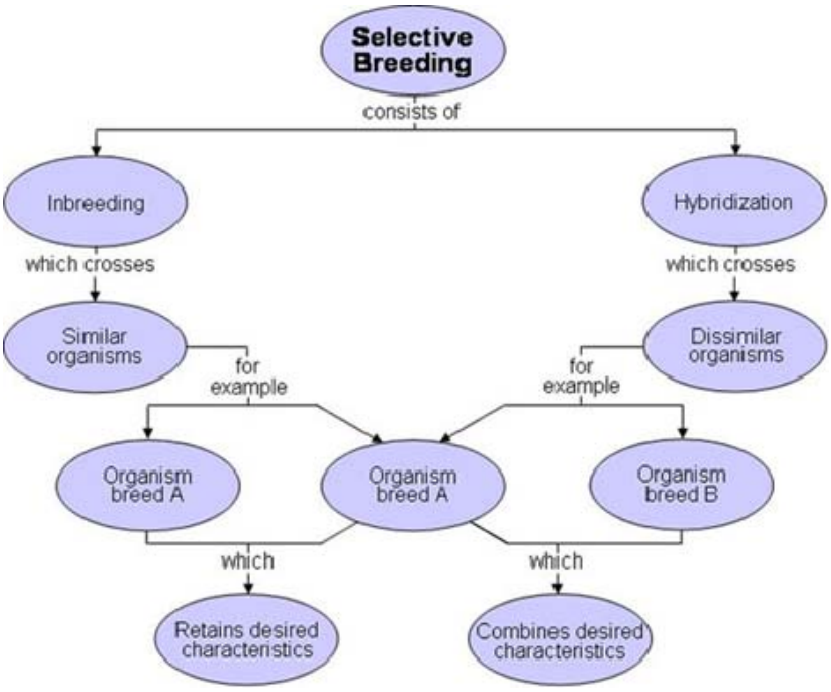
Biotechnology and Genetic Engineering

Biotechnology: the application of technology to biological sciences

1. ***Dairy, Baking, Beer and Wine Industries:*** cheese, buttermilk, yogurt, bread, beer, and wine are some the "biotech" products that are produces with the use of microbes such as bacteria (dairy industry) and yeast(baking and beer and wine industries)

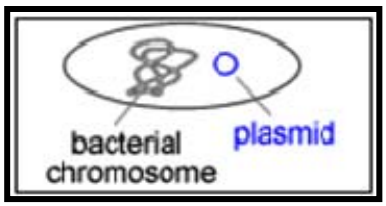
2. ***Selective Breeding:*** the process by which domestic animals and new varieties of plants are produced as a result of selection and breeding for organisms with desirable traits.
   - ***a.*** Artificial Selection: organisms with the most desirable traits are mated or crossed to obtain offspring with these selected traits.
   - ***b.*** Inbreeding: offspring with the selected traits are then mated or crossed with each other to produce more organisms that retain the desired traits
     - Ex: selective breeding of cattle to contain less fat and more meat
   - ***c.*** Hybridization: two varieties of a species may have different desirable traits. These organisms are crossed to produce an organism with the combined desirable traits.
     - Ex: roses with long stems may be crossed with roses without thorns to produces thornless long stemmed roses



Genetic Engineering: technology that is used to alter genetic instruction in order to obtain desirable traits in various organisms.

Definition

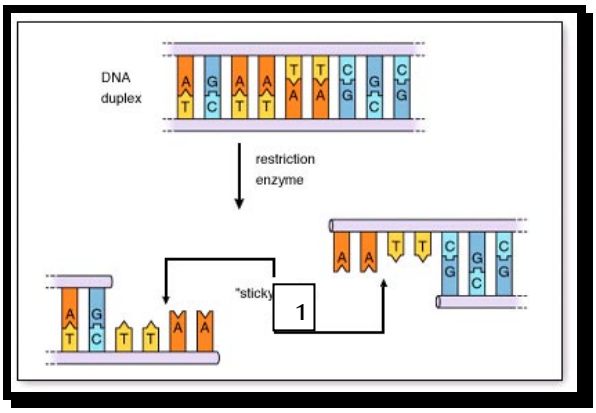
Plasmid: a small circular DNA strand in the cytoplasm of a bacterium cell that can replicate independently of its chromosome. Often used in research in the manipulation or splicing of genes.



