What have we done? Where are we going?

We learned about the diversity and evolution of life on the planet in the past.

What does that diversity include? (Prokaryotes-Bacteria and Archaea, Eukaryotes-Single celled "protists", plus multicellular fungi, plants, animals)

Unique contribution of Darwin his proposal of natural selection as the engine of evolution.

For natural selection to work you have to have some way of passing on your characteristics to your offspring (Lamarck was wrong in that muscles do not communicate to sperm and eggs to ensure next generation has larger, longer necks.)

So how does inheritance happen !!???

We are going to back up a little and focus on how traits get passed down from one generation to the next and how a material (DNA) in cells makes this happen.

Chapter 5
Raw material: heritable variation among individuals

The central metaphor of Dawkins's new book is a river of genes, flowing through geological time rather than space. Each river is a population of genes held together by sexual interbreeding. The river may fork in time. Each branch slowly drifts apart to give rise to a new species. Some branches dry up in extinction. Others split repeatedly, generating the 30 million branches that exist today.

How do these genes "flow" through time?

How do they get copied and passed down to other cells and to new individuals during reproduction?

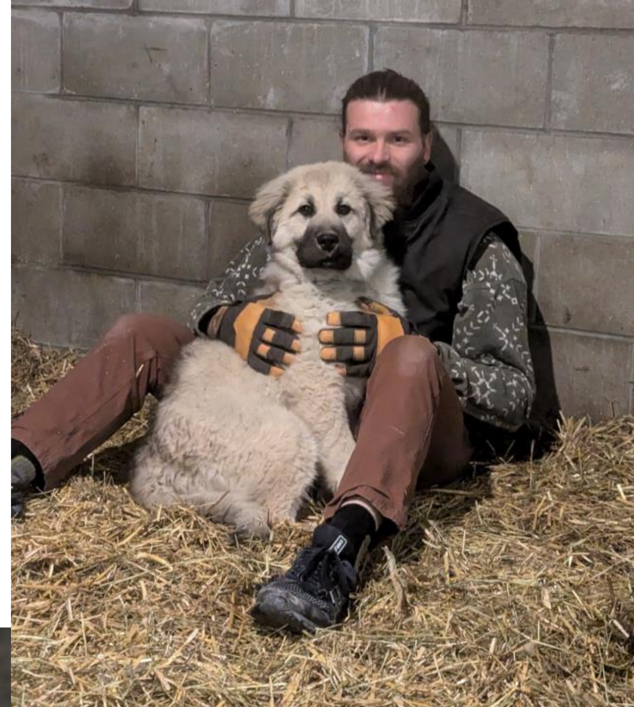
Read more: https://www.newscientist.com/article/mg14719904-900-the-making-of-a-metaphor/#ixzz6oiTtQ0Me

A question from your reading guide….

Q1. Why is height a great place to start as we think about how traits are inherited?

Variation within a single species!

Human height to Regents Hall Dogs Variation within a single species!

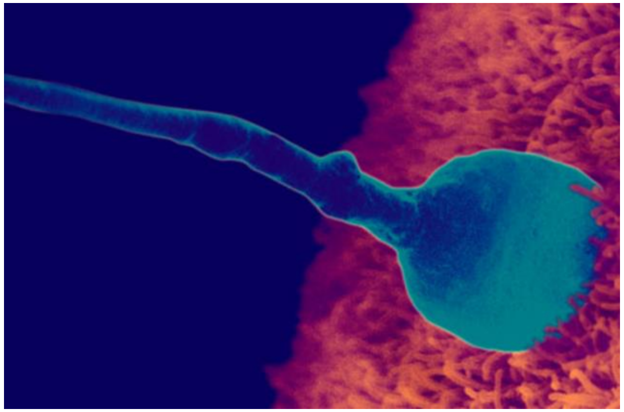


Chapter 5 Topics

1. Animal Life Cycles (We are kind of ignoring plants and many other groups!!! ☹)
2. Structure of DNA in Eukaryotes and Prokaryotes! *(and HGT)*
3. Replication of DNA *(copying of DNA*) in mitosis
4. Making proteins!
    - Transcription-going from DNA to mRNA
    - Translation-going from mRNA to protein
5. Gene regulation!
6. Sizing up the Genome
7. Mutations
8. Mitosis vs Meiosis *(sexual reproduction)*
9. Mendel and Punnett Squares

1. Review of Animal Life Cycle

Fertilization
Zygote
Mitosis (when cells copy themselves to make more body cells)
Meiosis (when cells copy themselves but make gametes)
Gametes
Haploid
Diploid

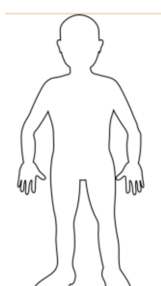


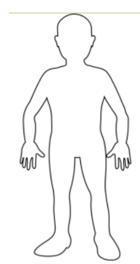
For your Review!

- Fertilization
- Zygote
- Mitosis
- Meiosis
- Gametes
- Haploid
- Diploid

Egg

Sperm





Life Cycle Practice!

Sperm are gametes that are ____________(single celled/multicelled) and _______(diploid/haploid).

Eggs are gametes that are _____________ (single celled/multicelled) and _____________(diploid/haploid).

When sperm fertilizes an egg a __________________ is formed which is ____________ (haploid/diploid).

This then goes through______________ (mitosis/meiosis) over and over again to create a body that is ____________ (single celled/multicelled).

During this process the DNA in the cells must go through______________.

Once an adult multicellular organism exists it is ____________ (haploid/diploid). In humans each cell will have _________________ (how many) chromosomes.

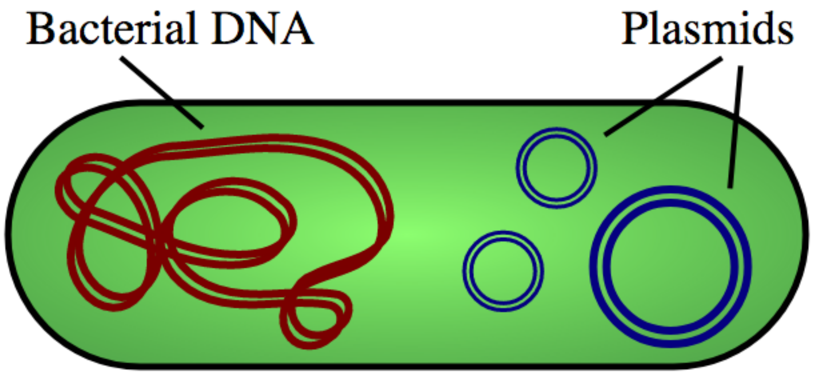
At this point, germ cells in the multicellular body must go through_____________(mitosis/meiosis) to make __________.

These are _____________(haploid/diploid) and have ___________ chromosomes in humans.

