Molecular and Cellular Biology

1. Life Begins with Cells

Prof. Dr. Klaus Heese

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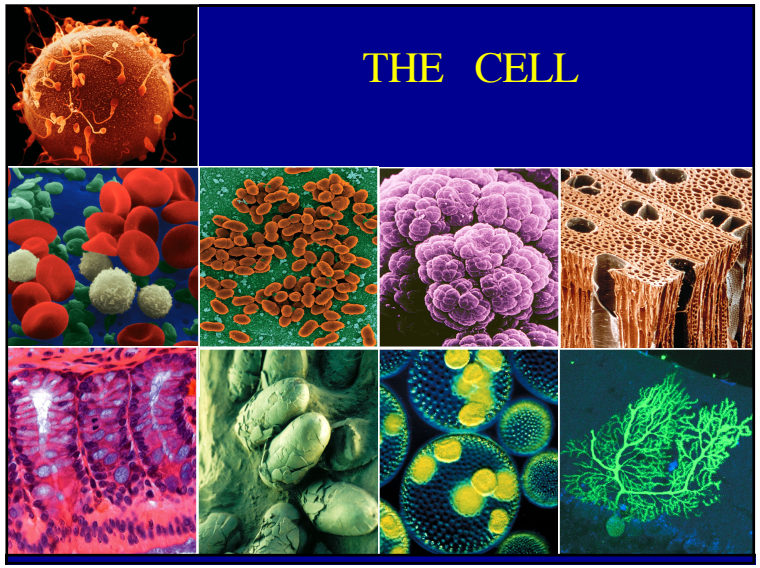
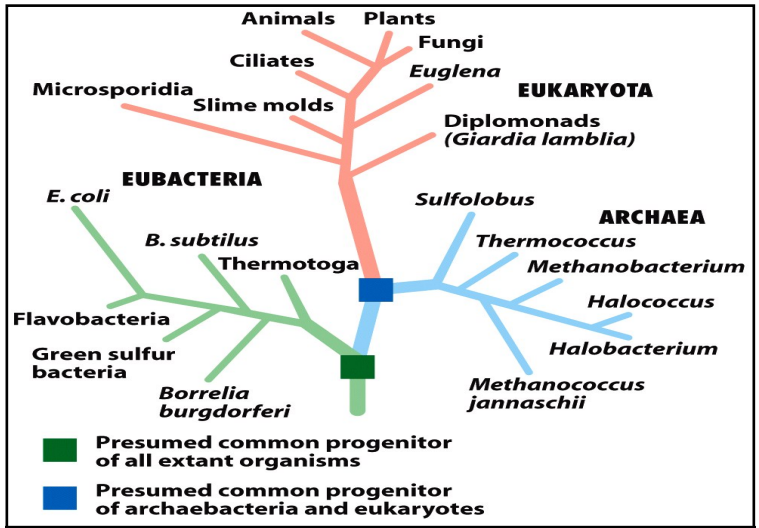
1. Life Begins with Cells

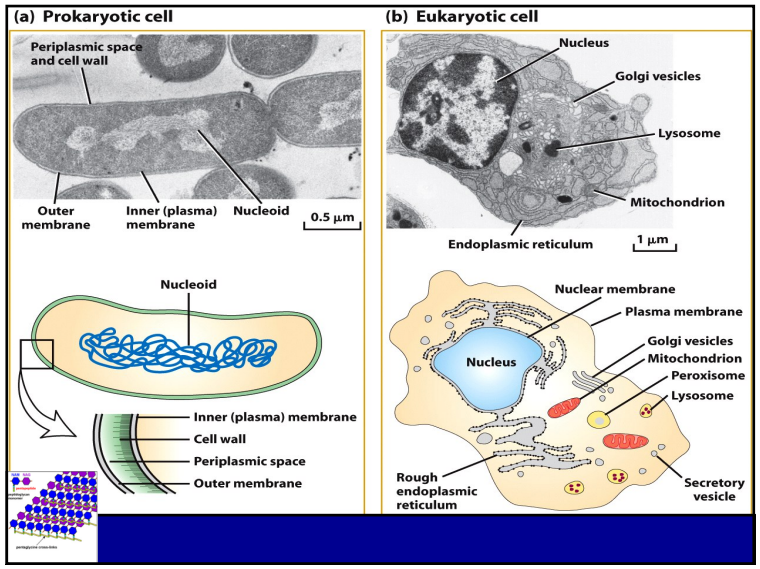
- Biology – the study of Life
- What defines Life ?
- How is Life characterized ?
- At the Cellular level? At the Molecular level ?

