**Cell Structure – Animal/Human**

A cell is the basic unit of all life; structural and functional if it is alive, it must contain at least a single cell. The function of an organism is the summation of functions of its individual cells.

- **First described 300 years ago by Robert Hook.**

In the human body:
- A single fertilized egg contains approximately 100 trillion cells (adult).
- There are about 200 different kinds of cells in the human body with a variety of sizes and shapes.
- Small sizes are measured in microns (µm): 1 millionth of a meter (10⁻⁶); 1 thousandth of a mm (10⁻³).
- The smallest thing most can see with the naked eye is about 100µm (~1/4th the size of a period in text).
- A few human cells, e.g., human egg, some fat cells, fall in this range.
- Most are 10 times smaller (10⁻¹⁵ µm).

Animal cells:
- Ostrich egg: largest single cell of any animal; 3 lbs, 11 oz (1.65kg).

3 M long giraffe leg nerve cell

Human cells range in size from:
- Sperm cells are some of the smallest human cells.
- Human eggs and fat cells are some of the largest, barely visible to the naked eye.
- Some nerve cells are 3 ft long (humans).

Several factors limit size a cell can be:
- Cell membrane is fragile and would rupture if the cell got too large.
- Molecules can't diffuse fast or far enough in a cell that is too large:
  - They couldn't maintain metabolism.
  - It couldn't maintain surface to volume problem.

While there is a great diversity in size and shape, there is less diversity in function.

**The "Microbiome" or "Normal Flora"**

In addition to the human cells we’re made of, we are beginning to appreciate that the bacteria that inhabit us are just as important as our own cells:

- Our bodies normally contain 3-5 lbs of bacteria.
- We have about 100 trillion bacterial cells, which is roughly 10²⁰.
- We have 400 microbial genes (per human gene).
- "You are born 100% human, but die 90% microbial!"

Even this adage has been recently disproven:
- Bacteria colonize our gut in the womb where they begin to shape our immune system and susceptibility to diseases.
- Dental plaque on human teeth contains 100 or more bacterial species; many of which are found nowhere else in nature.
- Some places on the skin contain up to 300 different species:
  - The "richest" areas: belly button, buttock, and gluteal crease.
  - Only a few species are found: greasy spot behind ear, side of nose, toe webs, and sternum.

Bacterial are essential for a healthy body:
- Eg. skin bacteria protect us from pathogens and unchecked inflammation triggered by injury and bacterial pathogens.
- Widespread use of antibacterial hand gels may exacerbate such skin inflammation.
- Which species you have on your skin determine whether you get acne or not.
- Gut bacteria:
  - Help break down hard to digest fibers and starches.
  - Make essential vitamins and additional nutrients.
  - Protect us from pathogens.
  - Metabolize and remove plant toxins and some carcinogens.
  - Activate our immune systems to better resist infections.

We are beginning to see that our symbiotic microorganisms play an essential role in our survival, adaptation, and even evolution:
- Obesity, diabetes, Crohn’s disease, colitis, autism may be the result of an imbalanced microbial ecosystem in our guts.
- Some forms of severe malnutrition have been linked to a particular group of intestinal bacteria.
- Intestinal bacteria have also been linked to celiac disease and inflammatory bowel syndrome.
our microbiome is strongly correlated with our genetic makeup

→ may be as distinctive as our fingerprints; eg. bacteria found on a keyboard can identify the user as well as fingerprints

the abundance of certain bacteria in your feces correlates with your age, gender, body mass index, and nationality

### Human Cell Structure

**Basic Components of Cell:**

- **a. cell (plasma) membrane** - boundary
  - includes everything except cell membrane
- **b. cytoplasm (=cytosol)**
  - highly organized, specialized structures
- **c. nucleus**
  - genetic material
- **d. organelles and internal structures**
  - misc. crystals and globules
- **e. cell inclusions**
  - nonmembrane-bound particles

#### 1. Cell Membrane

defines boundary

highly ordered molecules

→ phospholipids, cholesterol, proteins, carbohydrates

- **a. membrane phospholipids**
  
  ~75% of membrane lipids are phospholipids
  
  have polar and nonpolar ends
  
  tend to arrange themselves into double layered films

- **b. membrane proteins** “float” randomly in this bilayer creating a fluid mosaic
  
  (1972 Singer & Nicholson)
  
  proteins randomly arranged in lipid bilayer not fixed
  
  peripheral proteins and integral proteins

- **c. membrane cholesterol**

  ~20% of membrane lipids are cholesterol

  if lower % → cell becomes too fragile

  eg. people with too little cholesterol suffer increased incidence of strokes as blood vessels rupture

