Molecular biology applied to food production in Brazil

Aline Cesar

Young Researcher – Food Sciences Department

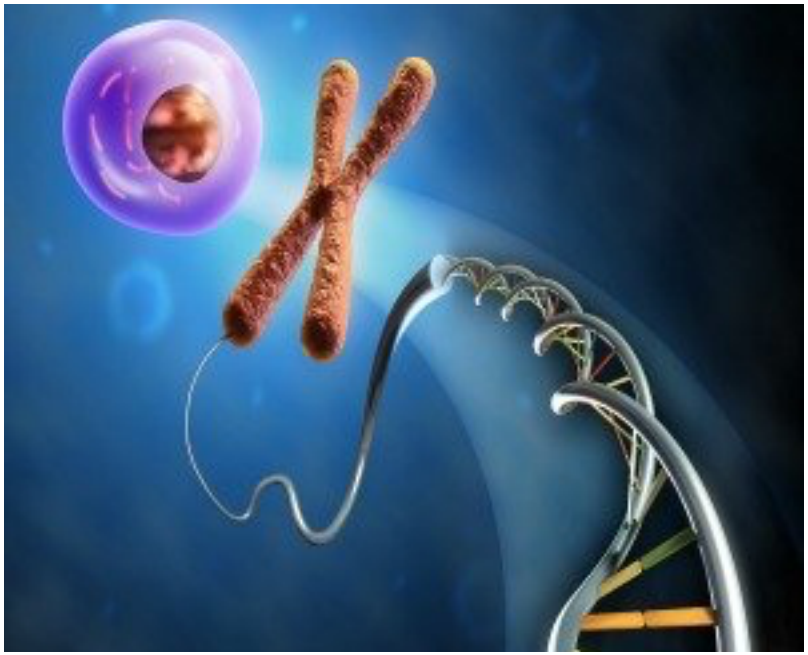
alinecesar@usp.br

Overview

- What is molecular biology?
- Terminology
- Important developments
- Disciplines related to molecular biology
- Animal models
- Central dogma of molecular biology
- Molecular biology tools
- Applications

What is molecular biology?

→ **Is the field of biology that studies the composition, structure and interactions of cellular molecules, such as nucleic acids and proteins, which carry out the essential biological processes for the cell**



Terminology

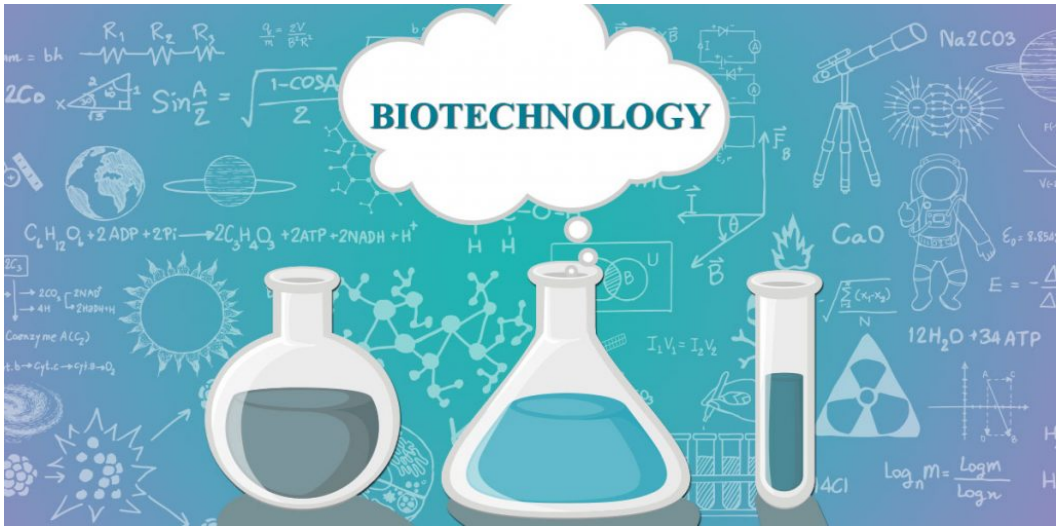
- **Recombinant DNA technology - a set of techniques for manipulating DNA, including:**
  - **the identification and cloning of genes**
  - **the study of the expression of cloned genes**
  - **the production of large quantities of gene product**

- **Genetic engineering - the process of transferring DNA from one organism into another that results in a genetic modification**

Terminology

- **Biotechnology - production of goods and services using biological organisms, systems, and processes**

- **Molecular biotechnology - rDNA technology + biotechnology**



Important developments

Date	Event
1917	Karl Ereky coins the term *biotechnology*
1940	A. Jost coins the term *genetic engineering*
1943	Penicillin produced on an industrial scale
1944	Avery, MacLeod, and McCarty demonstrate that DNA is the genetic material
1953	Watson and Crick determine the structure of DNA
1961	The journal *Biotechnology and Bioengineering* is established
1961–1966	Entire genetic code deciphered
1970	First restriction endonuclease isolated
1972	Khorana and coworkers synthesize an entire tRNA gene
1973	Boyer and Cohen establish recombinant DNA technology
1975	Kohler and Milstein describe the production of monoclonal antibodies
1976	First guidelines for the conduct of recombinant DNA research issued
1976	Techniques developed to determine the sequence of DNA
1978	Genentech produces human insulin in *E. coli*
1980	U.S. Supreme Court rules in the case of Diamond vs. Chakrabarty that genetically manipulated microorganisms can be patented
1981	First commercial, automated DNA synthesizers sold

Date	Event
1996	Recombinant protein erythropoietin exceeds $1 billion in annual sales
1996	Complete DNA sequence of all the chromosomes of a eukaryotic organism, the yeast *Saccharomyces cerevisiae*, is determined
1996	Commercial planting of genetically modified crops
1997	Nuclear cloning of a mammal—a sheep—with a differentiated cell nucleus
1998	FDA approves first antisense drug
1999	FDA approves recombinant fusion protein (diphtheria toxin–interleukin-2) for cutaneous T-cell lymphoma
2000	*Arabidopsis* genome sequenced
2000	Monoclonal antibodies exceed $2 billion in annual sales
2000	Development of "golden rice" (provitamin-A-producing rice) announced
2001	Human genome sequence is published
2002	Complete human gene microarrays (gene chips) commercially available
2002	FDA approves first nucleic acid test system to screen whole blood from donors for HIV and HCV
2004	Large-scale sequencing of the Sargasso Sea metagenome
2005	NCBI announces 100 gigabases of nucleotides in GenBank sequence database

(Continued)