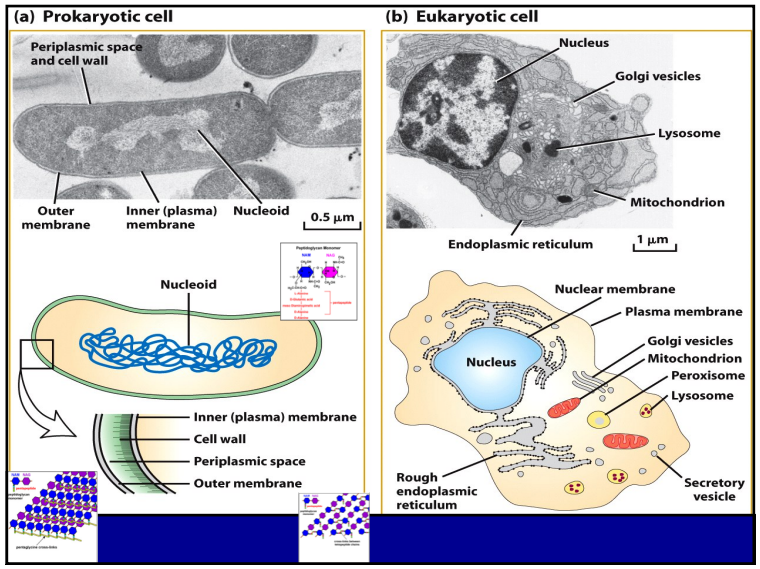
Prof. Dr. Klaus Heese



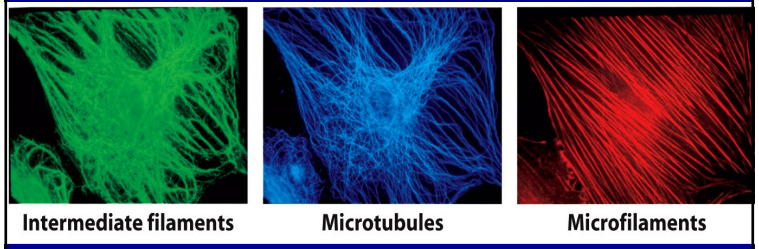


Taxonomy



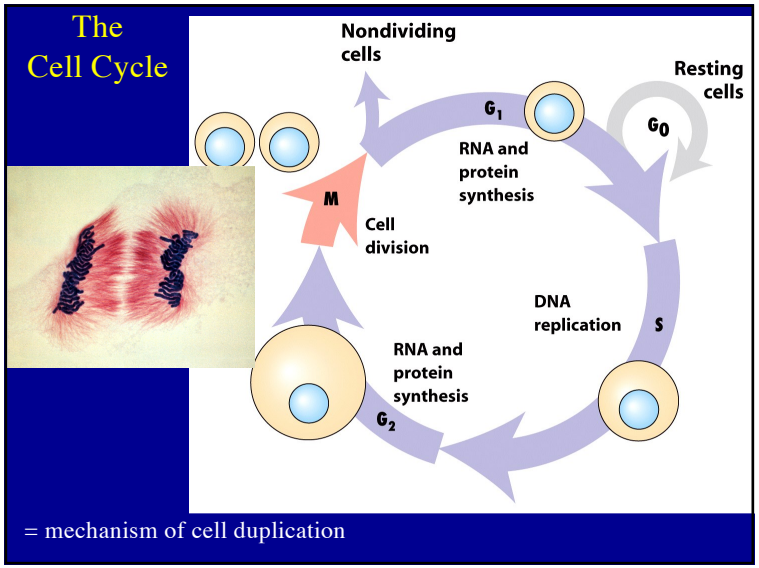


Cell Structure, Function & Movement



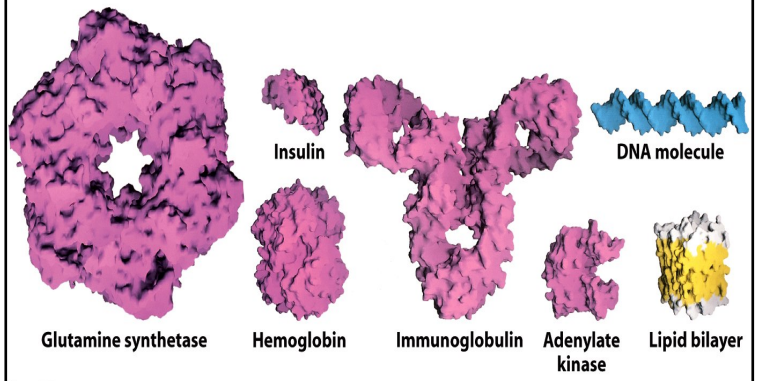
Each cell type in the body is different from the other by e.g. shape, function , … -- has its own characteristic feature