- **d. membrane carbohydrates**

  carbohydrates are mainly in the form of hybrid molecules

  eg. carbohydrates bound to proteins (=glycoproteins)

  these form a fuzzy, sugary coating = **glycocalyx** in the surface of every cell

- **enzymes**: energy transforming enzymes
- **anchoring**: bound to cytoskeleton
- **cell identity markers**: eg many glycoproteins
- **cell adhesion molecules**: cells do not grow or survive normally unless they are mechanically linked to extracellular material
→ cushions and protects from physical and chemical injury

→ functions in cell identity & recognition (cell markers)
  eg. human blood types and transfusion compatibility are determined by glycoalyx
  eg. helps control cell growth → defines boundaries

→ includes cell adhesion molecules

the cell membrane is selectively permeable
some things enter freely, some things cannot cross or cross only with "help"

the cell membrane structurally and functionally interconnected to many of the cells organelles including the nucleus
=endomembrane system

Endomembrane system:
  plasma membrane
  nucleus
  endoplasmic reticulum
  golgi bodies
  lysosome
  microbodies

2. Cytoplasm (=Cytosol)
contains mostly water, ions, organic molecules etc.

replication and reproduction
daily metabolism

genetic material = chromosomes
100’s times length of cell
humans ~6’ of DNA/cell
= DNA with chromatin = highly organized histones

4. Nucleolus
densely packed chromosome region within nucleus
with proteins and ribosome precursors
site of RNA synthesis
important in formation of ribosomes

7. Mitochondria:
about size of small bacterial cell
surrounded by two membranes (like nucleus)
inner membrane forms invaginations = cristae
contain their own set of DNA (genes):
  passed only from mother to child
mitDNA remains unchanged generation after generation except by slow random mutation
  → used as molecular clock to trace evolution of groups
  eg. all humans today descended from a single woman of about 200,000 years ago = mitochondrial EVE

power plants of cells:
contain enzymes for respiration and ATP synthesis
produces most of cells ATP (=energy)
most eucaryotic cells thrive in O₂
  → use oxygen gas in energy releasing reactions
  the oxygen dependent energy releasing
reactions = **aerobic respiration**
occur in mitochondria

typical cell has dozens to 100,000’s

→ number related to cells activity

eg: muscle cells (7) 100,000’s/cell
liver cells 1000’s/cell
sperm cells ~25/cell

animal cells have more than plant cells

6. **Ribosomes**

small granules of RNA and proteins in cytoplasm
and on surfaces of rough ER

~2/3rd RNA and 1/3rd protein

workbenches for protein synthesis

→ protein factories (translation)

some free in cytoplasm

→ sites of protein synthesis for enzymes in cytoplasm

make proteins for cells own use

some attached to ER

→ make proteins for export or for lysosomes

especially in protein exporting cells

eg. liver and pancreas

**Smooth ER:**

narrower channels & cisternae

no ribosomes

lipid metabolism

forms new cell membrane material

synthesizes steroids and other lipids

detoxifies alcohol and other drugs

breaks down glycogen and fats

transports lipids & proteins thru cell

most cells have only a small amt of smooth ER

most common in lipid synthesizing cells

eg. liver cells

adrenal cortex (steroid hormones)

testes – steroid hormone synthesis (plant seeds)

and detox cells of liver

long term abuse of alcohol, barbiturates and other drugs leads to tolerance partly because smooth ER proliferates and detoxifies the drugs more quickly

up to 1000’s per cell

→ # ribosomes = > amount of protein synthesis

often structurally and functionally grouped together

= polyribosomes

protein synthesis occurs in ribosomes but some synthesis, modification and transport of these proteins occurs in endomembrane system (esp. ER)

7. **Endoplasmic Reticulum** (= “little network within the cytoplasm”)

a single highly branched membranous tube, with sacs and flattened channels = cisternae

two types:

most cells contain both types
(in different proportions)

**Rough ER:**

continuous with nuclear membrane

lots of ribosomes attached to surface

protein synthesis and transport

esp those that are secreted or those found in lysosomes

especially in protein exporting cells

eg. liver and pancreas

**Smooth ER:**

narrower channels & cisternae

no ribosomes

lipid metabolism

forms new cell membrane material

synthesizes steroids and other lipids

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8. **Golgi Bodies, Golgi Apparatus**

usually near nucleus

stack of membranes (flattened sacs)

functions in “packing & shipping”

encloses chemicals in vesicles and takes them to the cell membrane for secretion

synthesize large carbohydrates and combine them with proteins brought by ER to form glycoproteins

refining cell products

directs molecular traffic

secretions of glycoproteins

makes lysosomes

proteins exported from ER move to GB’s

become modified then enclosed in vessels

pinched off and move to surface

released by exocytosis
usually 1 to several 100 golgi bodies in a cell 
but may be up to 25,000/cell 
→highest in secretory cells