Genetic engineering is possible because of ***restriction enzymes,*** which are special enzymes that cut DNA in a way that permit the resulting DNA fragments to be ***spliced*** (moved and attached) to the DNA of another organism.

Restriction enzymes are naturally produced by bacteria to prevent invasions by foreign DNA. These enzymes cleave foreign DNA into pieces so that it cannot function inside the bacteria.

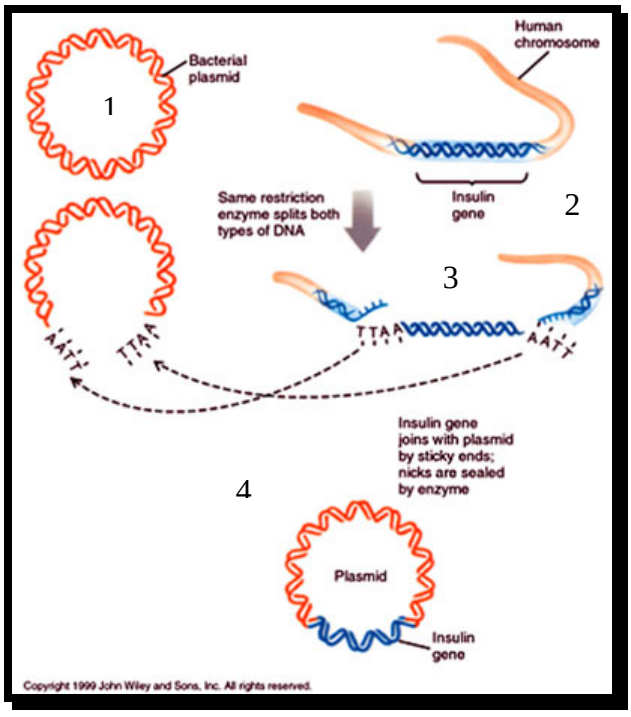
Example of How Restriction Enzymes Work



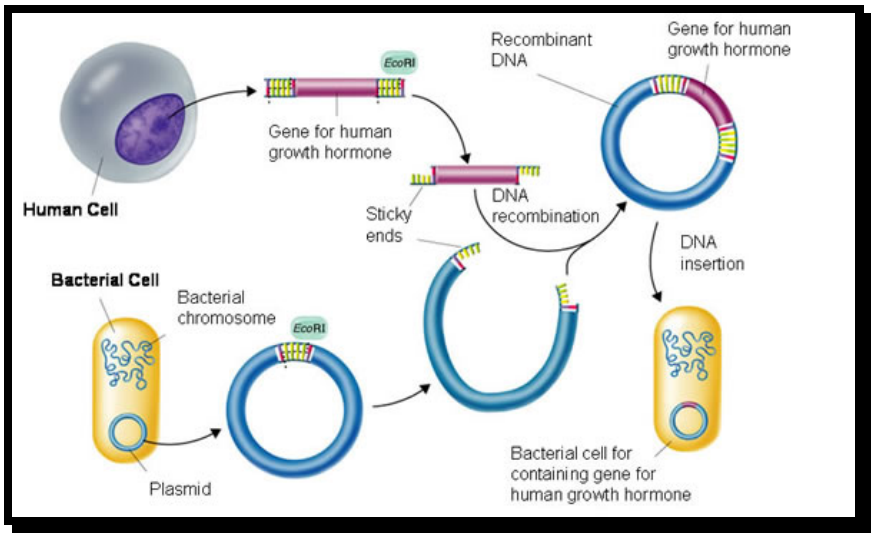
1. ***Recombinant DNA or DNA Cloning:*** the transfer of a DNA fragment of interest to a genetic element such as a bacterial plasmid. Plasmids are self-replicating extra-chromosomal circular DNA molecules, distinct from the normal bacterial genome. Scientists studying a particular gene often use **bacterial plasmids** to generate multiple copies of the same gene.