The Cell Cycle

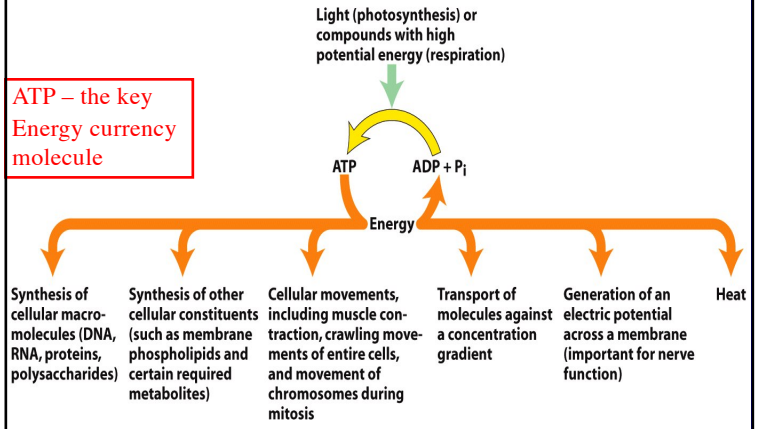


= mechanism of cell duplication

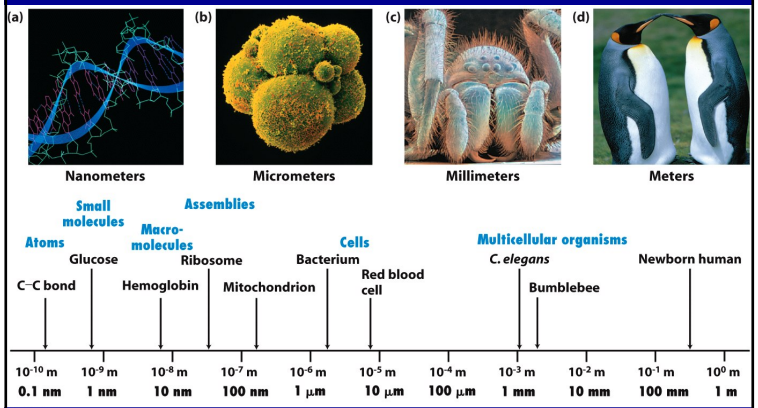
Molecules of the Cell



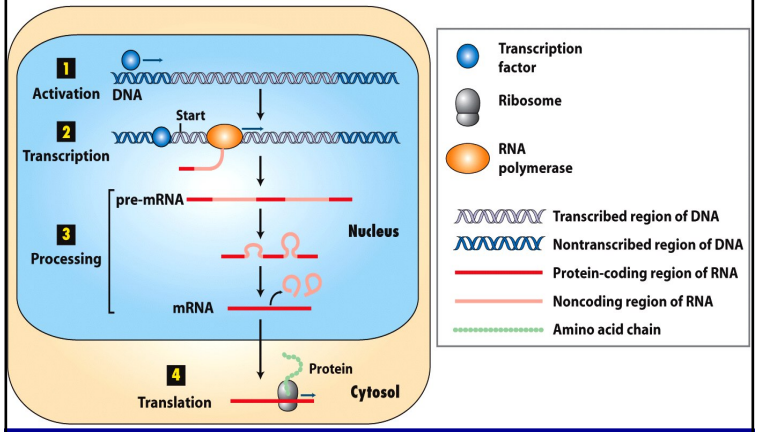
Cell & Energy



a single atom can define a human being

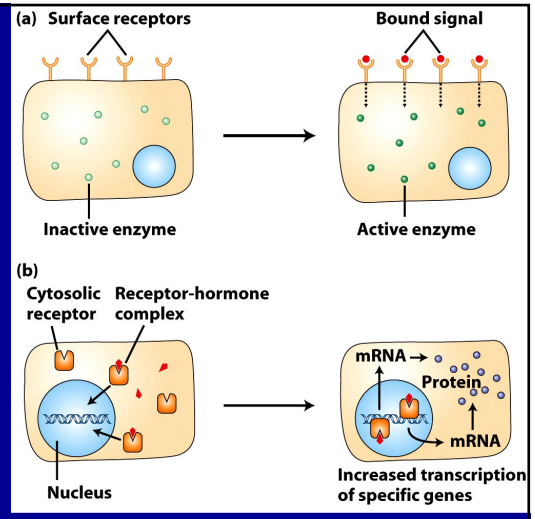


From Genes to Proteins



Cell

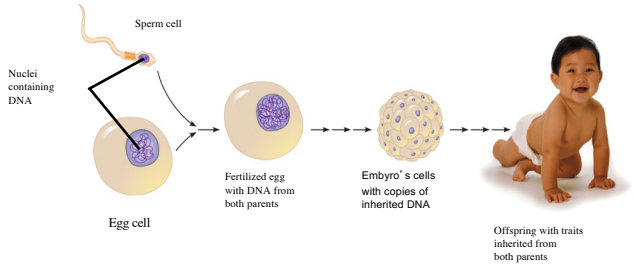
Signalling



The Cell's Heritable Information