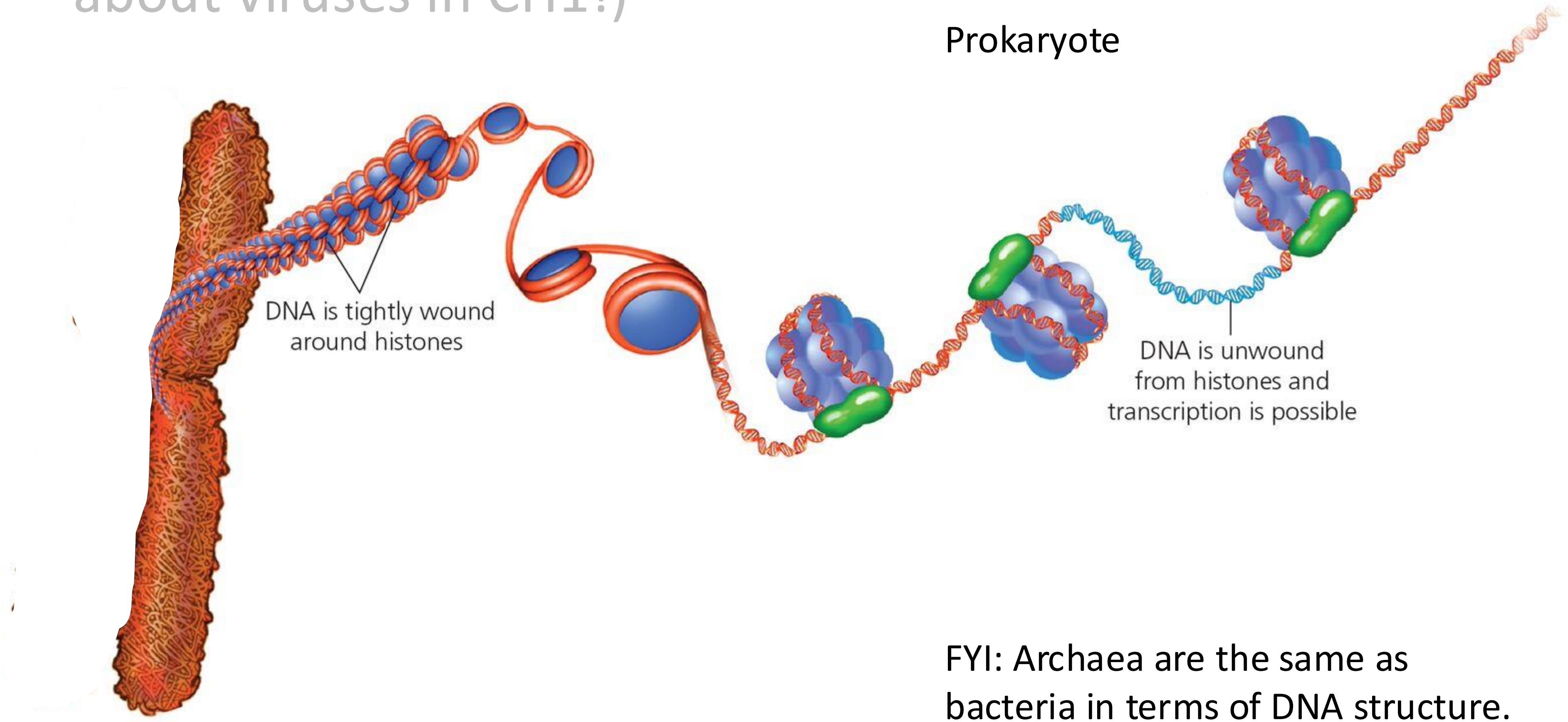
Fertilization, Zygote, Mitosis, Meiosis, Gametes, Haploid, Diploid

2. Structure of DNA in Eukaryotes and Prokaryotes!

(Remember we talked about viruses in CH1!)



Prokaryote



Eukaryote

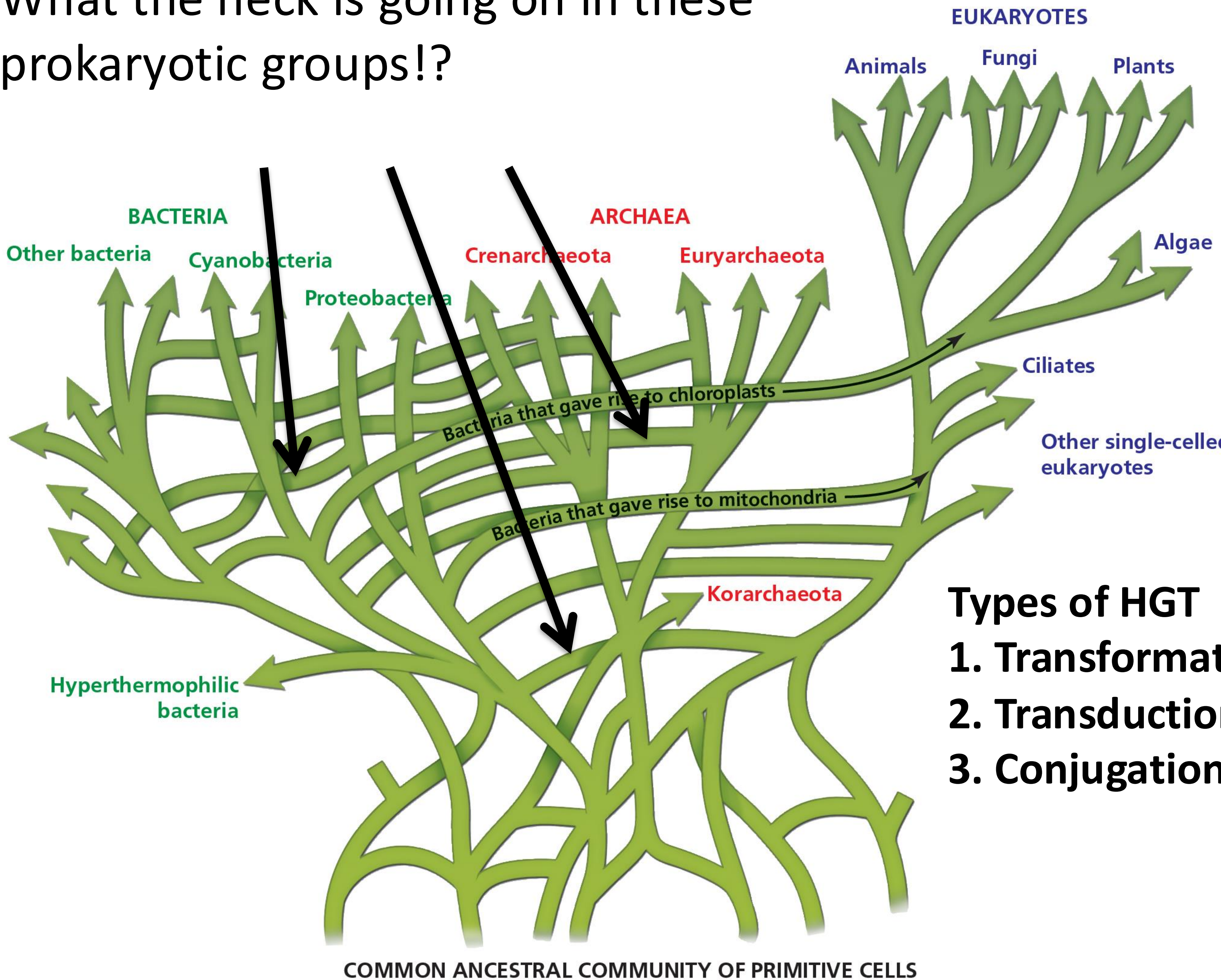
FYI: Archaea are the same as bacteria in terms of DNA structure.

