Chpt 12: 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----->
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

growth of cell, increases amount cytoplasm, increases # cell organelles, makes proteins

cells can stop in this phase called G0 (zero)

most cells in adult multicellular organism are in G0, these are metabolically active, maintaining life

most liver cells in G0, nerve cells

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: chromosomes begin attaching to
- the mitotic spindle by a kinetochore
  - the kinetochore is a protein structure at the centromere of the double-stranded chromosomes
- centrioles arrive at opposite poles of the cell
  - with the spindle fibers stretching out between them
  - the double-stranded chromosomes line up in center of cell, middle plate

Anaphase: centromeres divide resulting in
- sister chromatids separating
- chromatids 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?
- highly regulated process, things could go wrong at many places
  - cells could duplicate chromatin twice
  - cells could divide before genetic material is copied
  - 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

take cells in S phase, remove nucl, then fuse with cells in G1---->DNA immed begins to replicate
thus, there is a factor in S phase cells that enters G1 nucl & initiates DNA replication

take G2 cells, remove nucl, then fuse w/ early S phase cells----->immed enter G2 w/no DNA replication
thus factor from G2 cells sends cells into mitosis immed.

so what is going on? cyclins are regulating

cyclins are proteins that regulate the cell cycle
- proteins are made just prior to each stage
  - and tell the cell what to do
- 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 accumul
  - at end of S phase----->these tell cell to begin
    - mitosis
  - these peak at metaphase, then drop

cyclins work by binding to kinases
- kinases are enzymes that transfer a P from ATP, this activates the cyclin

cyclins stim 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
  - p53 is protein that detects DNA damage
    - when p53 detects damage, it activates inhibitors, these prevent G1 cyclins from working
    - damage is repaired, then p53 is inactivated, cell 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

there are genes in cells called proto-oncogenes
these genes promote cell division
there are also genes called tumor-suppressor genes: these inhibit cell division
in normal life, a signal arrives at the cell to say it is time to grow, this turns on proto-oncogene
these make cyclins to regulate cell cycle, send cell into mitosis
then tumor suppressor genes turn on, which says stop after division, may put cell into G0
in cancerous cells, both of these processes are interrupted
a mutation can change a gene from a proto-oncogene to an oncogene

oncogenes turn on cell division & don't listen to turn off proteins

mutation in tumor suppressor genes will not make proteins that tell division to stop

both of these allow uncontrolled growth