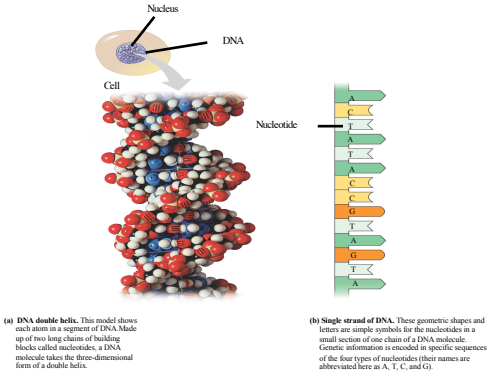
Cells contain chromosomes made partly of DNA, the substance of genes

– which program the cells' production of proteins and transmit information from parents to offspring

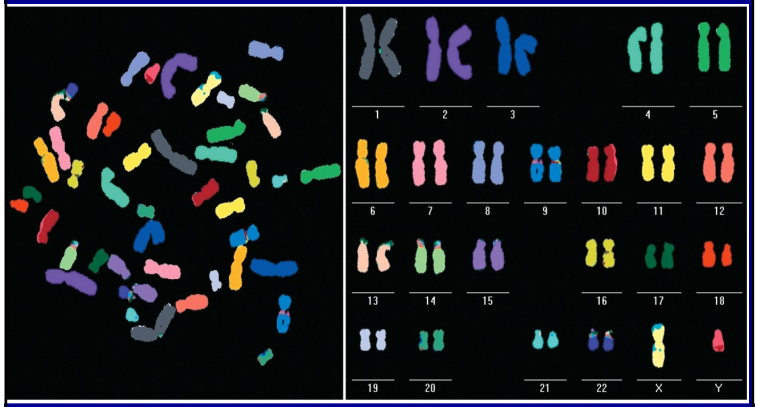


The molecular structure of **DNA**

– accounts for it information-rich nature



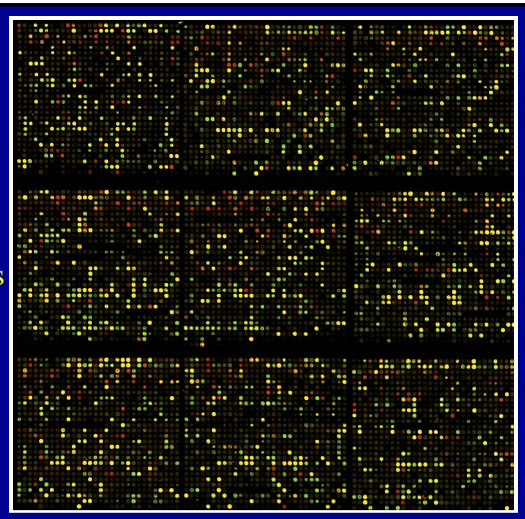
Cell Genome: Chromosomes



Genomics
(genes)