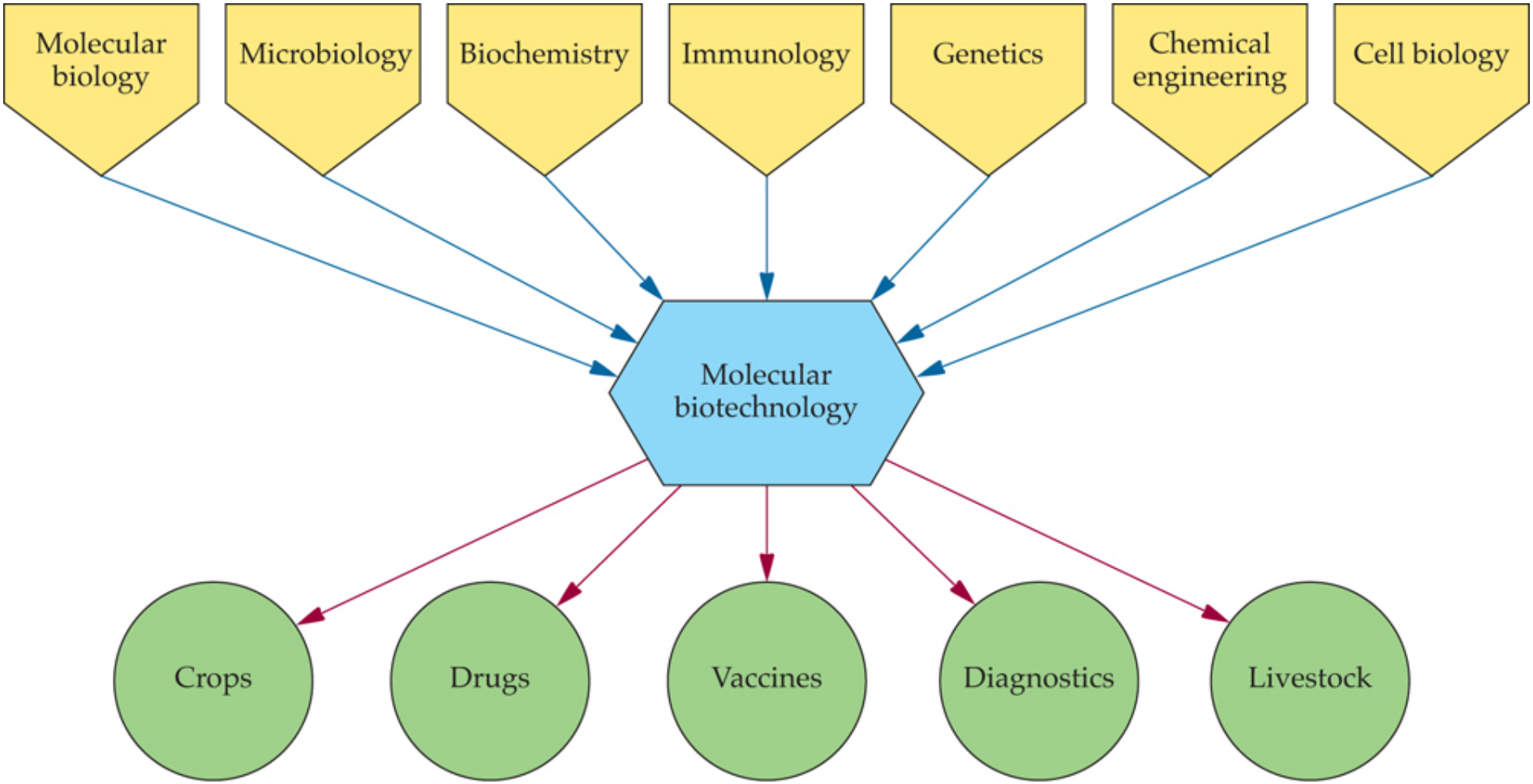
Important developments

Date	Event
1981	First monoclonal antibody-based diagnostic kit approved for use in the United States
1982	First animal vaccine produced by recombinant DNA methodologies approved for use in Europe
1983	Engineered Ti plasmids used to transform plants
1988	U.S. patent granted for a genetically engineered mouse susceptible to cancer
1988 ★	PCR method published
1990	Approval granted in the United States for a trial of human somatic cell gene therapy
1990	Recombinant chymosin used for cheese making in the United States
1994–1995	Detailed genetic and physical maps of human chromosomes published
1994	FDA announces that genetically engineered tomatoes are as safe as conventionally bred tomatoes
1995 ★	First genome sequence of a cellular organism, the bacterium *Haemophilus influenza*

Date	Event
2006	Recombinant cancer vaccine available to protect against cervical cancer
2009 ★	FDA approves first drug produced in a genetically engineered animal (goat)
2009	First clinical trial using embryonic stem cells
2010 ★	Researchers create the first synthetic cell
2013	U.S. Supreme Court rules that isolated genes are not eligible for patenting
2014	FDA approves recombinant drug produced in the mammary glands of transgenic rabbits
2014	U.S. state of Vermont passes legislation requiring the labeling of genetically modified food ingredients
2015 ★	FDA approves first transgenic animal (salmon) for human consumption
2015	Genetically engineered crops are grown in 28 countries on 180 million hectares
2016 ★	NIH approves a proposal to test the safety of the CRISPR genome editing technology in a clinical trial

FDA, Food and Drug Administration; HCV, hepatitis C virus; HIV, human immunodeficiency virus; NCBI, National Center for Biotechnology Information; NIH, National Institutes of Health; PCR, polymerase chain reaction; tRNA, transfer ribonucleic acid; CRISPR, clustered regularly interspaced short palindromic repeats.

Many scientific disciplines contribute to molecular biotechnology



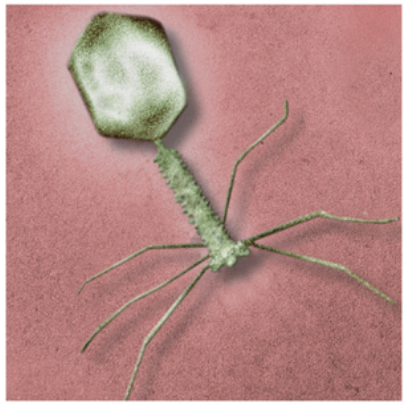
Animal Models

- **Viruses**
- **Bacteria (*E. coli)***
- **Yeast (*Saccharomyces cerevisiae*)**
- **Round worms *(Caenorhabditis elegans)***
- **Alga (*Chlamydomonas reinhardtii*)**
- **Fruit fly *(Drosophila melanogaster)***
- **Zebrafish (*Danio rerio)***
- ***Arabidopsis thaliana* (thale cress)**
- **Mouse (*Mus musculus)***

https://www.dnalc.org/resources/animations/model_organisms.html

Each experimental organism used in cell biology has advantages for certain types of studies

(a)



