Chpt 5: the Cell Cycle

the life of a cell

you started out life as a single cell

a fertilized egg

1 cell--->2 cells---->4 cells---->8 cells----->

16 cells------->ball of cells

this was rapid cell division w/no growth

then cell specialization began

nerve cells, muscle cells, blood cells, etc

every cell in body has same genetic material

in nucleus regardless of type of cell

at birth--->complex multicellular organism

but you still needed to grow & develop

-growth involves cell division

-development involves turning on specific genes that regulate specific processes

How do cells divide & how do they know when to divide?

it is programmed into genetic material

You are made up of trillions of cells

why not have less cells, but larger cells?

cells are limited by **SA to volume ratio**

cells must get O2 & nutrients, get rid of CO2 & wastes, all this has to move across surface of cell membrane

larger cells have larger volume, smaller cells have better SA to volume ratio

as cells grow, SA doubles as volume triples, so you don't have enough surface for necessary items that are needed by the cell

also nucleus must control entire cell, if contents get too big, nucleus has trouble directing cell

Cell cycle: phases in life of cell

cell spends majority of time in growth & development, little time dividing

Purposes of cell division

1-growth
2-replace worn out cells
3-repair tissues

Cell cycle: IPMAT

interphase
prophase
metaphase
anaphase
telophase

mitosis = division of genetic material
prophase, metaphase, anaphase, telophase

cytokinesis = division of cytoplasm
this happens by the end of telophase

every cell must have complete copy of genetic material, thus **must copy DNA prior to mitosis**

DNA is found in several forms in cell depending on phase cell is in

prior to division, DNA is in long strands called **chromatin**

after copying, chromatin condenses (shortens & thickens) into **double-stranded chromosomes** (proteins help do this)

each strand is copy of other called **sister chromatids**

chromatids are connected by **centromeres**

Cell Cycle

Interphase: longest stage of cycle
- cells spends approx 75-90% of life here
- used to be called "resting phase"
- bad name, cell is carrying out all life process
  - growth & development, cell respiration, biosynthesis, active transport, passive transport, protein synthesis, etc.
- divided into 3 parts

1-**G1** Gap1 or Growth
- this is the first phase in the life of a newborn cell
- the cell grows by increasing amount of cytoplasm, increasing # cellular organelles, the cell makes proteins, the cell obtains nutrients & O2, gets rid of wastes & CO2, these 2 processes occur by passive & active transport
- cells can stop in this phase called G0 (zero)
  - your liver cells and nerve cells spend their lives in this phase
  - most cells in adult multicellular organisms are in G0, these are metabolically active cells, maintaining the life of the cell and the organism
- when cells get signal to divide, they move into next phase

2-**S phase**: Synthesis
- copy genetic material, DNA
- copy centrioles

3-**G2 phase**: Gap2
- cells get ready for mitosis
- make necessary proteins & RNA

Growth occurs in all subphases of interphase
- growth includes making proteins that are necessary for each stage

Mitosis: division of nucleus, series of steps ensuring that each daughter cell gets copy of genetic material

Cytokinesis: division of cytoplasm
most cells exhibit cytokinesis, but muscle cells are an exception, this results in multinucleated cells that are very long

What happens in each stage of cell cycle? What do cells look like?

Interphase: nucleus present, nucleolus present
DNA in form of chromatin, long strands

Prophase: DNA shortens and condenses into double-stranded chromosomes
nucleus disappears, nucleolus disappears
centrioles appear and begin migrating to opposite poles of cell, as they migrate, they set up the mitotic spindle
these are microtubules that will attach to the chromosomes

Metaphase: centrioles arrive at opposite poles of the cell with the spindle fibers stretching out between them
chromosomes attach to the mitotic spindle at the centromere of the double-stranded chromosomes
the double-stranded chromosomes line up in center of cell, middle plate

Anaphase: centromeres divide resulting in sister chromatids separating
sister chromatids are pulled to opposite poles by spindle fibers
this is the shortest phase of mitosis