Let's say we want to splice a human gene that makes insulin into a bacterial plasmid.

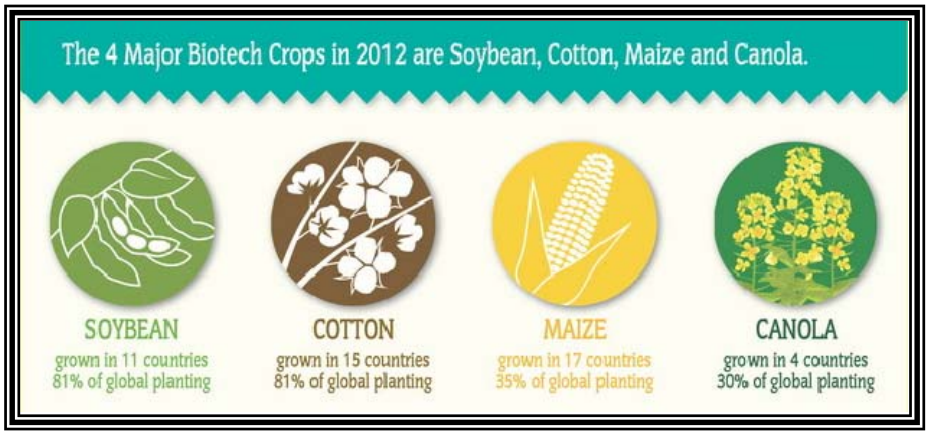
1. First we would remove a plasmid from a bacteria cell. Then we would cut out a piece of DNA from the bacterial plasmid using a specific restriction enzyme (see # 1 in the diagram below).
2. Then we would isolate the gene we wanted to transfer on the human chromosome and cut it out of the human DNA with the same restriction enzyme we used to remove a section of the plasmid DNA. (see # 2 in diagram below)
3. We would then insert the insulin gene into the cut out portion of the plasmid. They should fit in perfectly together since complimentary ends were cut by the restriction enzymes so the nitrogen bases match up (A-T and C-G). (see # 3 in the diagram below).
4. The result is what we call ***recombinant DNA.*** The recombinant plasmid is then inserted back into the bacterial cell. The bacteria will function normally except that it will also now make human insulin (see # 4 in the diagram below)



Example: Diabetics have blood glucose levels that are too high. Normally, the hormone, insulin, which is produced in the pancreas, lowers blood glucose levels by encouraging cells to remove glucose from the blood. In diabetics, their insulin does not work correctly or they do not produce enough for it to be effective. In the past, diabetics took animal glucose in order to control their blood glucose levels. However, since animal insulin is foreign protein to the body, after a time, the human body will "fight" off the insulin and reject it Scientists decided to try to manufacture human insulin by using recombinant DNA. If a human **insulin-producing gene** is transferred and spliced into a plasmid of a bacterial cell, the bacterium will begin to produce human insulin. **Not only is the human insulin produced in large quantities and at low cost but there is also less of a chance that diabetics will develop a resistance to human insulin as they did when using animal insulin.** This technique is also used to produce **Human Growth Hormone. (see below)**



2. *Genetically Modified Organisms (GMOs)*
   - Also referred to as **transgenic organisms** since genes are combined from different organisms.
   - Today, GM products include medicines and vaccines, foods and food ingredients, feeds, and fibers.