Viruses

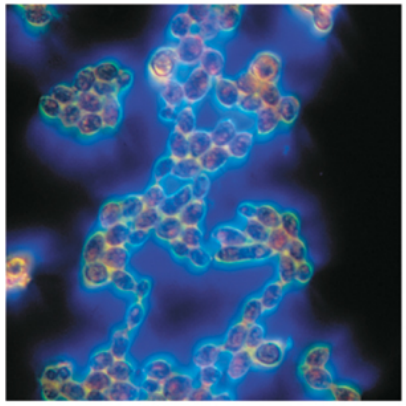
Proteins involved in DNA, RNA, protein synthesis
Gene regulation
Cancer and control of cell proliferation
Transport of proteins and organelles inside cells
Infection and immunity
Possible gene therapy approaches

(b)

Bacteria

Proteins involved in DNA, RNA, protein synthesis, metabolism
Gene regulation
Targets for new antibiotics
Cell cycle
Signaling

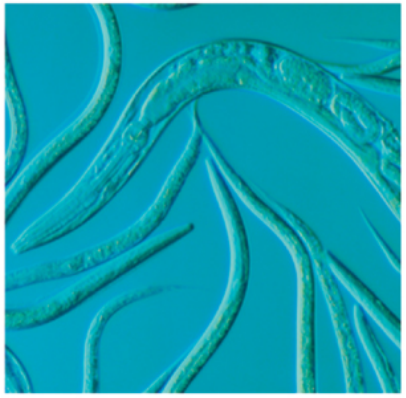
(c)



Yeast (*Saccharomyces cerevisiae*)

Control of cell cycle and cell division
Protein secretion and membrane biogenesis
Function of the cytoskeleton
Cell differentiation
Aging
Gene regulation and chromosome structure

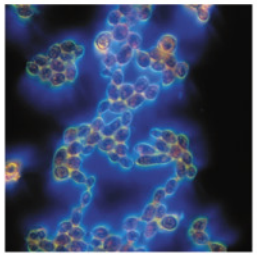
(d)



Roundworm (*Caenorhabditis elegans*)

Development of the body plan
Cell lineage
Formation and function of the nervous system
Control of programmed cell death
Cell proliferation and cancer genes
Aging
Behavior
Gene regulation and chromosome structure

(a)



Yeast (*Saccharomyces cerevisiae*)

Control of cell cycle and cell division
Protein secretion and membrane biogenesis
Function of the cytoskeleton
Cell differentiation
Aging
Gene regulation and chromosome structure

(b)

Alga (*Chlamydomonas reinhardtii*)

Structure and function of flagella
Chloroplasts and photosynthesis
Organelle movement
Phototaxis

(c)

Roundworm (*Caenorhabditis elegans*)

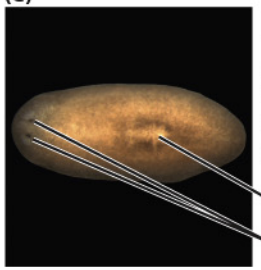
Development of the body plan
Cell lineage
Formation and function of the nervous system
Control of programmed cell death
Cell proliferation and cancer genes
Aging
Behavior
Gene regulation and chromosome structure

(d)

Fruit fly (*Drosophila melanogaster*)

Development of the body plan
Generation of differentiated cell lineages
Formation of the nervous system, heart, and musculature
Programmed cell death
Genetic control of behavior
Cancer genes and control of cell proliferation
Control of cell polarization
Effects of drugs, alcohol, pesticides

(e)



Planarian (*Schmidtea mediterranea*)

Stem cells
Turnover of adult tissues
Wound healing
Regeneration

(f)

Zebrafish (*Danio rerio*)

Development of vertebrate body tissues
Formation and function of brain and nervous system
Birth defects
Cancer

(g)

Mouse (*Mus musculus*), including cultured cells

Development of body tissues
Function of mammalian immune system
Formation and function of brain and nervous system
Models of cancers and other human diseases
Gene regulation and inheritance
Infectious disease
Behavior

(h)

Plant (*Arabidopsis thaliana*)

Development and patterning of tissues
Genetics of cell biology
Agricultural applications
Physiology
Gene regulation
Immunity
Infectious disease

(a) Scimat/Photo Researchers, Inc.; (b) William Dentler University of Kansas; (c) Science Source; (d) Darwin Dale/Science Source; (e) Peter Reddien, MIT Whitehead Institute; (f) blickwinkel/Hartl/Alamy; (g) J. M. Labat/Jacana/Photo Researchers, Inc.SCIMAT/Science Source (h) Darwin Dale/Science Source