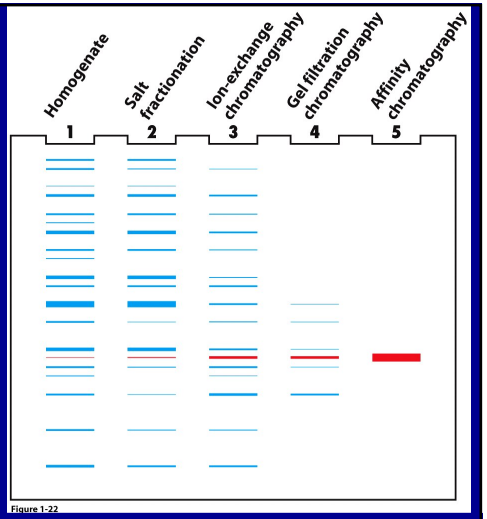
&

Proteomics



Proteomics

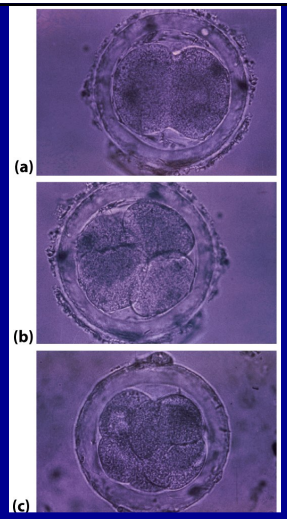
(proteins)



From Cell

To

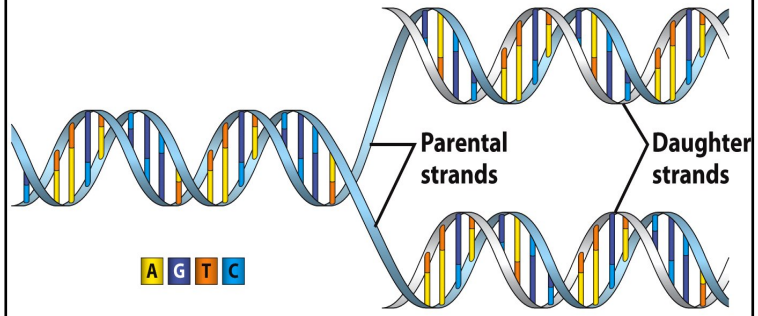
Stem Cell Technology



Stem Cell Technology

'Dolly'

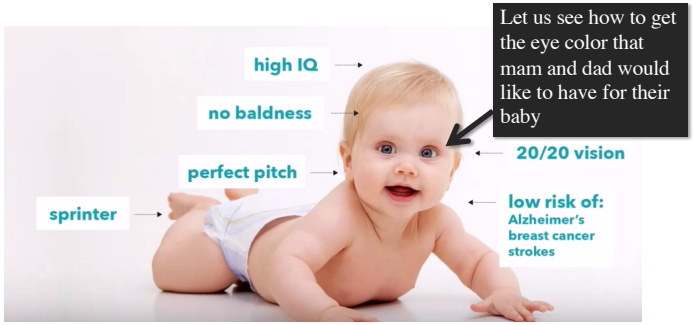
DNA



Genome editing ---> CRISPR technology

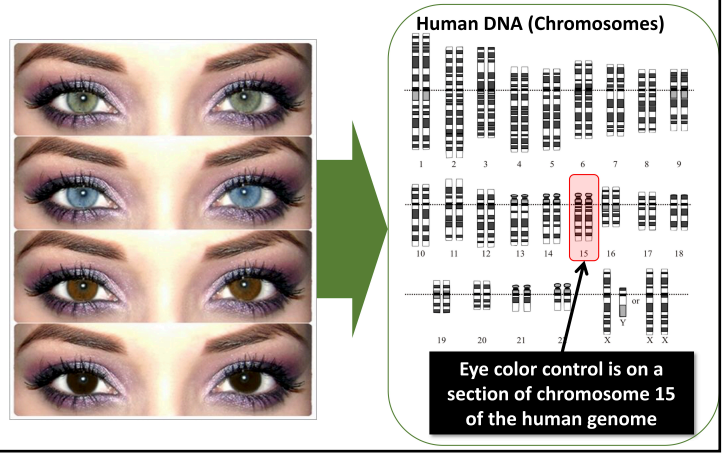
Example: Designer Baby (bio system)

Definition (Wikipedia):
A designer baby is a human embryo that has been genetically modified, usually following guidelines set by the parent or scientist, to produce desirable traits.