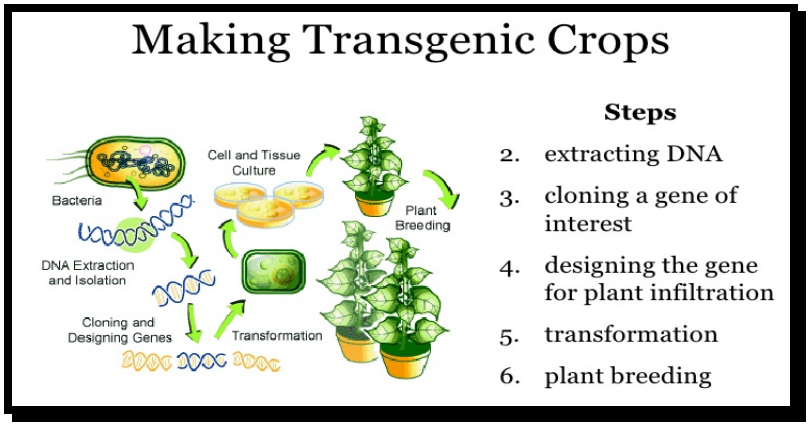
   - Technologies for genetically modifying (GM) foods offer dramatic promise for meeting some areas of greatest challenge in feeding and maintaining a healthy world population. Like all new technologies, they also pose risks, some of which we still are unaware.
   - ***Pros:***
     - ✓ **Crops**
       --Enhanced taste and quality

--Reduced maturation time
--Increased nutrients, yields, and stress tolerance
--Improved resistance to disease, pests, and herbicides
--New products and growing techniques

- ✓ **Animals**
  --Increased resistance to disease
  --increased productivity, hardiness, and feed efficiency
  --Increased yields of meat, eggs, and milk
  --Improved animal health
- ✓ **Society**
  --Increased food production for growing world population

♦ *Cons:*

- ✓ **Safety**
  -- Potential human health impact: allergens, transfer of antibiotic resistance markers, unknown effects
  -- Potential environmental impact: unintended transfer of transgenes through cross-pollination, unknown effects on other organisms (e.g., soil microbes), and loss of flora and fauna biodiversity
- ✓ **Access of Intellectual Property**
  --Domination of world food production by a few companies
  --Increasing dependence of developing nations on industrialized nations
  --Biopiracy—foreign exploitation of natural resources
- ✓ **Ethics**
  --Violation of natural organisms' intrinsic values
  --Tampering with nature by mixing genes among species
  --Objections to consuming animal genes in plants and vice versa
  --Stress for animals
- ✓ **Labeling**
  --Not mandatory in some countries
  --Mixing GM crops with non-GM crops confounds labeling attempts
- ✓ **Society**
  --New advances may favor the interests of rich countries