Figure 1-22

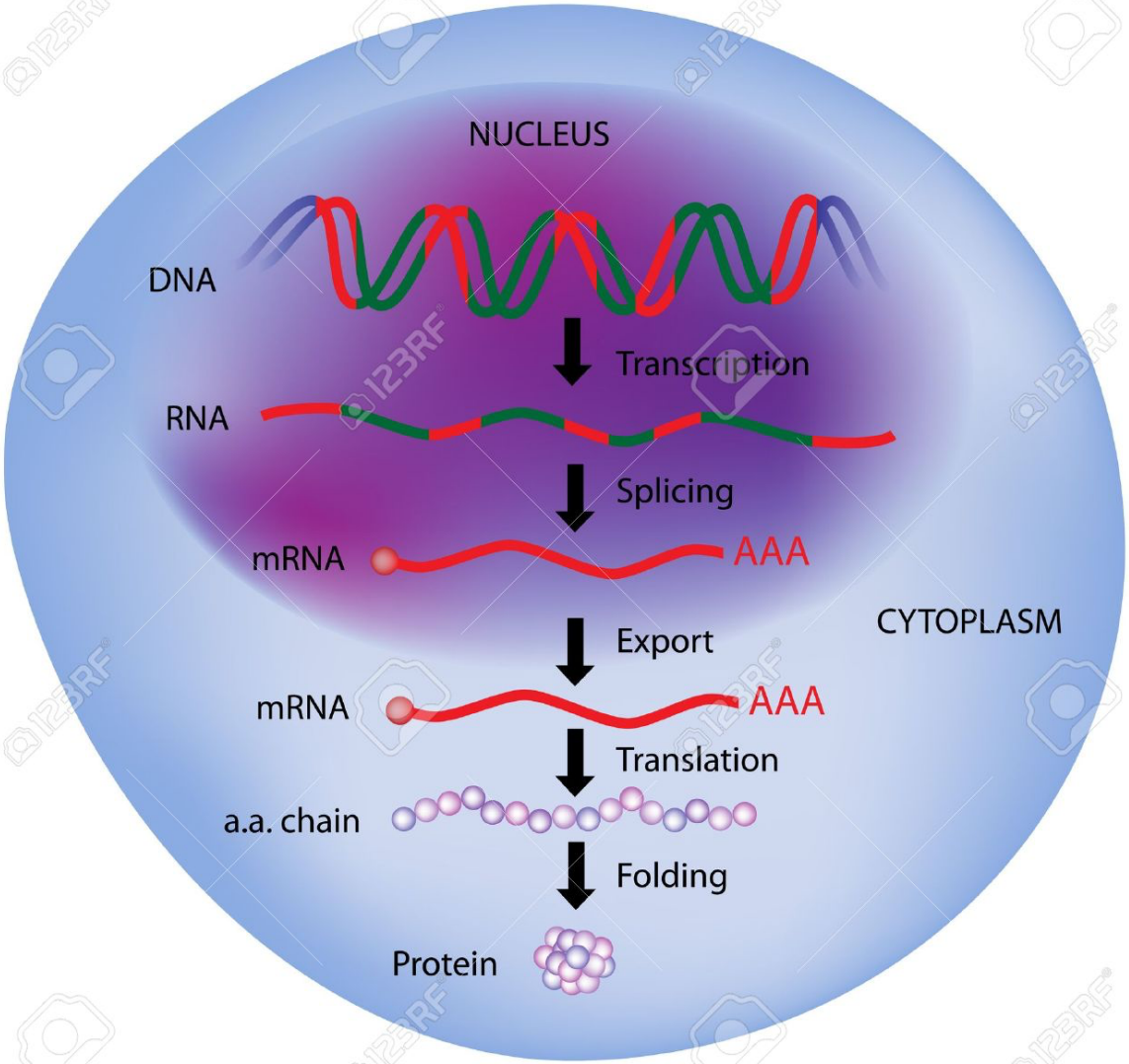
Molecular Cell Biology, Eighth Edition

TABLE 1-2 Genome Sizes of Organisms Used in Molecular Cell Biology Research That Have Been Completely Sequenced

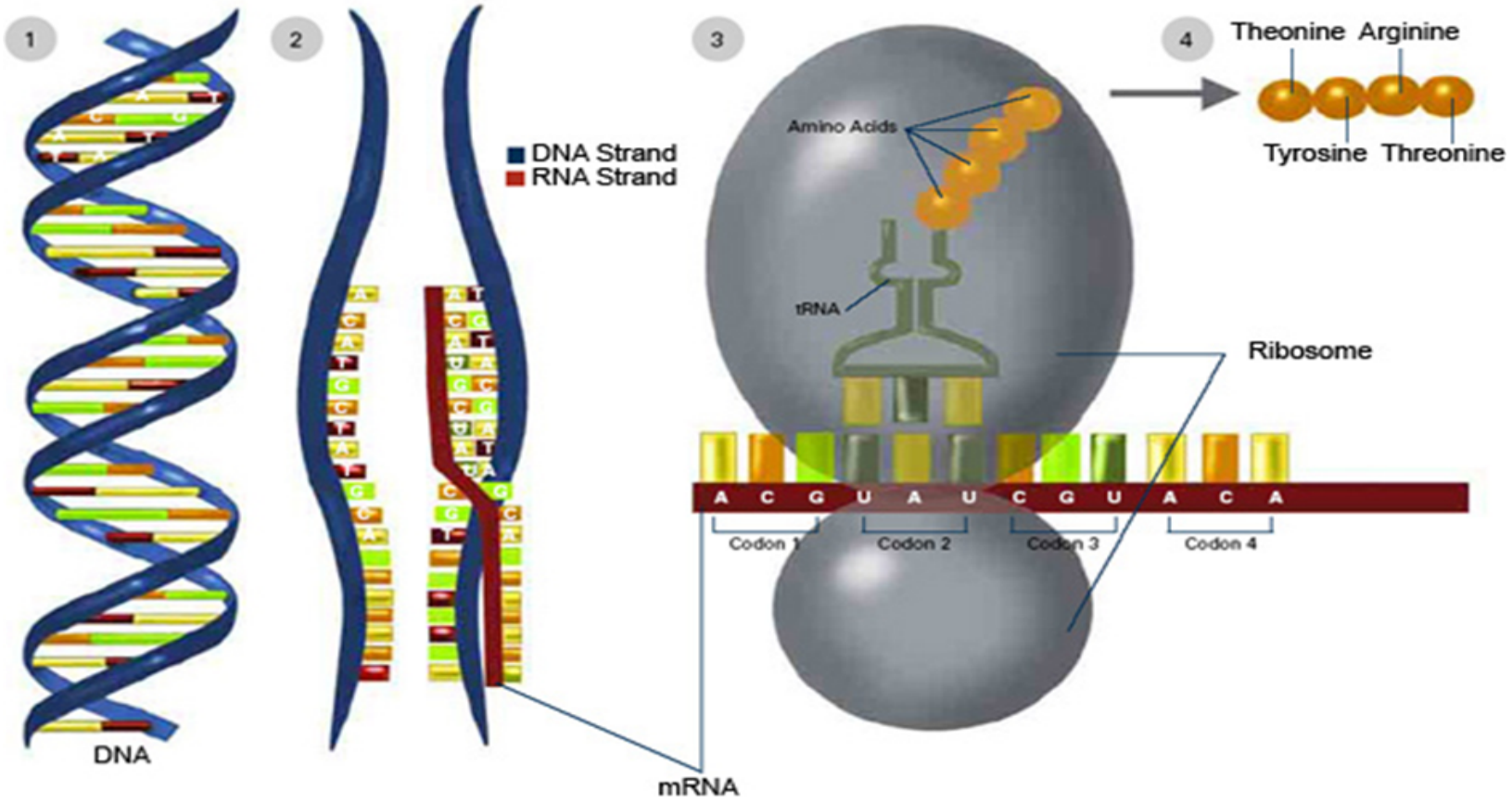
	Base Pairs (Millions)	Approximate Number of Encoded Proteins*	Chromosomes**	Reference
Eubacteria				
Mycoplasma genitalum	0.58	500	1	a
Helicobacter pylori	1.67	1,500	1	a
Haemophilus influenza	1.83	1,600	1	a
Escherichia coli	4.64	4,100	1	a
Bacillus subtilis	4.22	4,200	1	a
Archaea				
Methanococcus jannaschii	1.74	1,800	1	a
Sulfolobus solfataricus	2.99	3,000	1	a
Single-Celled Eukaryotes				
Saccharomyces cerevisiae	12.16	6,700	16	b
Chlamydomonas reinhardtii	120.4	14,400	17	b
Plasmodium falciparum	23.26	5,400	14	b
Multicellular Eukaryotes (Metazoans)				
Drosophila melanogaster	168.74	13,900	6	b
Caenorhabditis elegans	100.29	20,500	6	b
Schmidtea mediterranea (planarian)	480	>20,000***	4	c
Danio rerio (zebrafish)	1412.46	26,500	25	b
Gallus gallus (chicken)	1072.54	15,500	33	b
Mus musculus (mouse)	3480.96	23,100	21	b
Homo sapiens (human)	3326.74	20,800	24	b
Arabidopsis thaliana	135.67	27,400	5	b