Telophase: chromatids reach opposite poles, now called single-stranded chromosomes
spindle disassembles, nuclear membrane begins reappearing

Cytokinesis occurs
in animal cells this is done by cleavage
cells pinch in and pull apart
in plant cells a cell plate forms

Differences in Mitosis: Plant vs Animal Cells

plant cells do not have centrioles, the mitotic spindle is set by centrosomes and asters

cytokinesis

animal cells pinch in & pull apart

plants must begin making cell wall

vesicles containing cellulose appear between 2 nuclei

vesicles then fuse together---->forms new cell membrane

cellulose inside vesicles forms new cell wall

forms from edges to inside

What controls mitosis?

mitosis is a highly regulated process, things could go wrong at many places
cells could duplicate chromatin twice
cells could divide before genetic material is copied
cells could divide when they are too small
spindle fibers could fail to attach to chromo

Cell Fusion Experiments have been done to figure out what controls mitosis
in cell fusion, you fuse 2 cells together
removing the nucleus of one cell, then see what the cell does
remember the nucleus is the control center, it tells the cell what to do

for example, if you take cells in S phase and remove the nucleus, then fuse them with cells in G1 (these cells have their nucleus intact)---->the DNA immediately begins to replicate
thus, there is a factor in S phase cells that enters the G1 nucleus & initiates DNA replication

if you take G2 cells, remove nucleus, then fuse w/ early S phase cells----->these cells immediately enter G2 without DNA replication
thus a factor from G2 cells is sending these cells into mitosis immediately

so what is going on? cyclins are regulating

Cyclins are proteins that regulate the cell cycle
these are proteins are made just prior to each stage of the cycle and they tell the cell what to do
the instructions for the proteins are in the DNA in the nucleus, but then proteins are made in the cytoplasm of the cell

G1 cyclins are made and begin accumulating in late G1---->these tell cell to begin S phase
these reach peak during S phase, then drop
mitotic cyclins are made and begin accumulating at end of S phase----->these tell cell to begin mitosis
these peak at metaphase, then drop

cyclins stimulate every part of mitosis
some cyclins turn on spindle formation
some cyclins activate enzymes that break down centromeres so sister chromatids can separate at anaphase

So what if something still goes wrong?

- UV radiation can damage DNA
- what if sister chromatids don't attach to spindle?

the cell has **checkpoints** where the cell can be stopped, can make repairs, then proceed

there are checkpoints in G1, S, G2,& M

- at these spots, proteins can detect if there is a problem, can stop cell cycle, put cell into **Cell-Cycle Arrest**, correct mistake & then restart cycle

for example, p53 is protein that detects DNA damage

- when p53 detects damage, it activates inhibitors which prevent G1 cyclins from working
- when the damage is repaired, then p53 is inactivated and the cell cycle proceeds

Cancer is cell division out of control
- "cells gone wild"
- cell cycle regulators prevent cells from leaving G0, but if regulators are inactivated, cells can divide at wrong time
- when checkpoint controls are damaged, cells repeatedly divide forming mass of cells--> tumor
  - benign tumor: cells stay together, cause little harm, can be removed surgically
  - malignant tumor: cells break free & migrate to new areas called metastasis
    - these cells can stimulate other cells to divide out of control

Everyone has the potential to have cancerous cells because the root lies within our genes

We all have genes in our cells called **proto-oncogenes**
these genes promote or turn on cell division
there are also genes called **tumor-suppressor genes**: these genes inhibit cell division

in normal life, an external signal arrives at the cell to say it is time to grow, this turns on the proto-oncogene
this gene tells the cell to make cyclins to regulate cell cycle and send the cell into mitosis
then tumor suppressor genes turn on, which says stop after division, may put cell into G0

in cancerous cells, one or both of these processes may be interrupted
a mutation can change a gene from a proto-oncogene to an oncogene
oncogenes turn on cell division & don't listen to signals saying to turn off division
a mutation in tumor suppressor genes can result in them not making proteins that tell division to stop
both of these allow uncontrolled growth