Prokaryotic cells make new individuals by copying their genome and then dividing-making sure that each daughter cell created has a copy that is the same as the parent cell===Binary Fission===kind of boring.

BUT they can do other cool things Eukaryotes can't do!

Horizontal Gene Transfer (HGT)

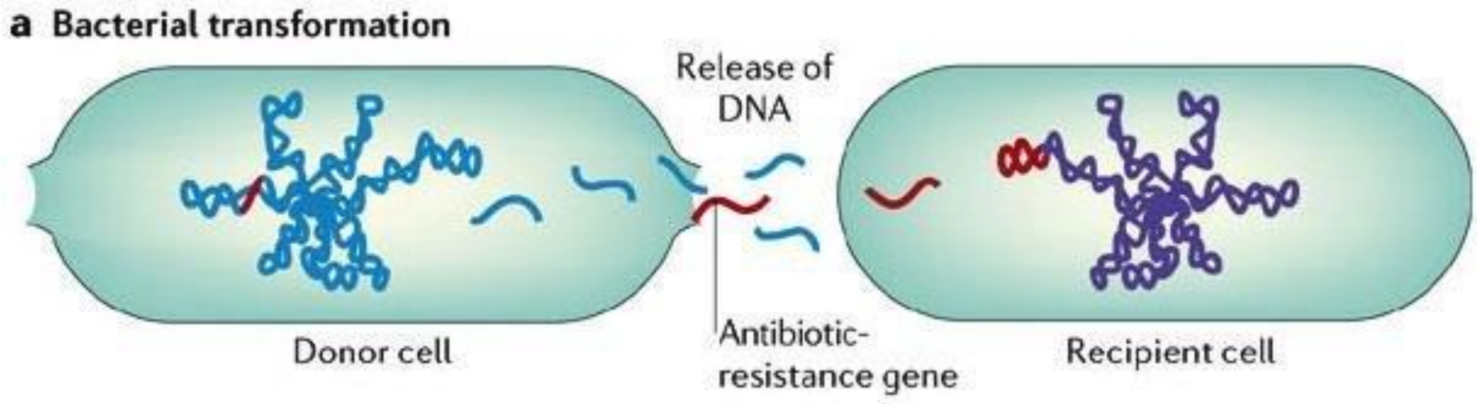
What the heck is going on in these prokaryotic groups!?