*Numbers of encoded proteins are current estimates rounded to the nearest 100 based on genome DNA sequences. They will likely change slightly in eubacteria and archaea because of the inclusion of newly discovered genes that code for very small proteins, and modestly in eukaryotes because of newly discovered small genes and because of pseudogenes that are not expressed.
**Only nuclear chromosomes are counted in eukaryotes, including distinct sex chromosomes in metazoans.
***Predicted value.
SOURCE: Table courtesy of Dr. Juan Alvarez-Dominguez. References: a, http://www.ncbi.nlm.nih.gov/genome/; b, http://ensemblgenomes.org/; c, http://www.genome.gov/12512286.

Central dogma of molecular biology



From DNA to Protein



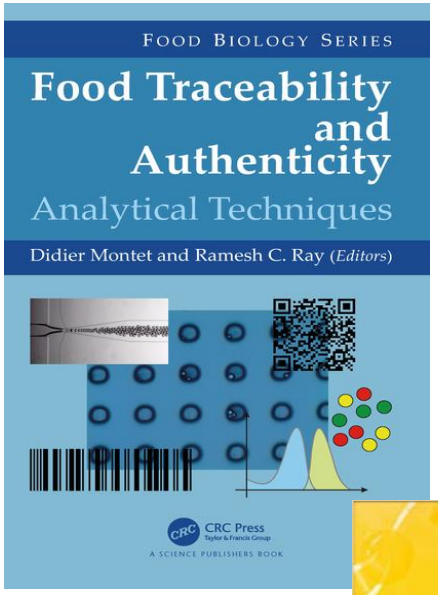
Ashcraft. Source: http://creationwiki.org/File:Gene_expression.PNG

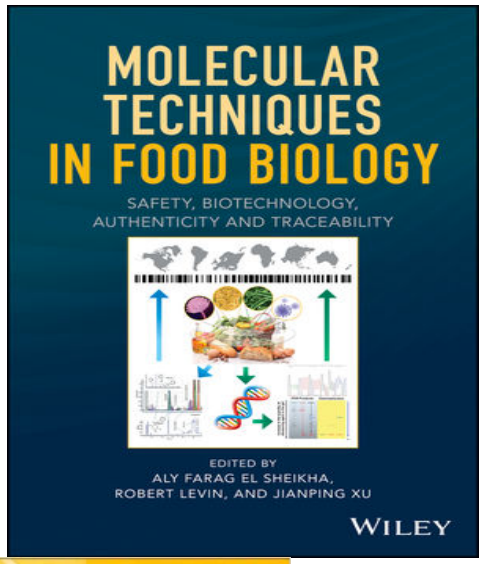
Molecular biology tools

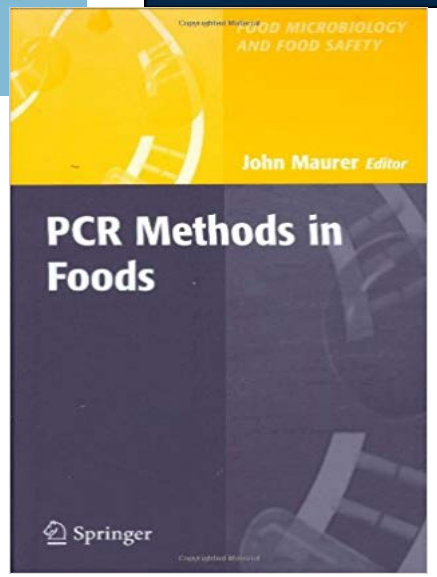
- Nucleic acid fractionation − extraction of DNA and RNA
- Polymerase chain reaction − PCR
- qPCR
- Probes, hybridization
- Molecular cloning
- Microarrays
- DNA and RNA sequencing
- Electrophoretic separation of nucleic acid
- Etc.

Applications – Brazil and World

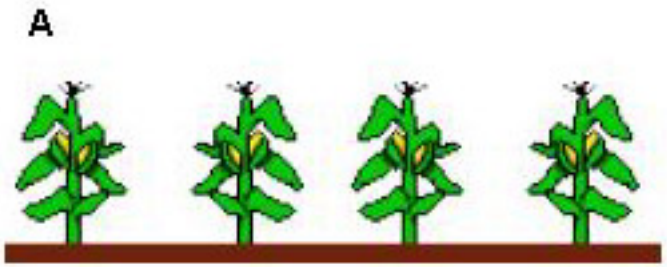
- Plant breeding
- Animal breeding
- Food safety
- Food fraud