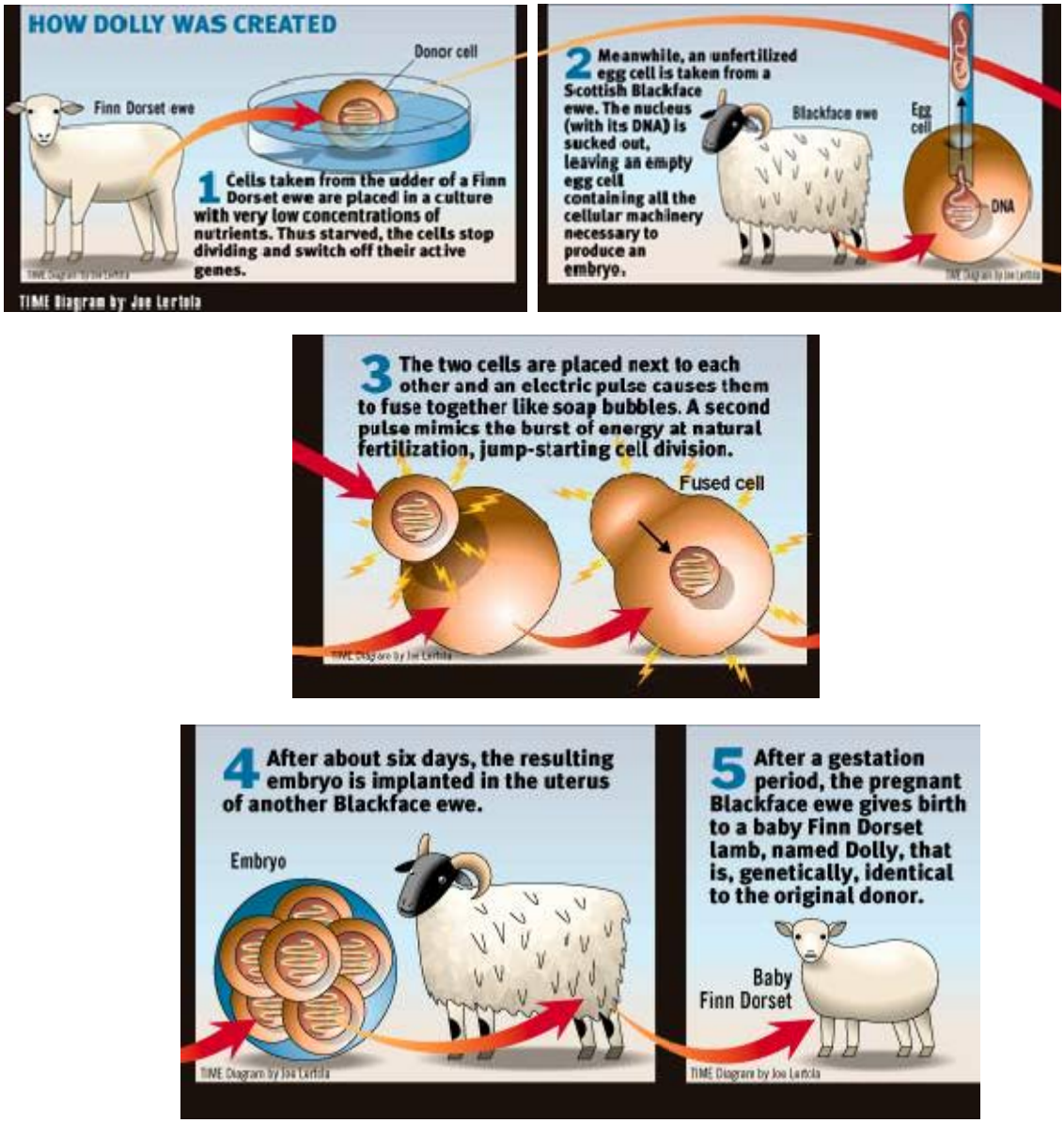
3. ***Reproductive Cloning***: Reproductive cloning is a technology used to generate an animal that has the same nuclear DNA as another currently or previously existing animal.

♦ For reproductive cloning you need **3 sheep:**

- ✓ The first sheep to donate a body cell
- ✓ The second sheep to donate an egg cell
- ✓ A third sheep to act as a "foster mother" by carrying the cloned embryo

- **Dolly** the first successfully cloned animal, was created by process called "somatic cell nuclear transfer" (SCNT), where scientists transfer genetic material from the nucleus of a donor adult cell (sheep 1) to an egg (sheep 2) whose nucleus (with the genetic material) has been removed.
- The reconstructed egg containing the DNA from a donor cell must be treated with chemicals or electric current in order to stimulate cell division.
- Once the cloned embryo reaches a suitable stage, it is transferred to the uterus of a female "foster mother" (sheep 3) where it continues to develop until birth.

The diagram below explains how Dolly was created… from Times Magazine March 10, 1997.