9. Lysosomes

membrane bound package of digestive enzymes 
several 100/cell 
size and shape changes 
contains at least 50 different enzymes 
→capable of breaking almost every kind of large organic molecule 
“digestive system” of cell: 
contains at least 50 different enzymes 
→capable of breaking almost every kind of large organic molecule 
a. destroys unwanted materials, cellular debris, worn out organelles 
eg. mitochondria 
b. also used by WBC’s and neuroglia cells to destroy invading pathogens 
c. gets rid of worn out cells = suicide bags = apoptosis (programmed cell death) 
eg. during development, removes “webs” from between fingers and toes 
eg. restores original size of uterus after delivery at full term weighs ~30 oz (900g) shrinks to 2 oz (60g) within 5 or 6 weeks after delivery

10. Peroxisomes 

resemble lysosomes but with a different set of enzymes 
→contains oxidases 
removes poisons from cells = detox 
eg. free radicals 
eg. alcohol and other drugs 
several 100 per cell 
→esp in liver and kidney cells 
Functions of peroxisomes: 
detoxification of alcohol and other drugs
neutralize free radicals 
digests large fatty acids and amino acids into fragments that can be used to produce ATP 
help destroy bacteria 
named for the H\textsubscript{2}O\textsubscript{2} they produce while detoxifying chemicals and killing bacteria

11. Cytoskeleton

microfilaments and microtubules 
some are contractile 
responsible for the overall shape & rigidity of each kind of cell 
nonrigid, contractile 
Functions of cytoskeleton: 
cell movement 
phagocytosis 
holds organelles in place 
helps move things around in the cell another ‘highway’ to move proteins and other things around in cell 

12. Centrioles (Centrosome)

each cell has a pair – at right angles to each other made of microtubules 9 bundles of 3 tubules functions in cell division: mitosis & meiosis helps to form spindle in ciliated cells each cilium has a basal body composed of a single centriole

13. Inclusions

everything else 
storage crystals oil globules

14. Cell Surface Structures (Specializations of Plasma Membrane):
a. microvilli 
extensions of cell membrane that greatly increase its surface area for absorption (intestine) or reabsorption (kidney)
best developed in cells specialized for absorption
   → intestinal lining
   → nephric tubule (PCT)

1000's/cell in intestine
   → give cells 15 – 40 times more surface area
when very dense = "brush border"
microvilli on taste cells and cells in inner ear have sensory rather than absorptive function

b. Membrane (=intercellular) Junctions
formed by various proteins associated with the cell membrane
allows cells to attach to each other in different ways

**tight junctions**
proteins of two different cell membranes fuse together
form impermeable junction encircling cells
   → makes it difficult for materials to pass between cells, must get through cells to cross membrane
esp in epithelial layers of membranes
   → any passage through membrane must be

only 1 per cell
found on almost every kind of human cell (except hepatocytes)
wide variety of sensory functions:
   fluid flow (kidneys)
   pressure
   chemicals (nose)
   osmotic concentrations
   gravity
   temperature
play an important role in cell migration in embryonic development
serve as “communication hubs”
as part of “hedgehog signaling system”
a growing list of diseases (>30 so far) are apparently related to a malfunction of primary cilia, eg.:
   blindness
   obesity
   learning problems
   respiratory failure
   kidney failure
   shortened limbs
   thin ribs
   → some cilia are able to move = motile cilia

through cells, cant squeeze between adjacent cells
eg: keep digestive enzymes in intestine from leaking into blood
eg: prevents intestinal bacteria from invading tissues

desmosomes
rivet-like couplings of "linked proteins"
guy wires throughout sheet of cells
especially in tissues subjected to stretching
   → prevents sheets of cells from tearing
   eg: skin, neck of uterus, heart muscle

gap junctions
allows direct passage of small molecules and ions between cells
   eg. intercalated discs in cardiac muscle cells

c. cilia

cilia are hairlike processes found in most body cells
   → most are nonmotile "primary cilia"
   (they lack the central pair of microtubules found in moving cilia)
mainly in respiratory tract and uterine tubes
beat in waves moving mucus or egg cells along tubes
made from microtubules (9+2) with central axoneme
d. flagella
is essentially a long, solitary cilium
flagella found only in sperm cells
e. membrane surface receptors
diverse molecular sites at which cells chemically recognize and bind extracellular substances
proteins, glycoproteins, lipoproteins
binding often causes metabolic changes
   => "activates" cell to do something
also important in cell-to-cell identity
   eg. surface markers
   → defense against foreign cells and tissues