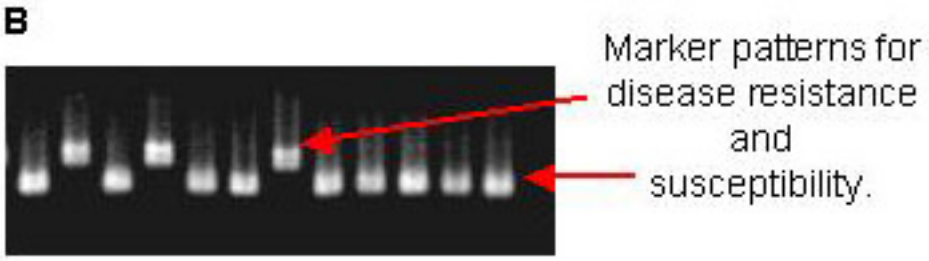


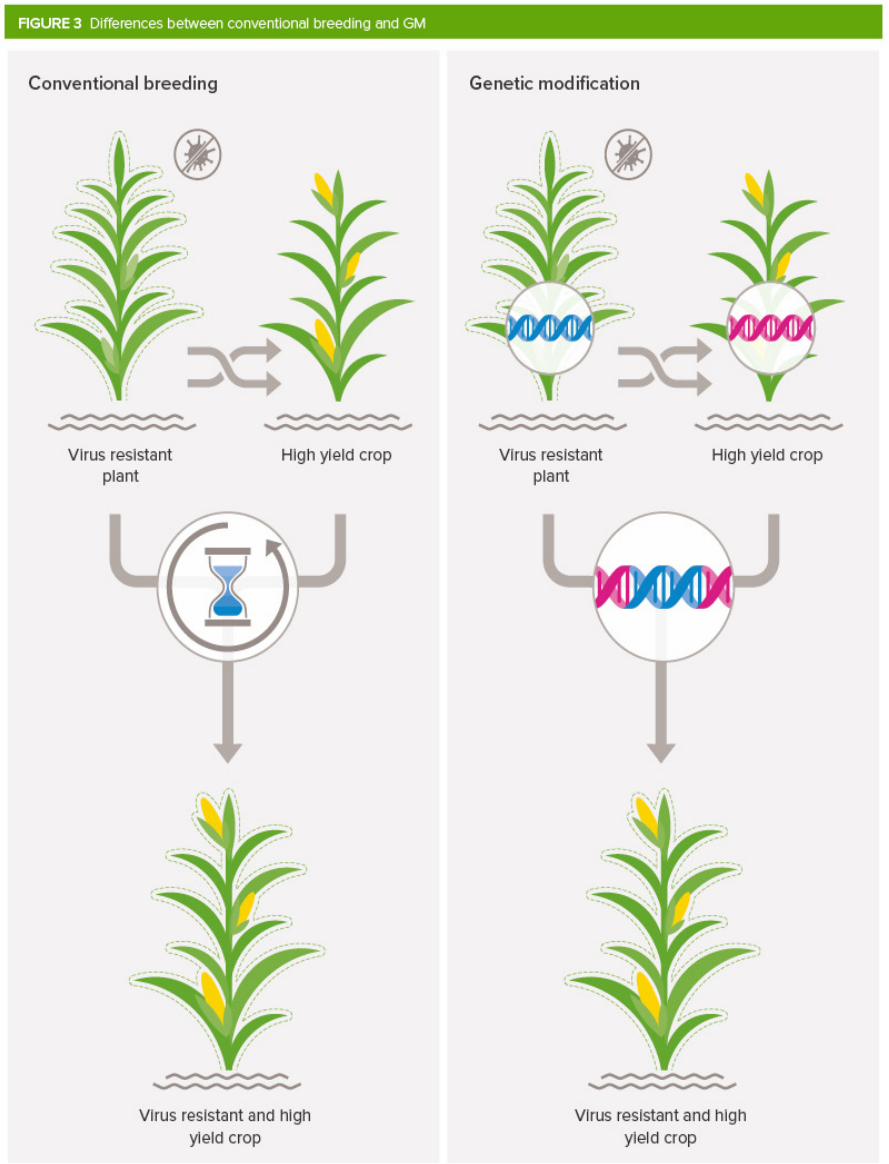




Plant breeding

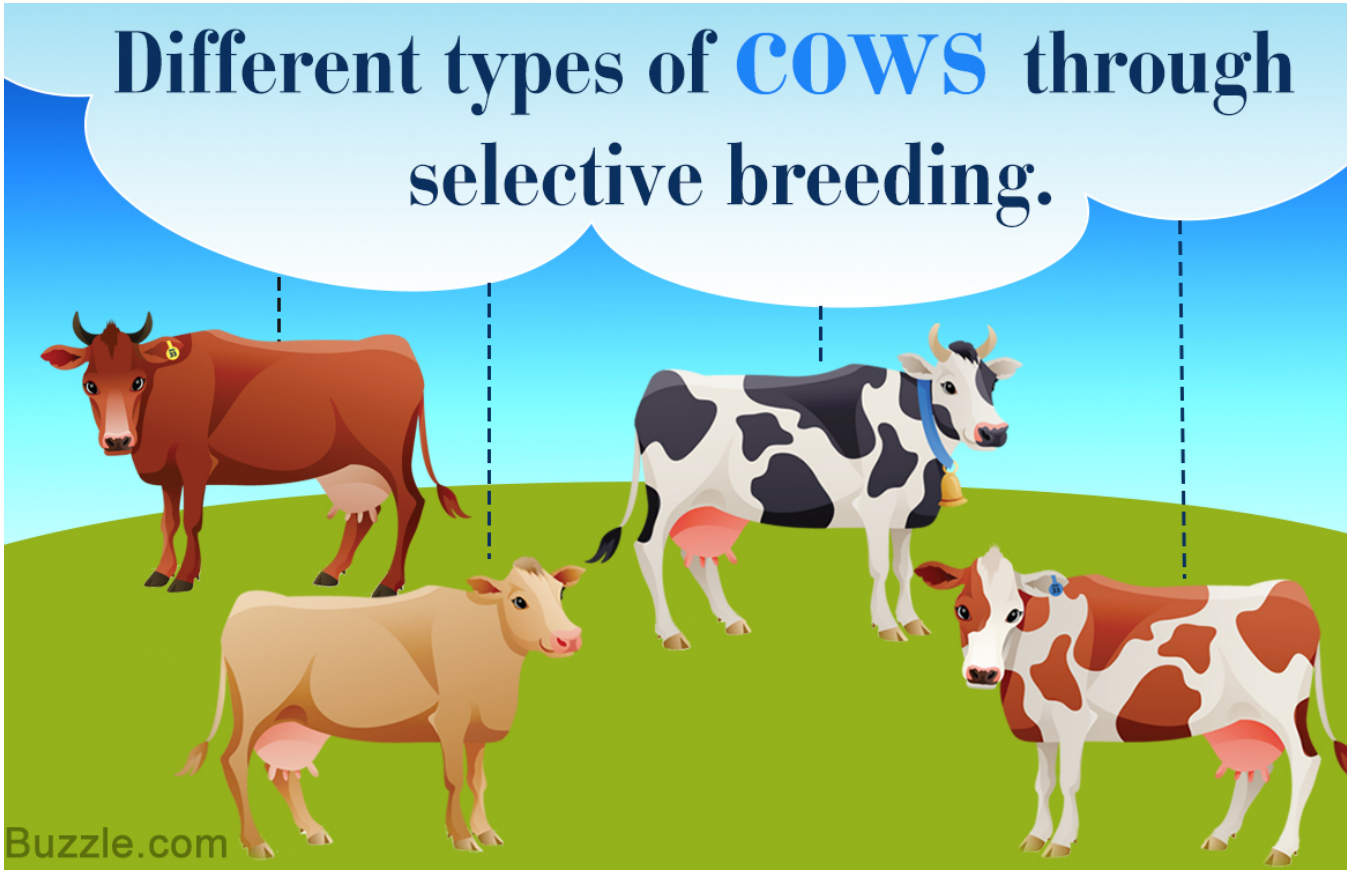






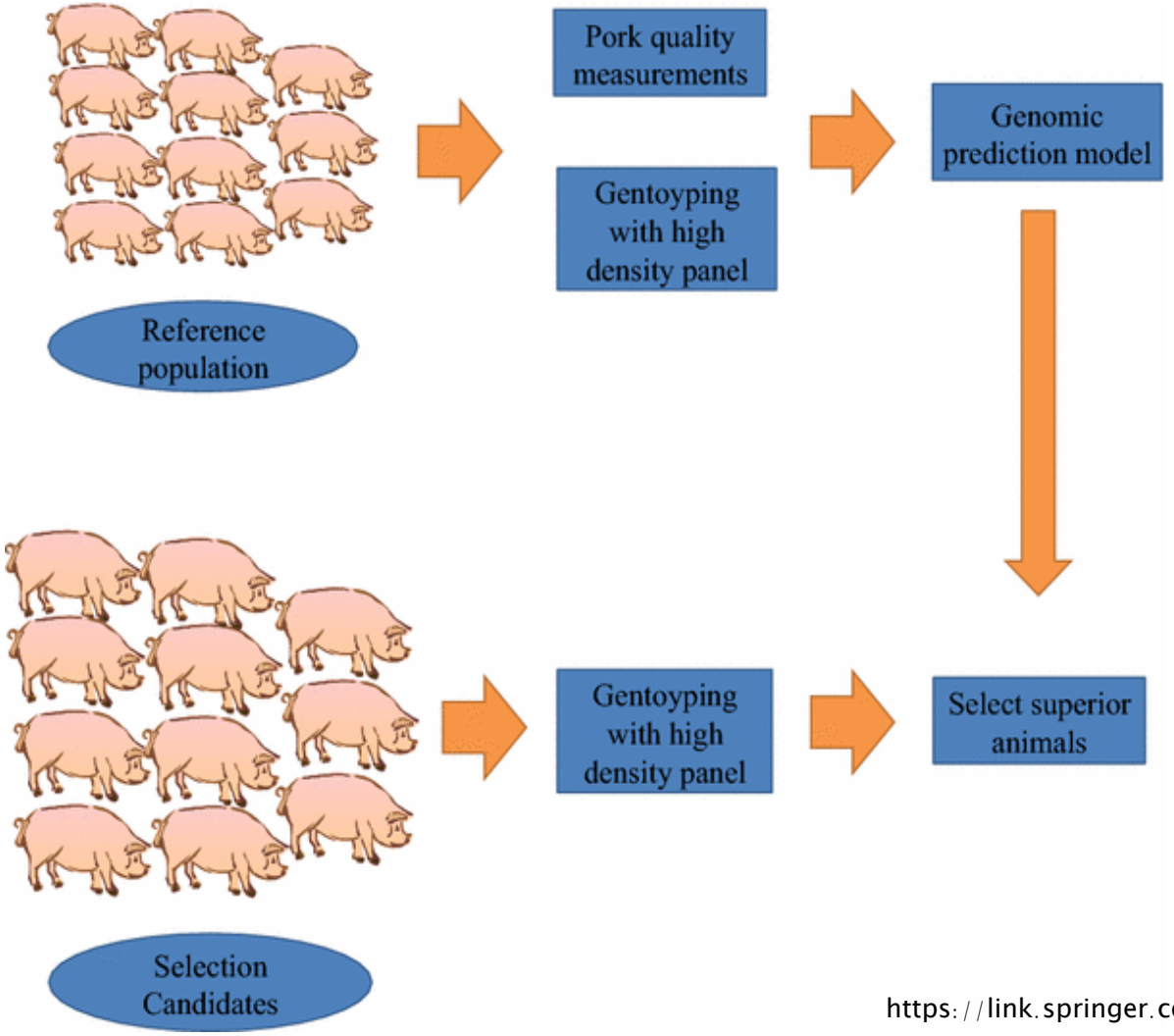
https://royalsociety.org/topics-policy/projects/gm-plants/how-does-gm-differ-from-conventional-plant-breeding/

Animal breeding - Bovine



- More or less muscle
- More or less fat
- Less methane emission