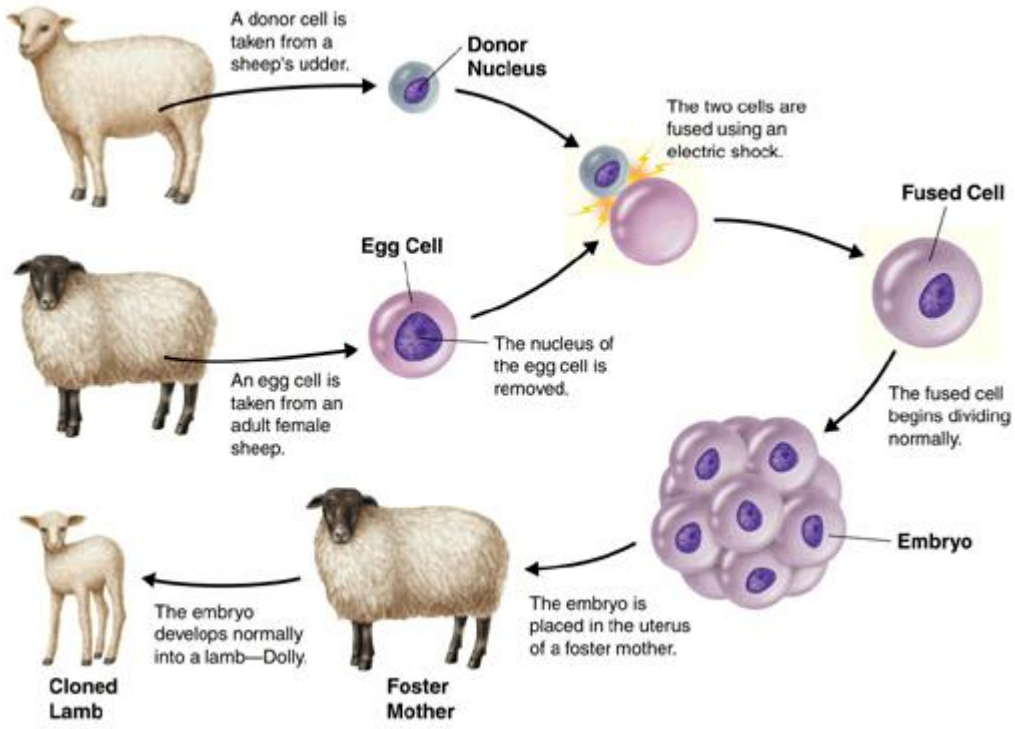
Dolly or any other animal created using nuclear transfer technology is not truly an identical clone of the donor animal. Only the clone's chromosomal or nuclear DNA is the same as the donor.

Some of the clone's genetic materials come from the mitochondria in the cytoplasm of the enucleated egg. Acquired mutations in mitochondrial DNA are believed to play an important role in the aging process.

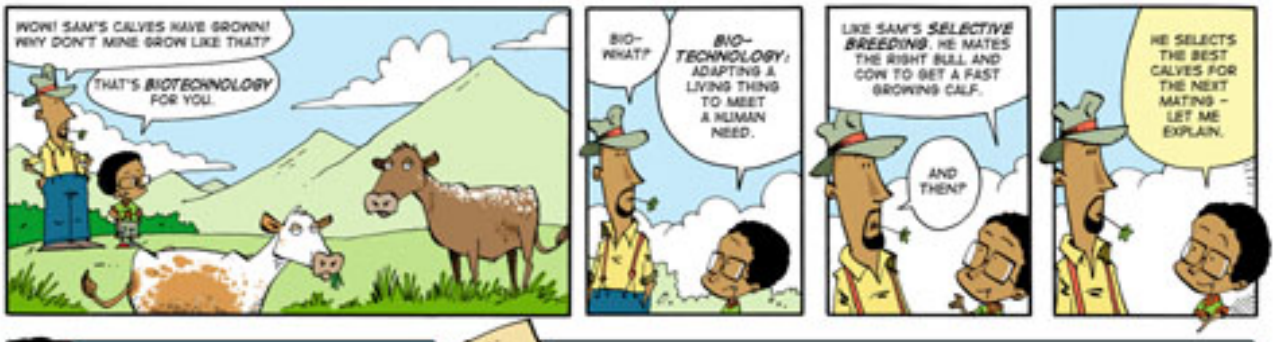
Dolly's success is truly remarkable because it demonstrated **that the genetic material from a specialized adult cell (in this case an udder cell) could be reprogrammed to generate an entire new organism.**

Dolly, the first mammal to be cloned from adult DNA, was put down by lethal injection on Febuary 14, 2003 at the age of 6. Prior to her death, Dolly suffered from lung cancer and crippling arthritis. Dolly was mother to six lambs, bred the old-fashioned way. Dolly's chromosomes were a little shorter than those of other sheep, but in most other ways she was the same as any other sheep of her chronological age. However, her early ageing may reflect that she was raised from the nucleus of a 6-year old sheep. Study of her cells also revealed that the very small amount of DNA outside the nucleus, in the mitochondria of the cells, is all inherited from the donor egg cell, not from the donor nucleus like the rest of her DNA. This finding could be important for sex-linked diseases such as hemophilia, and certain neuromuscular, brain and kidney conditions that are passed on through the mother's side of the family only.

