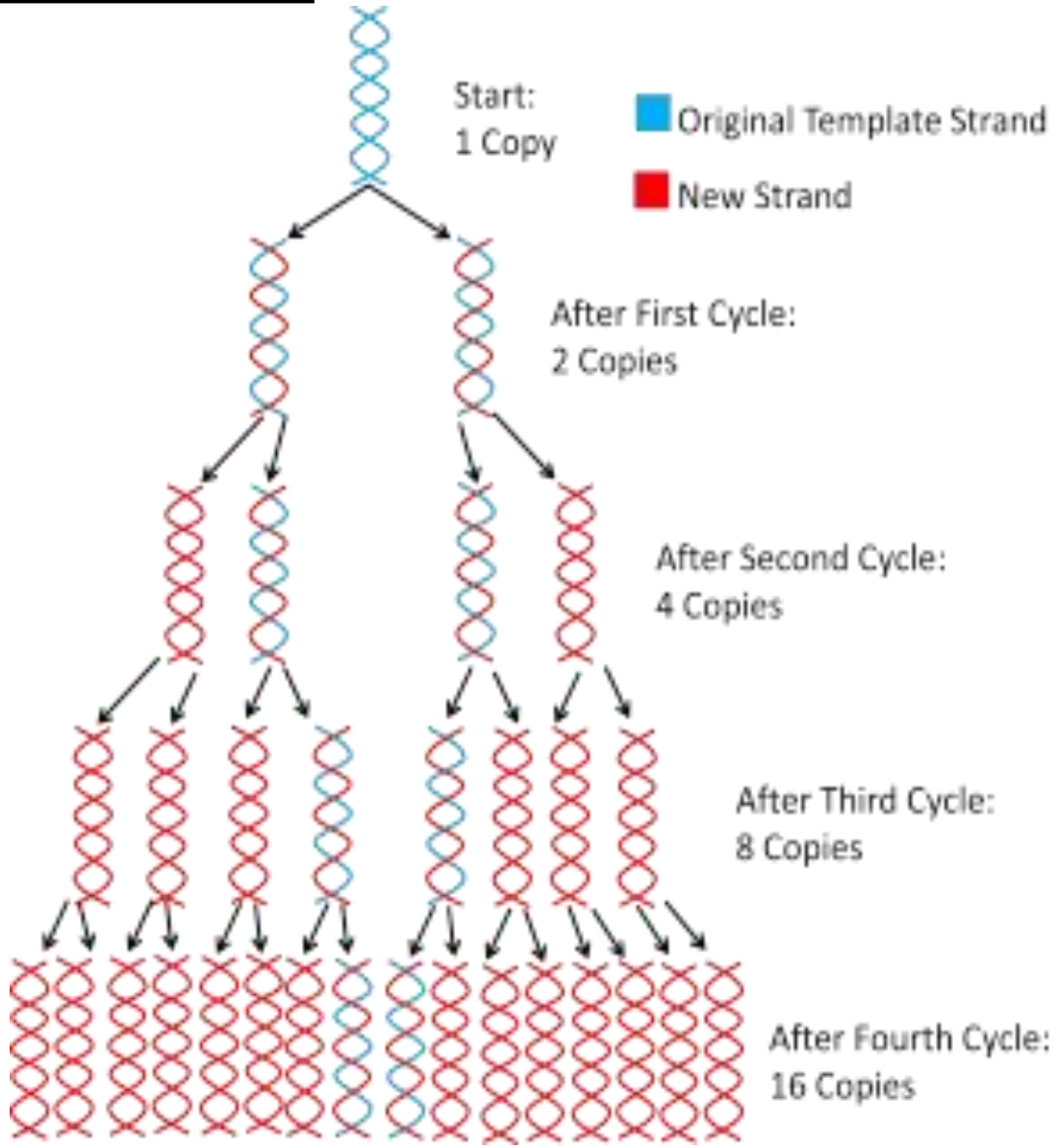


Which two species are most closely related? Explain.

Species A and B because they have most similar banding pattern.

PCR (Polymerase Chain Reaction)

- To study genes, many copies are required and can be made by a technique called PCR
  - Uses the enzyme DNA Polymerase to make many copies of DNA



PCR Song (based on "We Are the World"

We Are the World

Applications of Gel Electrophoresis

60 Minutes News Clip – A Not So Perfect Match (12min)