- Disease resistance
- Feed efficiency

Animal breeding - Pig



- **More or less muscle**
- **More or less fat**
- **Disease resistance**
- **Feed efficiency**
- **# of winning piglet per sow**

https://link.springer.com/article/10.1007/s40362_015_0029_3

Animal breeding - Chicken

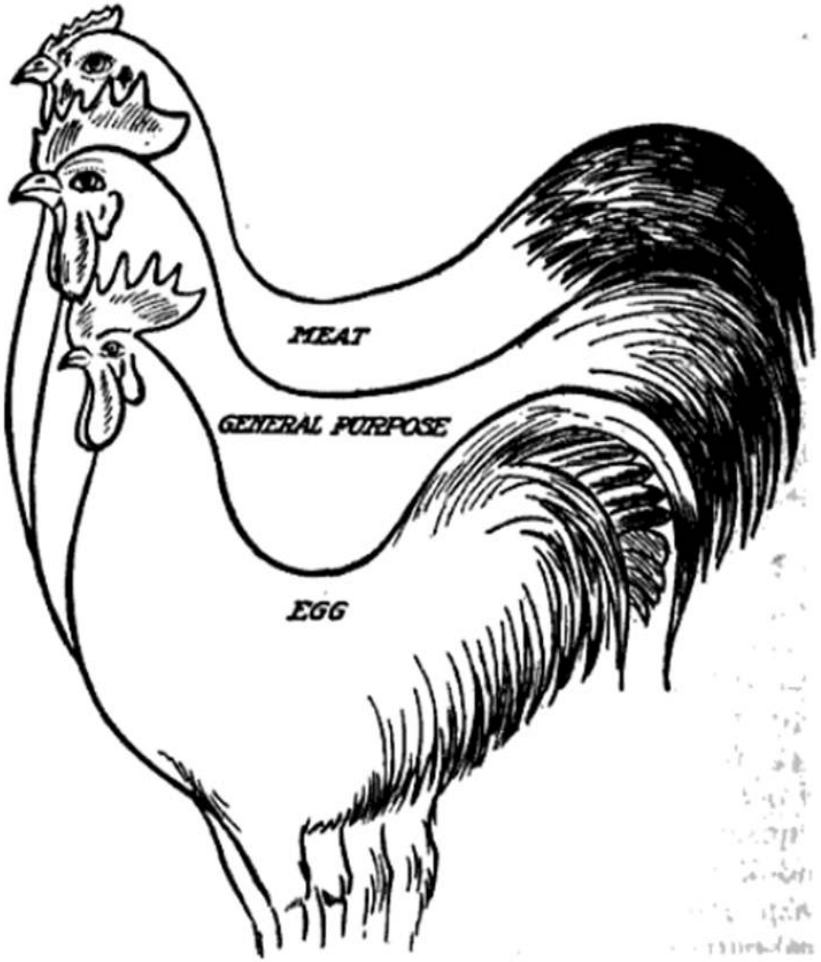
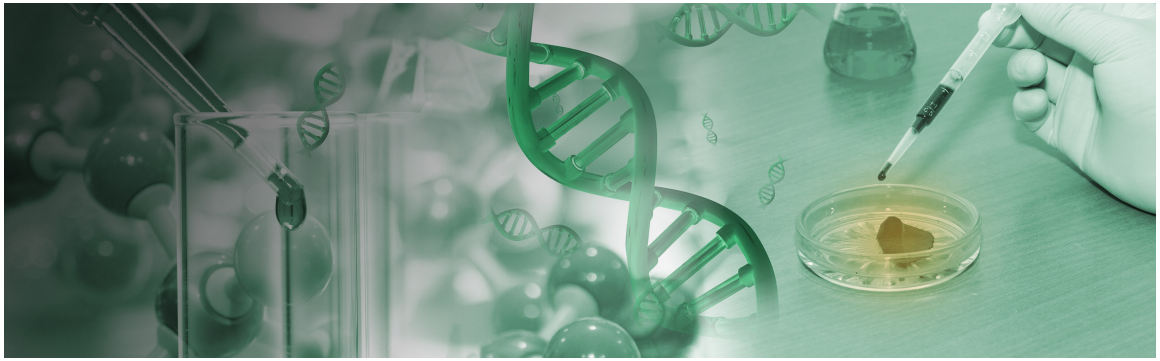
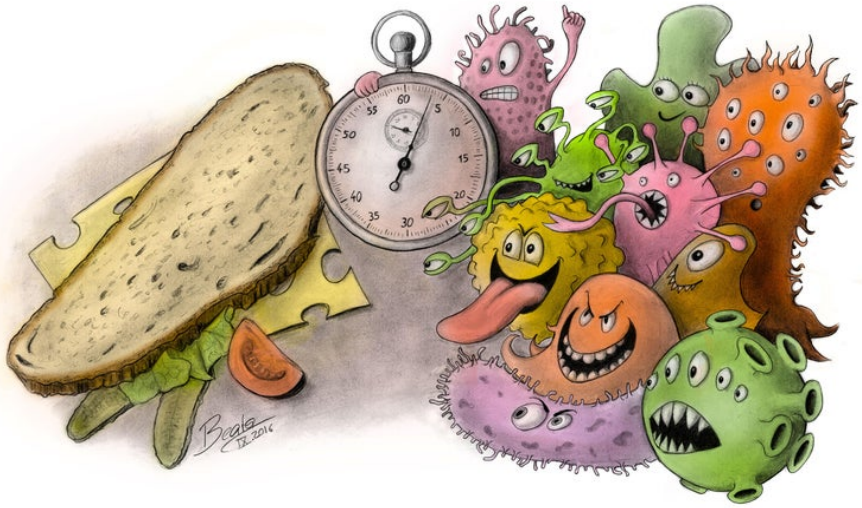