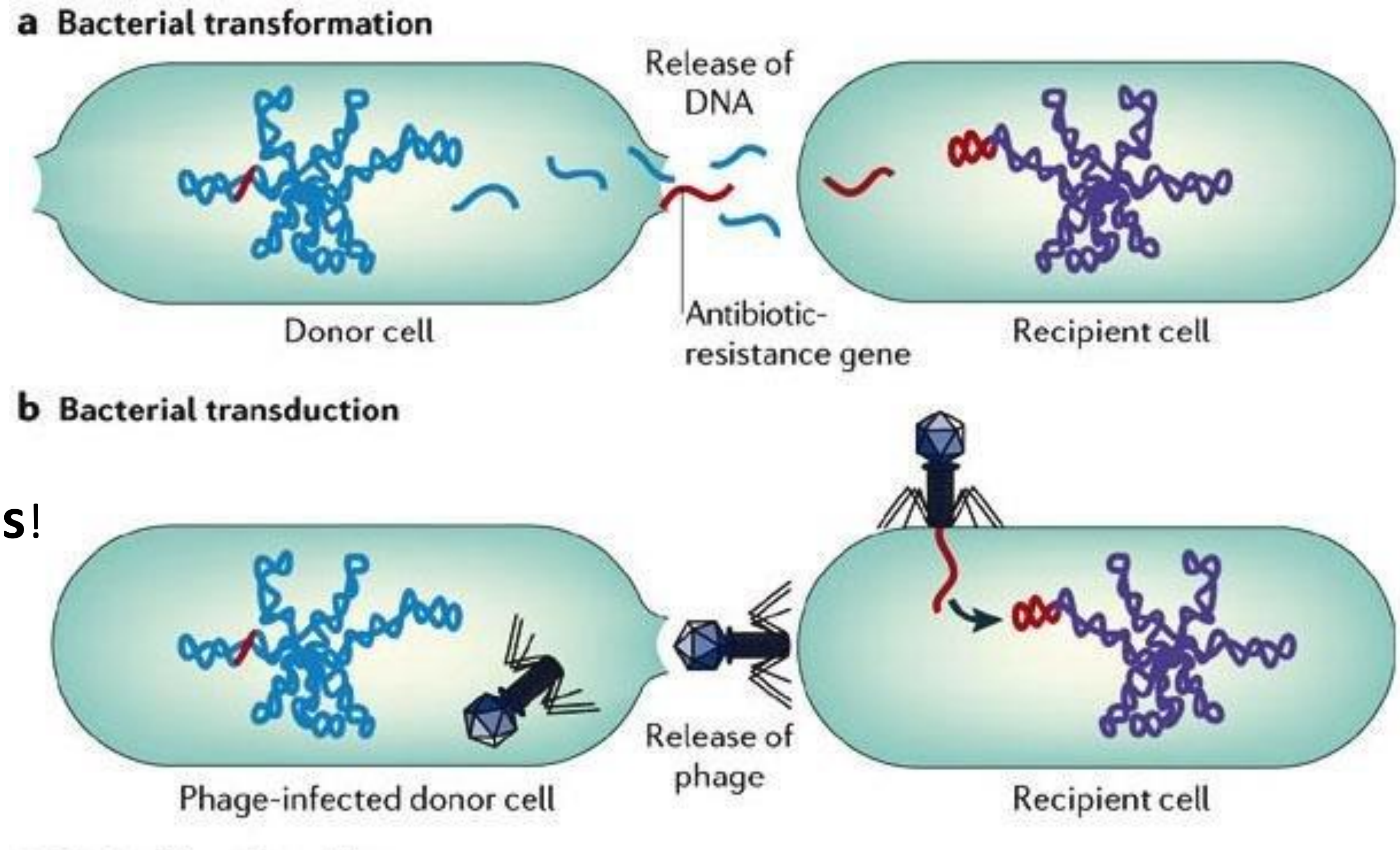
Types of HGT

1. **Transformation**
2. **Transduction**
3. **Conjugation**

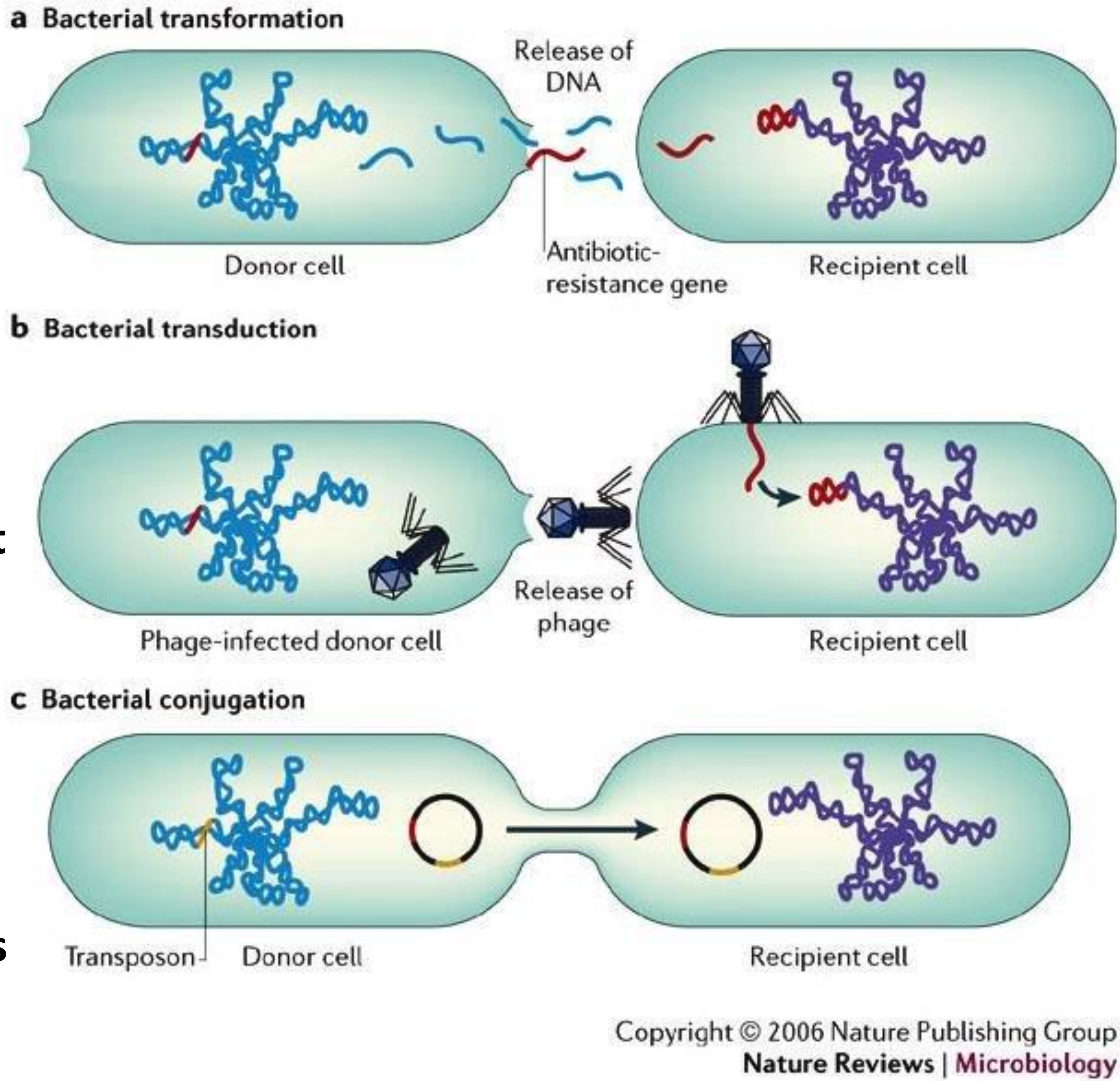
Horizontal or lateral gene transfer in prokaryotes!



Horizontal or lateral gene transfer in prokaryotes!



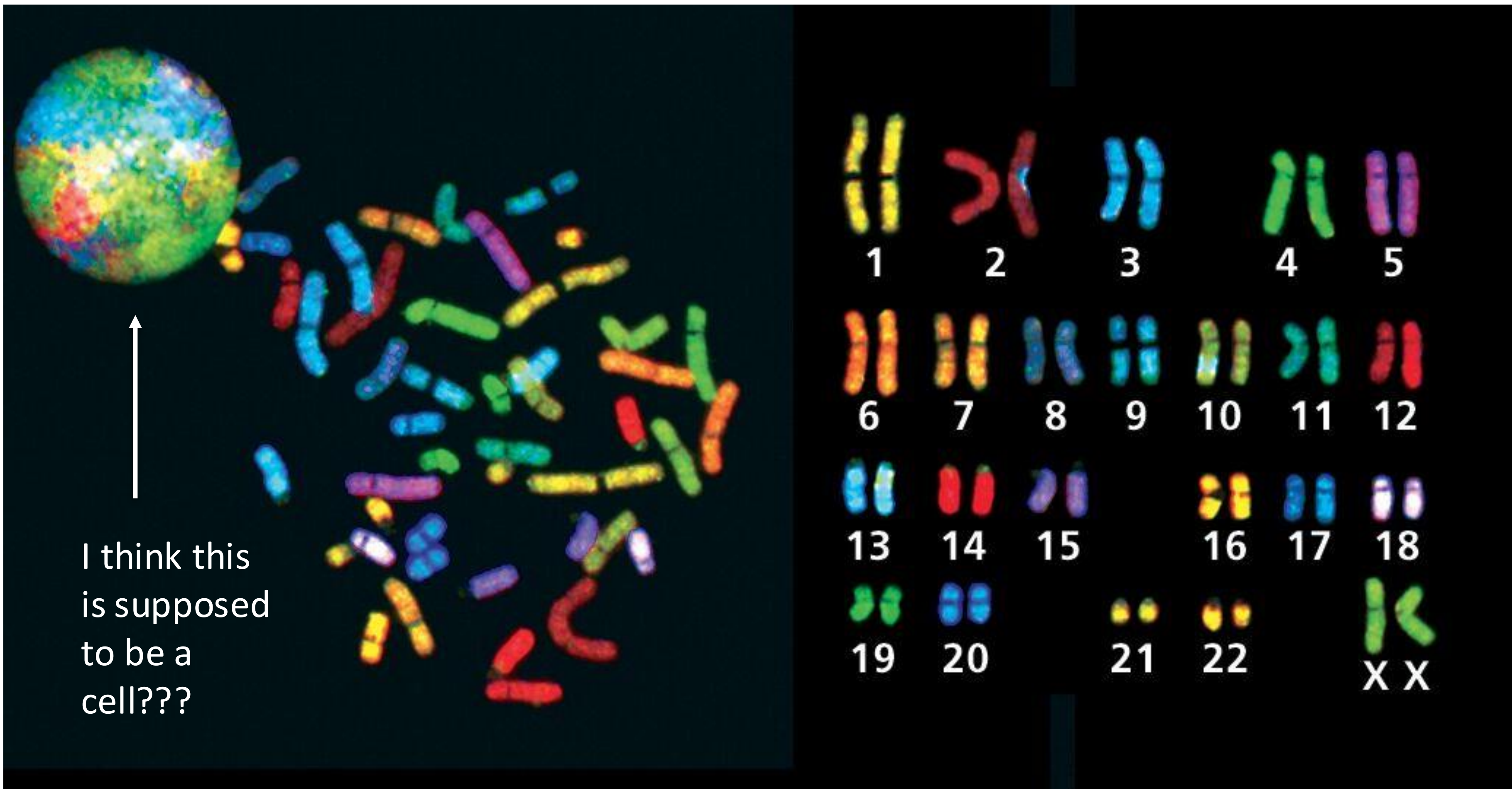
All three of these result in genetic material being moved around within populations of bacteria.