If the low success rates of reproductive cloning can be improved (Dolly was only one success out of 276 tries), this technique co be used to repopulate endangered animals or animals that are difficult to breed.



BIOTECHNOLOGY:
SELECTIVE BREEDING

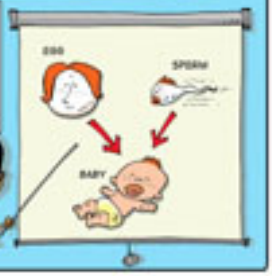


GENES

HAVE YOU NOTICED HOW CHILDREN AND ANIMALS OFTEN LOOK LIKE THEIR PARENTS?

OUR BODIES ARE BUILT ACCORDING TO INSTRUCTIONS CALLED **GENES**. GENES GIVE A PERSON OR ANIMAL ITS SPECIAL QUALITIES.

HALF OUR GENES COME FROM OUR MOTHER (IN AN EGG CELL) AND HALF FROM OUR FATHER (IN A SPERM CELL).



BREEDING

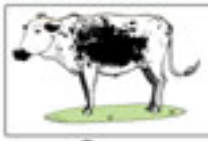
CATTLE ARE OFTEN KEPT TO PRODUCE MEAT.

A BULL IS MATED WITH A COW. A GOOD BULL HAS A BETTER CHANCE OF PRODUCING GOOD CALVES.

A CALF THAT RECEIVES GOOD GENES GROWS WELL, PRODUCING LOTS OF BEEF. SOME CALVES GROW POORLY, AND ARE REMOVED FROM THE HERD.

HEY BABE... COME HERE OFTEN?

OVER TIME, THE FARMER HAS MORE AND MORE CATTLE THAT GROW WELL.



AFRICAN CATTLE ARE SUITED TO AFRICAN CONDITIONS. THEY HAVE GENES THAT HELP THEM SURVIVE IN DRY AREAS AND FIGHT DISEASES.

SOME CATTLE HAVE GENES THAT MAKE THEM GROW QUICKLY AND PRODUCE GOOD BEEF.

THE CALF OF AN AFRICAN COW AND A BEEF PRODUCING BULL SURVIVES AFRICAN CONDITIONS **AND** PRODUCES GOOD BEEF.

PRIME BULLS ARE VERY **EXPENSIVE**. NOT EVERYONE CAN AFFORD THEM.

GROUP FARMING

WHY NOT SHARE THE COST OF THE BULL WITH A GROUP OF FARMERS?

A GOOD BULL WILL PRODUCE MORE GOOD BEEF PRODUCING CALVES. KEEP THESE TO MATE AGAIN. YOU CAN SELL THE OTHERS.

YOU CAN TRADE YOUR BULL WITH OTHER FARMERS TO GET A GOOD MIXTURE OF GENES (A BULL SHOULD NOT MATE WITH HIS DAUGHTER)

ARTIFICIAL INSEMINATION

ONLY THE SPERM OF THE BULL IS REQUIRED.

YOU CAN BUY THE SPERM OF A GENETICALLY SUPERIOR BULL WITHOUT BUYING THE BULL. WHEN A COW IS READY TO MATE, THE SPERM IS INSERTED INTO HER. IT FERTILISES AN EGG, WHICH GROWS INTO A CALF.

NOT ALL CALVES HAVE THE DESIRED QUALITIES. SELECT ONLY THE ONES THAT DO FOR THE NEXT MATING.

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REPUBLIC OF SOUTH AFRICA

For more information or support on breeding contact the Public Understanding of Biotechnology.

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PUBLIC UNDERSTANDING OF BIOTECHNOLOGY

Questions:

1. Define the following terms:
   a. biotechnology
   b. selective breeding
   c. group farming
   d. artificial insemination
2. Discuss at least 2 benefits of selective breeding
3. Describe at least 1 disadvantage of selective breeding