Fig. 55.—Comparison of the three utility types of poultry.

https://scratchcradle.wordpress.com/2012/09/09/gms11-breeding-for-type/

Food Safety - Microbiology

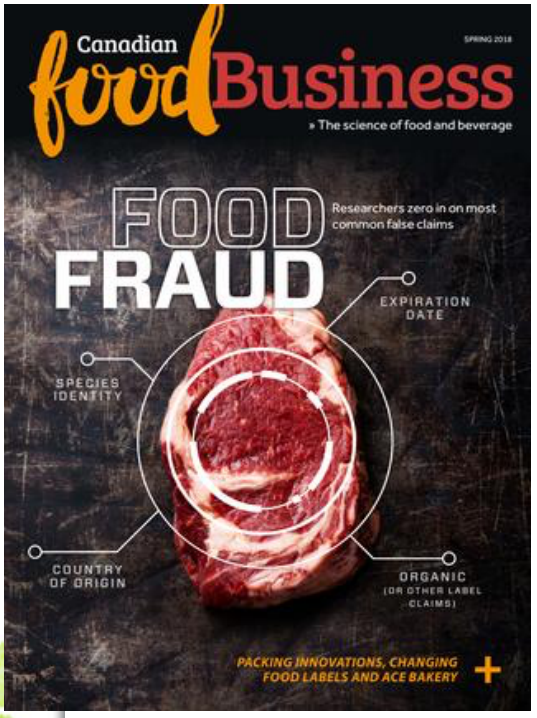




- **Salmonella**
- **E. coli**
- **Listeria**

https://www.etsy.com/ca/listing/560280786/the-five-second-rule-science-art-print

Food Fraud



https://www.ioes.ucla.edu/person/paul-barber/

http://www.bruker.com/events/webinars/is-it-really-pure-honey-detecting-adulterations-frauds-and-quality-issues-by-nmr-based-honey-profiling.html

https://qualitymatters.usp.org/food-fraud-webinar-series-features-usp-runs-march-april

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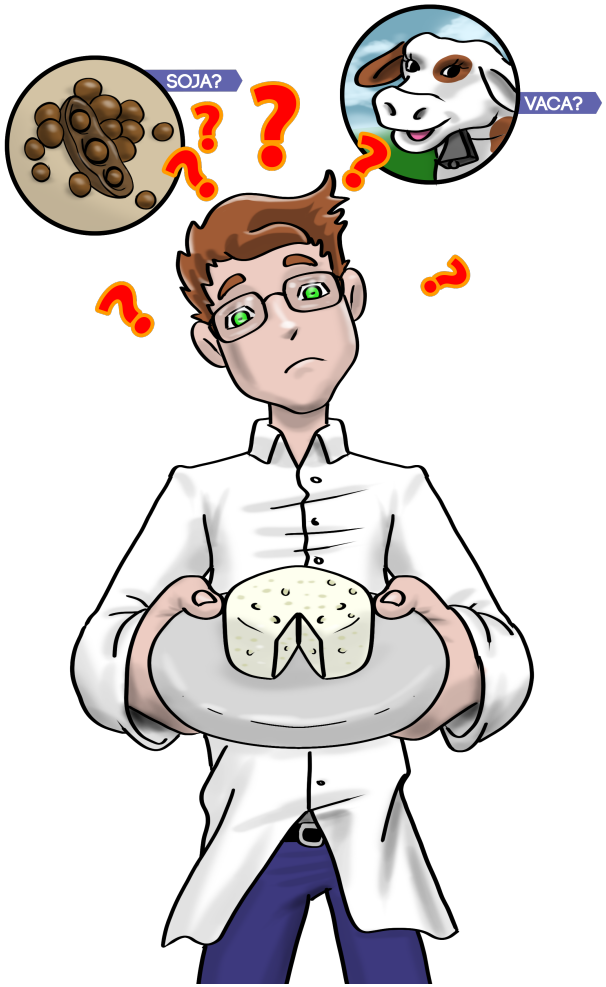

Thank you

Obrigada

Aline Cesar

alinecesar@usp.br