More on Eukaryotic Structure

Linear chromosomes in eukaryotes typically come in **homologous pairs**

Each cell in a multicellular adult has a whole set (2 of each chromosome=we are "diploid" =23 pairs so 2N=46)



More on Eukaryotic Structure

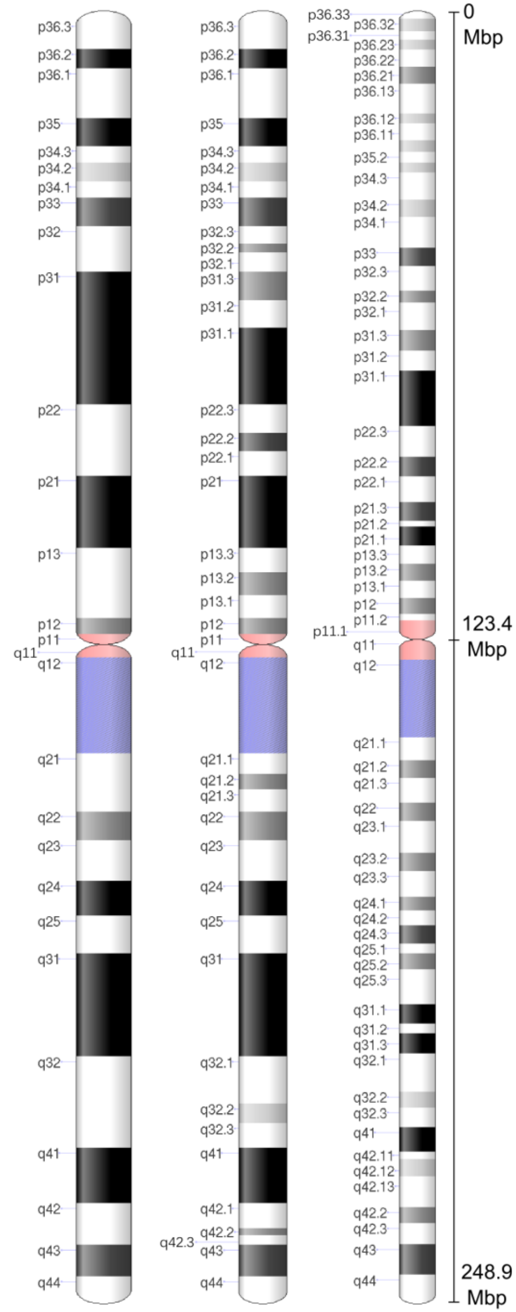
FYI 3 snapshots of same chromosome at different levels of detail.

p-arm [edit]

GenBank CM00

Partial list of the genes located on p-arm (short arm) of human chromosome 1:

- AADACL3: Arylacetamide deacetylase-like 3
- AADACL4: Arylacetamide deacetylase-like 4
- ACADM: acyl-Coenzyme A dehydrogenase, C-4 to C-12 straight chain
- ACTL8: Actin-like 8
- ADGRL2 (1p31.1): adhesion G protein-coupled receptor L2
- ADPRHL2: Poly(ADP-ribose) glycohydrolase ARH3
- AMPD2: encoding enzyme AMP deaminase 2
- ARID1A (1p36)
- ATXN7L2: Ataxin 7-like 2
- AZIN2: encoding enzyme Antizyme inhibitor 2 (AzI2) also known as arginine decarboxylase (ADC)
- BCAS2: Breast carcinoma amplified sequence 2
- BCL10 (1p22)
- BCL2L15 (1p13)
- LRIF1: encoding protein Ligand-dependent nuclear receptor-interacting factor 1
- C1orf109: chromosome 1 open reading frame 109
- CZIB: chromosome 1 open reading frame 123
- CACHD1 encoding protein Cache domain containing 1
- CAMTA1 (1p36)
- CASP9 (1p36)
- CASZ1 (1p36): Castor zinc finger 1
- CSDE1: Cold shock domain containing E1
- CHD5 (1p36)
- CLIC4 (1p36)
- CLSPN (1p34)
- MEAF6: MYST/ESA1 associated factor 6
- MECR: Trans-2-enoyl-CoA reductase, mitochondrial
- MFAP2: Microfibrillar-associated protein 2
- MIB2 (1p36)
- MIER1 (1p31)
- MFN2: mitofusin 2
- MFSD2: Major facilitator superfamily domain containing 2A
- MIR6079: microRNA 6079
- MMEL1: Membrane metallo-endopeptidase-like 1
- MTFR1L: mitochondrial fission regulator 1 like
- MTHFR (1p36): 5,10-methylenetetrahydrofolate reductase (NADPH)
- MUL1: Mitochondrial E3 ubiquitin protein ligase 1
- MUTYH (1p34): mutY homolog (E. coli)
- NBPF3: Neuroblastoma breakpoint family member 3
- NGF: Nerve Growth Factor
- NOL9: Nucleolar protein 9
- NRAS (1p13)
- NOTCH2 (1p12)
- OLFML3: Olfactomedin-like 3
- OMA1: Metalloendopeptidase OMA1, mitochondrial
- OVGP1: Oviductal glycoprotein 1
- PARK7 (1p36): Parkinson disease (autosomal recessive, early onset) 7
- PINK1: PTEN induced putative kinase 1
- PLOD1: procollagen-lysine 1, 2-oxoglutarate 5-dioxygenase 1
- PRMT6: Protein arginine methyltransferase 6



400 bphs 550 bphs 850 bphs

Human chromosome 1

If we zoomed into one of these chromosomes and unraveled it

we would see......