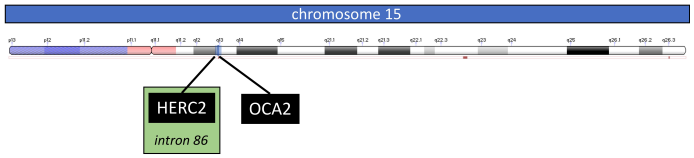


(bottom ---> up approach)

Designer Baby: Eye Color "Programming"



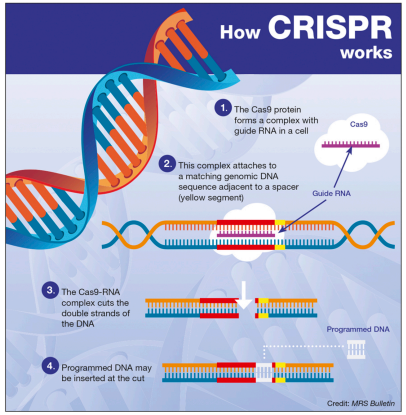
Designer Baby
Eye Color "Program" on Chromosome 15



- A region of the **HERC2** gene known as **intron 86** contains a segment of DNA that controls the activity (expression) of the **OCA2** gene, turning it on or off as needed. At least one polymorphism in this area of the HERC2 gene has been shown to reduce the expression of OCA2, which **leads to less melanin in the iris and lighter-colored eyes**.
- Further genes with reported roles in eye color include **ASIP**, **IRF4**, **SLC24A4**, **SLC24A5**, **SLC45A2**, **TPCN2**, **TYR**, and **TYRP1**. The effects of these genes likely combine with those of OCA2 and HERC2 to produce a continuum of eye colors in different people.

(bottom ---> up approach)

Genome – DNA editing:
Up-coming Technique: CRISPR-Cas9



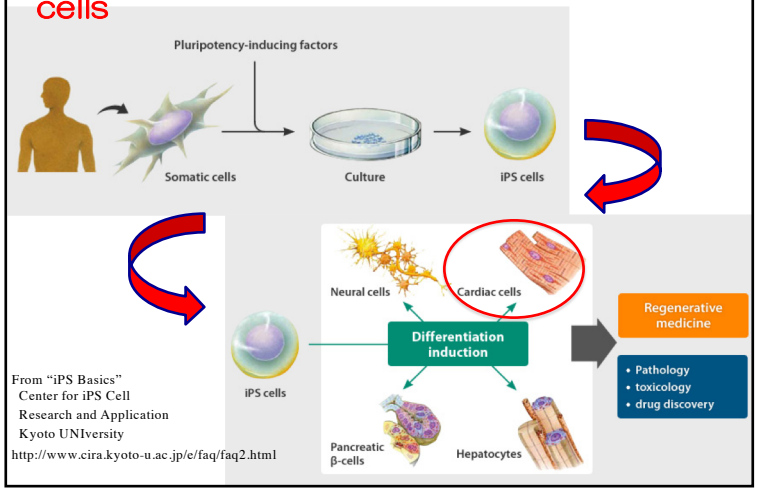
- CRISPR allows controlled modifications of DNA
  - Insertion of new DNA-segments
  - Deletion of DNA-segments
  - Exchange of DNA-segments (and so alteration of existing DNA)

CRISPR-Cas9

First proposed in 2013
Technique gets continuously improved and is on the verge of maturity for large scale laboratory usage.