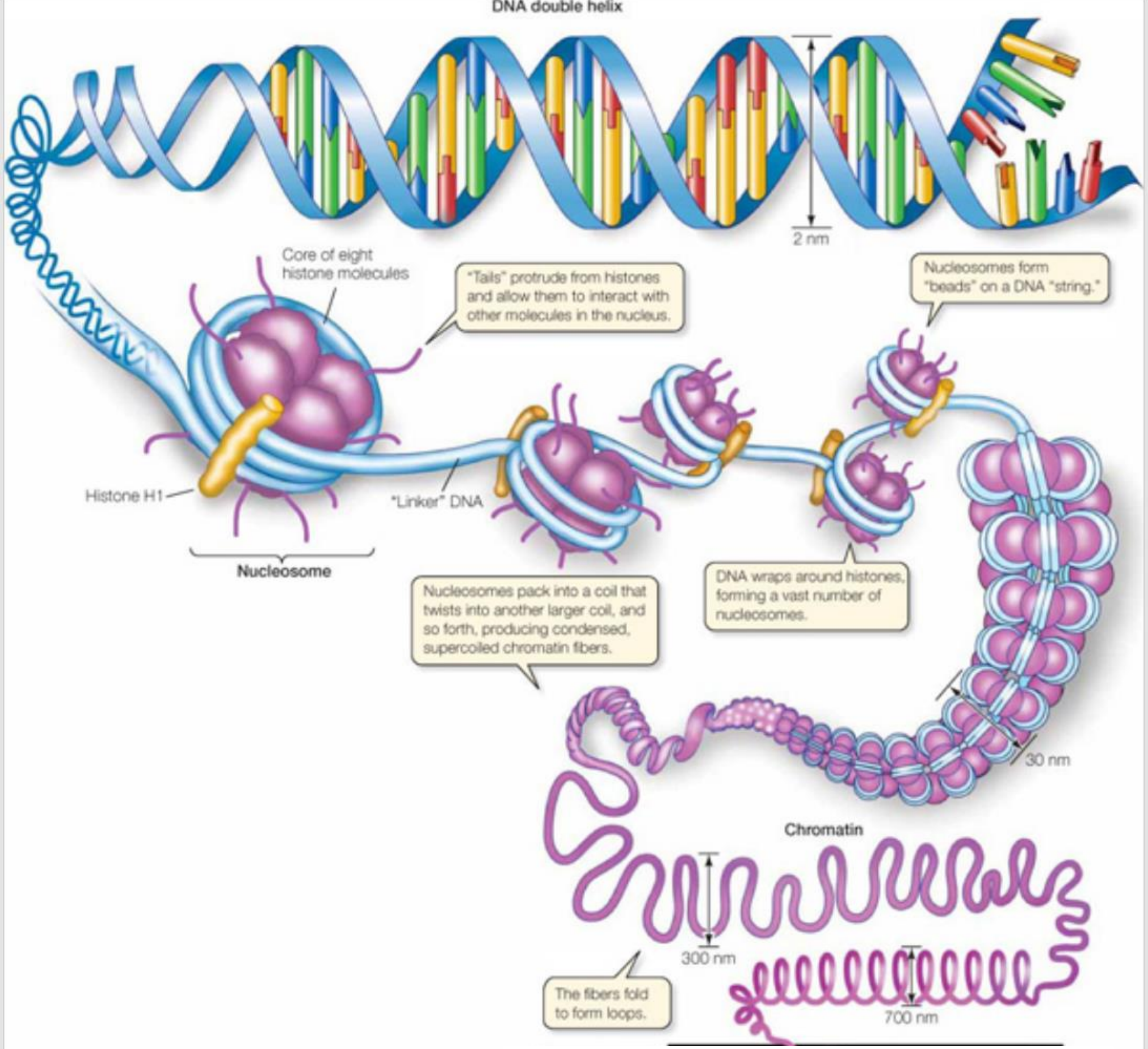
More on Eukaryotic Structure

Double helix

Bases

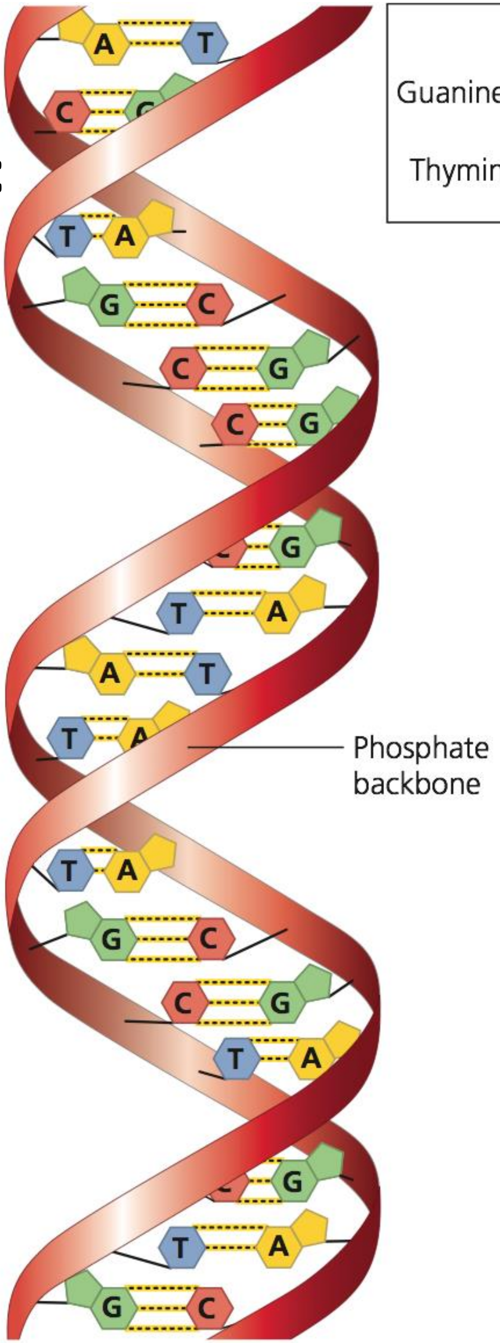
Histone+DNA wrapped around it= **nucleosome**.

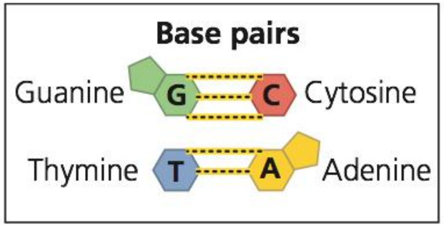
What is with all the wrapping and coiling?



https://www.nature.com/scitable/content/DNA-is-Packed-into-a-Mitotic-Chromosome-3497/

More on Eukaryotic Structure





Structure in more detail….

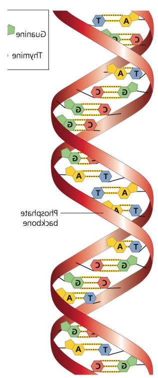
- Sugar-Phosphate backbone (red)
- Nitrogen rich bases A, T, G, C
- Adenine and Guanine both have double rings (Two double rings would not fit …. so A bonds with T and G with C)
- “pointy” letters bond together + “curvy” letters bond together

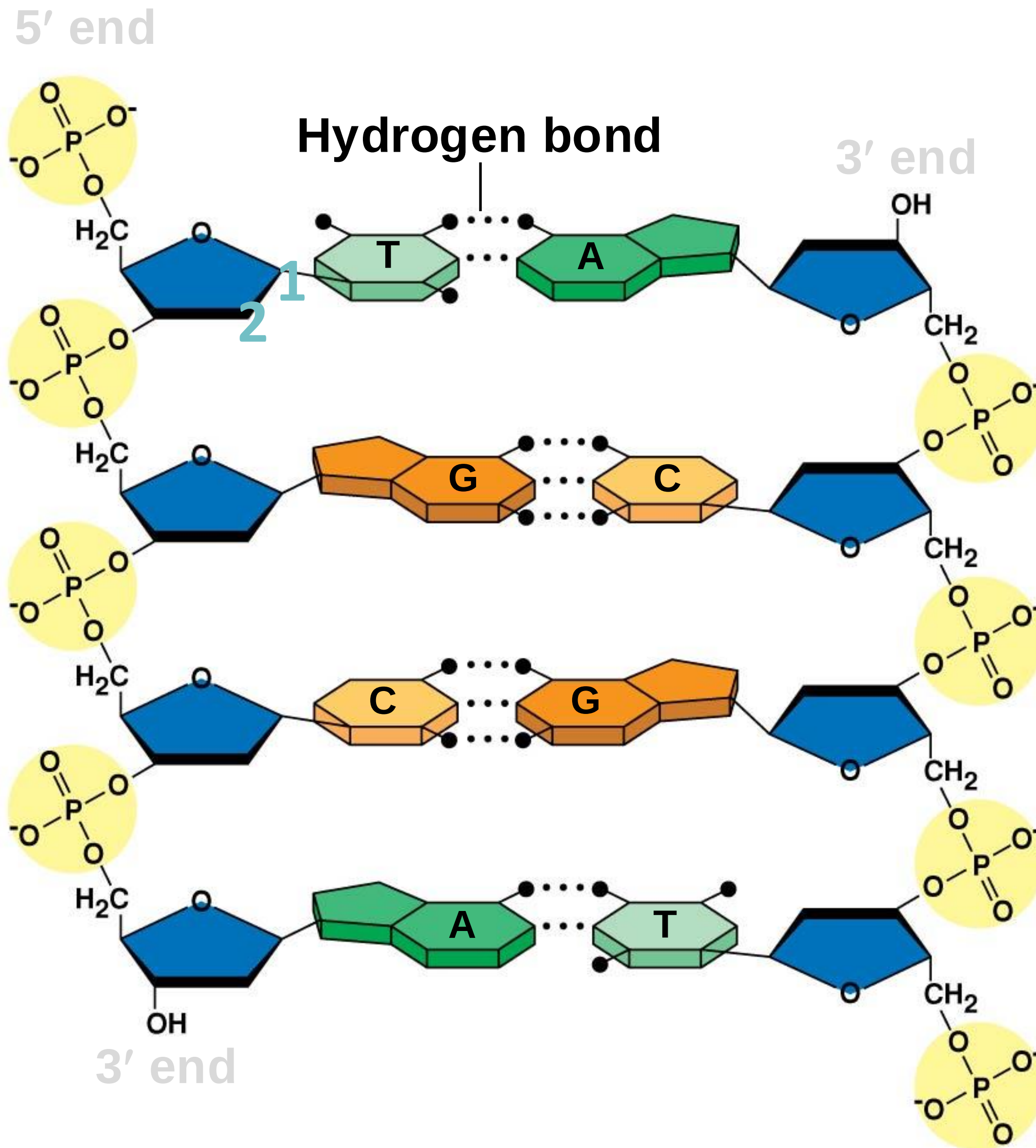
And then even more detail! (ignore 5’ and 3’)