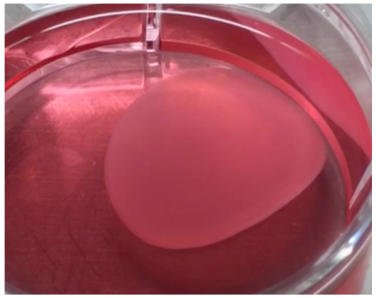
CRISPR-related gene editing might be a revolution like the WEB or mobile phones and could change our world significantly within the next 20 years.

iPS Cells – induced pluripotent stem cells



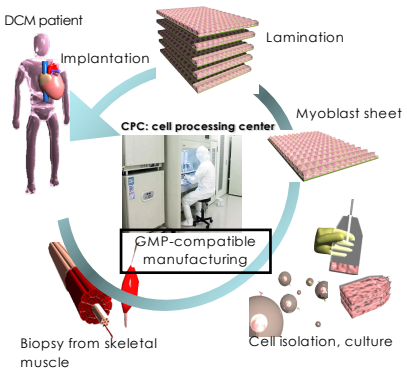
From "iPS Basics"
Center for iPS Cell Research and Application
Kyoto UNIversity
http://www.cira.kyoto-u.ac.jp/e/faq/faq2.html

iPS cell-derived cardiac cell-sheet



Regeneration therapy using myoblast sheet for the treatment of severe cardiomyopathy

Successful Clinical Result in 1st Case

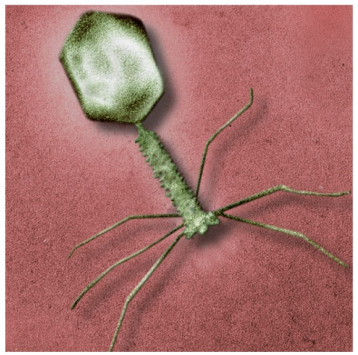


Freed from VAD at 3 months

More improvement of heart function

Alternative to heart transplants

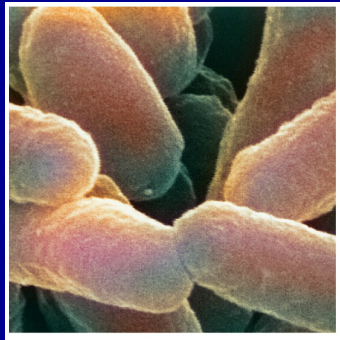
Models in Biomedical Technologies



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

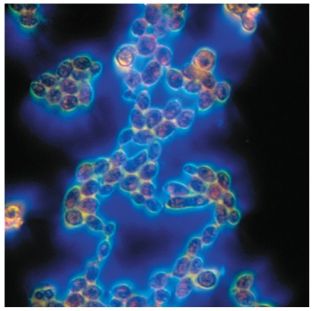
Models in Biomedical Technologies



Bacteria

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

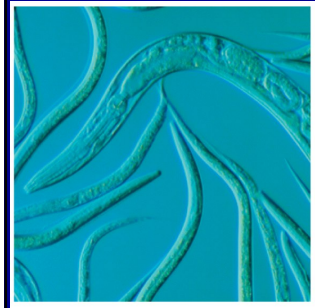
Models in Biomedical Technologies



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

Models in Biomedical Technologies



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

Models in Biomedical Technologies

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

Models in Biomedical Technologies

Zebrafish

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

Models in Biomedical Technologies

Mice, 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

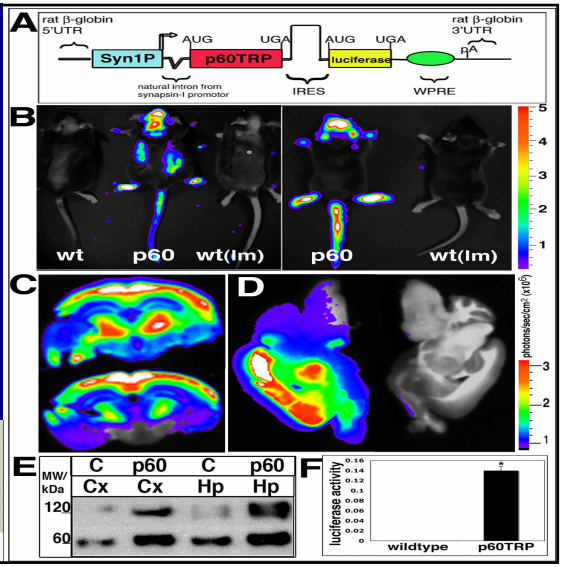
Genetic engineering to produce transgenic and knock-out mice

Bio-Genetic-Engineering

Establishing a p60TRP transgenic mouse model

***in-vivo*-Imaging in a living mouse**

Mishra & Heese, JCMM, 2011



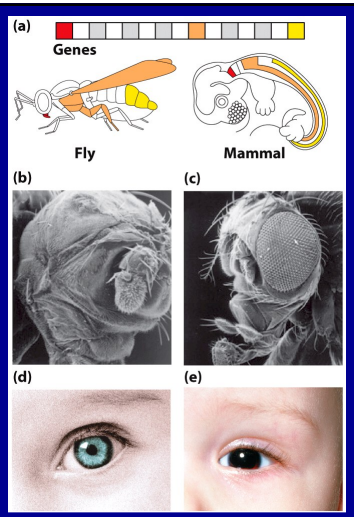
Models in Biomedical Technologies

Plant (*Arabidopsis thaliana*)

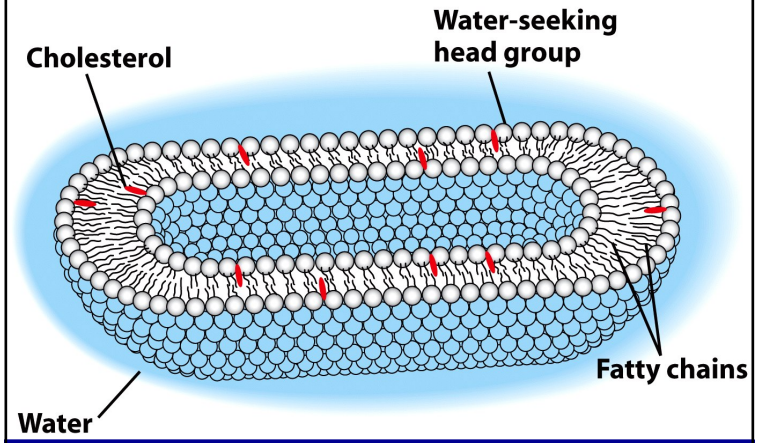
Development and patterning of tissues
Genetics of cell biology
Agricultural applications
Physiology
Gene regulation
Immunity
Infectious disease

Genetic engineering to produce transgenic and knock-out plants (corn, rice, …, rose)

Models in Biomedical Technologies

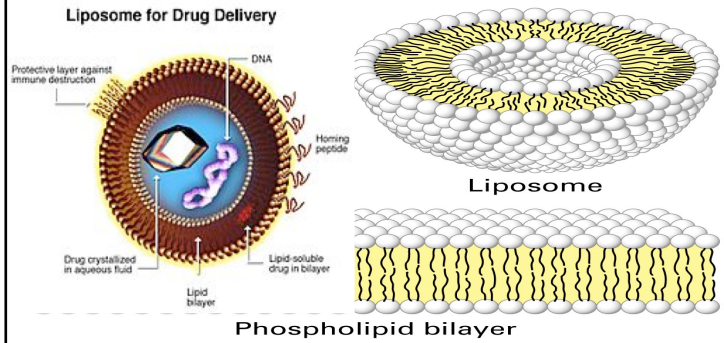


Cell membrane – a lipid bilayer …

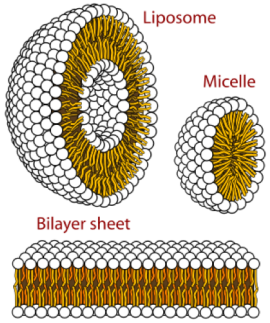


eukaryotic cell membrane

Cross-sectional views of the three structures formed by phospholipids in aqueous solutions



The white spheres depict the hydrophilic heads of the phospholipids, and the squiggly black lines (in the yellow regions) represent the hydrophobic tails. Shown are a spherical micelle with a hydrophobic interior composed entirely of fatty acyl chains; a spherical liposome, which has two phospholipid layers and an aqueous center; and a two-molecule-thick sheet of phospholipids, or bilayer, the basic structural unit of bio-membranes.



A micelle is an aggregate of surfactant molecules dispersed in a liquid colloid

Micelles are approximately spherical in shape.