Here you can see phosphate groups in backbone!

Blue pentagons are?

Sugars!

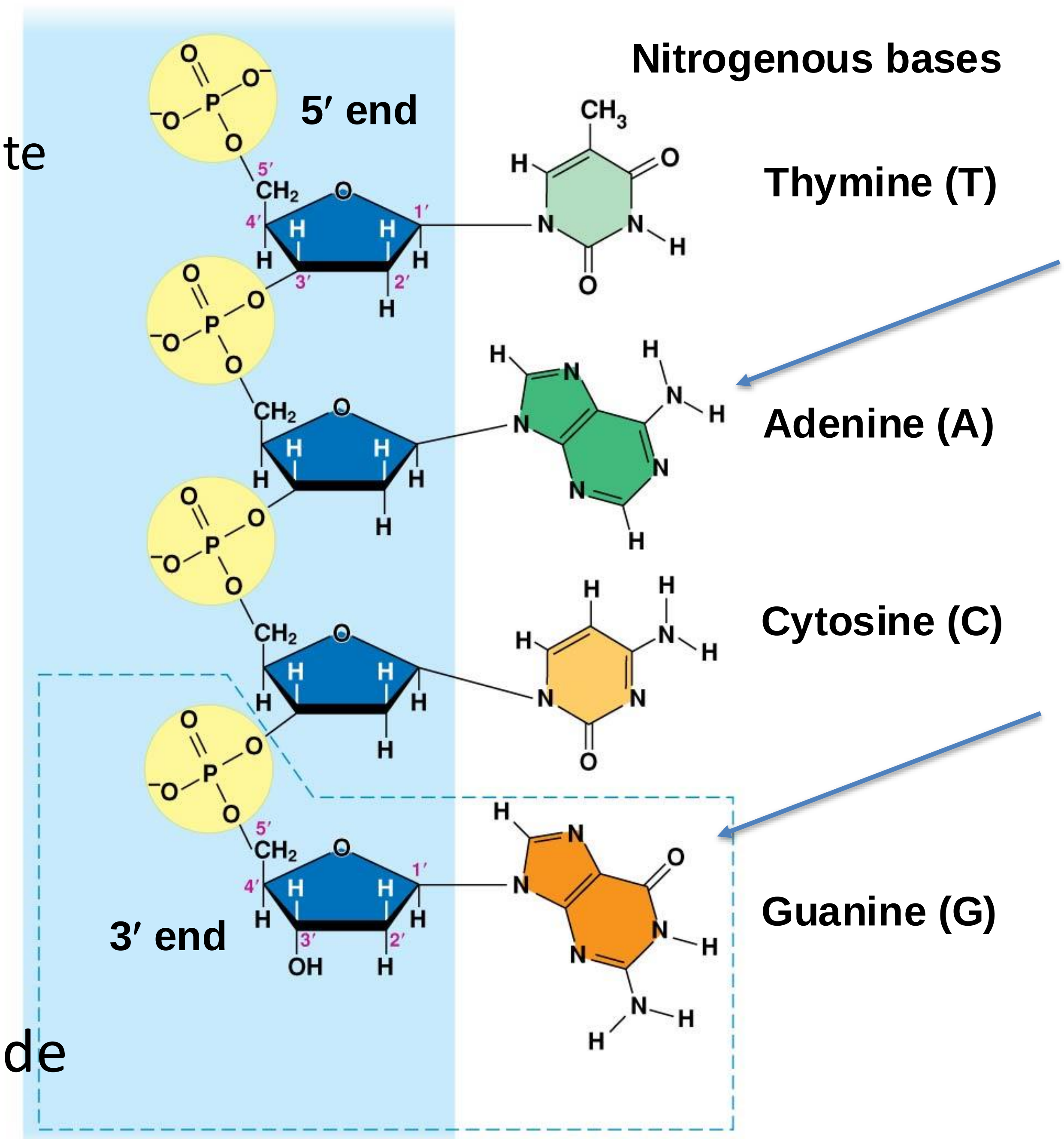




A DNA **nucleotide** = a phosphate molecule + a sugar molecule + one nitrogen rich base.

Blue shading =

Sugar–phosphate backbone



DNA nucleotide

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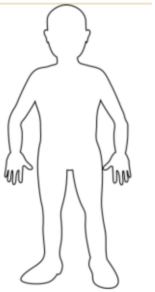
3. Replication (copying of DNA) has to happen whenever cells divide or go through MITOSIS



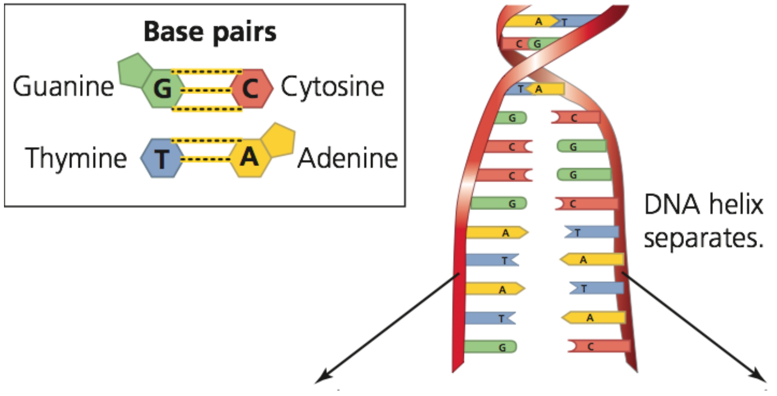
(DNA also replicates during meiosis which we will cover later)

When does **mitosis** take place during a life cycle?

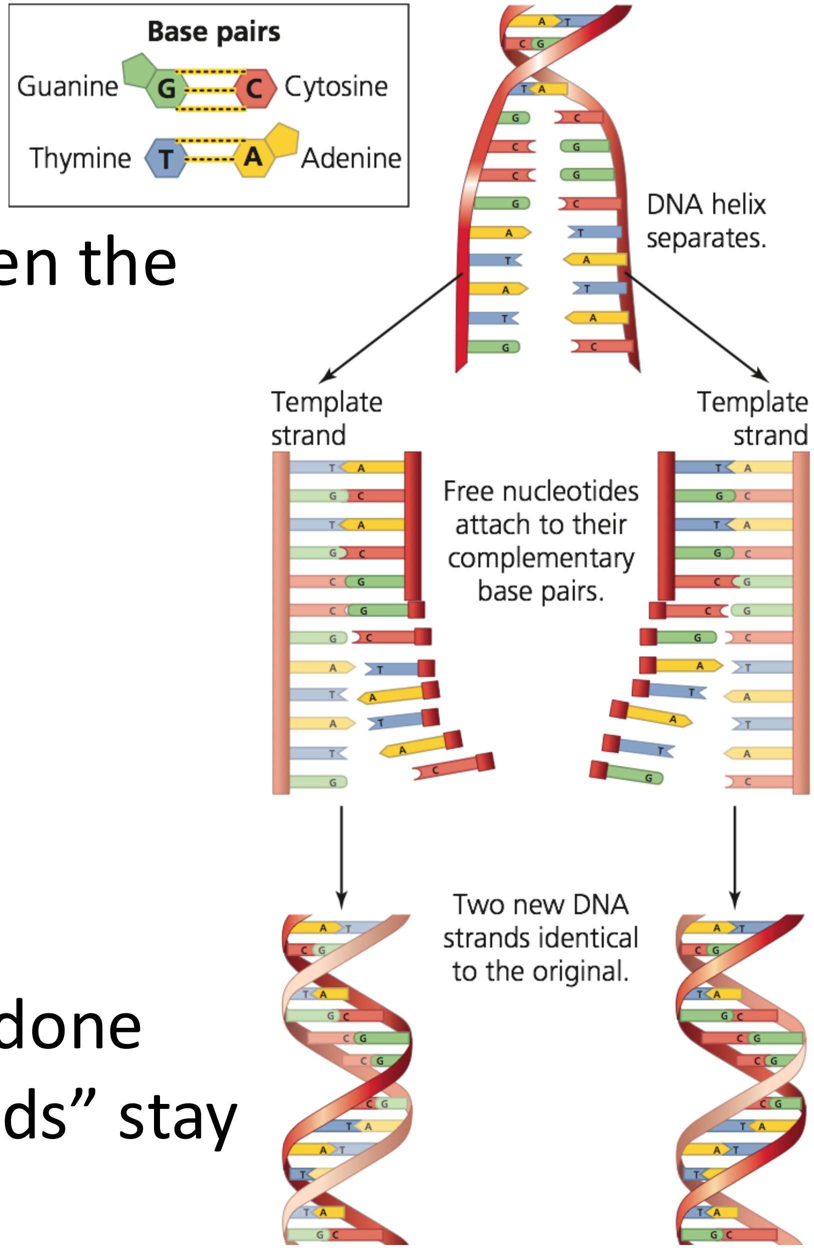
When/where are cells in your body doing lots of **mitosis**?

When a cell divides or goes through mitosis how is the DNA copied or replicated?

How does DNA copy itself? (or go through **replication**)



How does DNA copy itself?

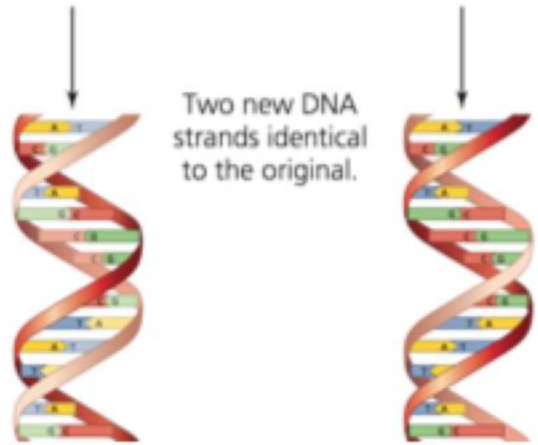


What is the difference between the **template** strand and the **complementary** strand?

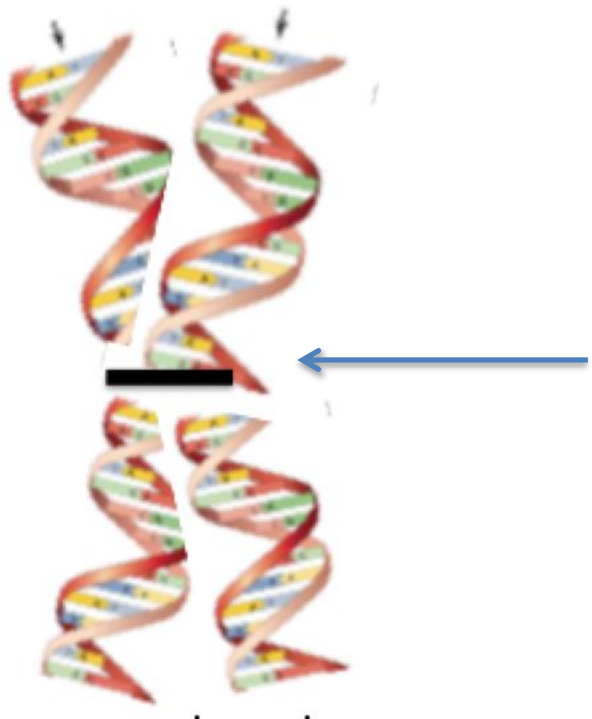
Where are nucleotides?

https://www.yourgenome.org/video/dna-replication

In reality…once replication is done the two new DNA helix "strands" stay attached.



These two new strands actually stay "attached to one another" for a bit....



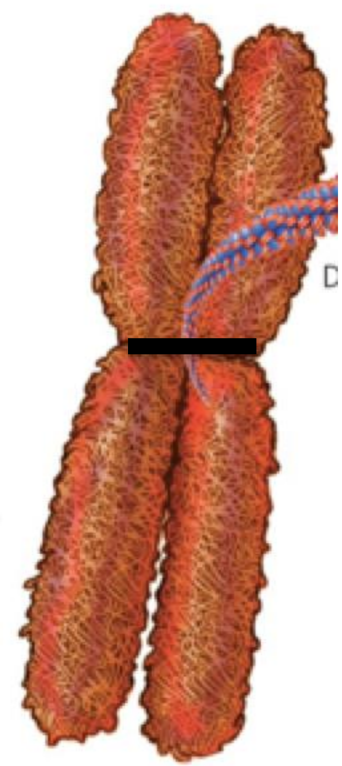
They are attached most tightly here at the centromere.

(My attempt to show that connection.)

Once replication has taken place they stay attached. These two strands together are called **sister chromatids**.

How different are they likely to be from one another?

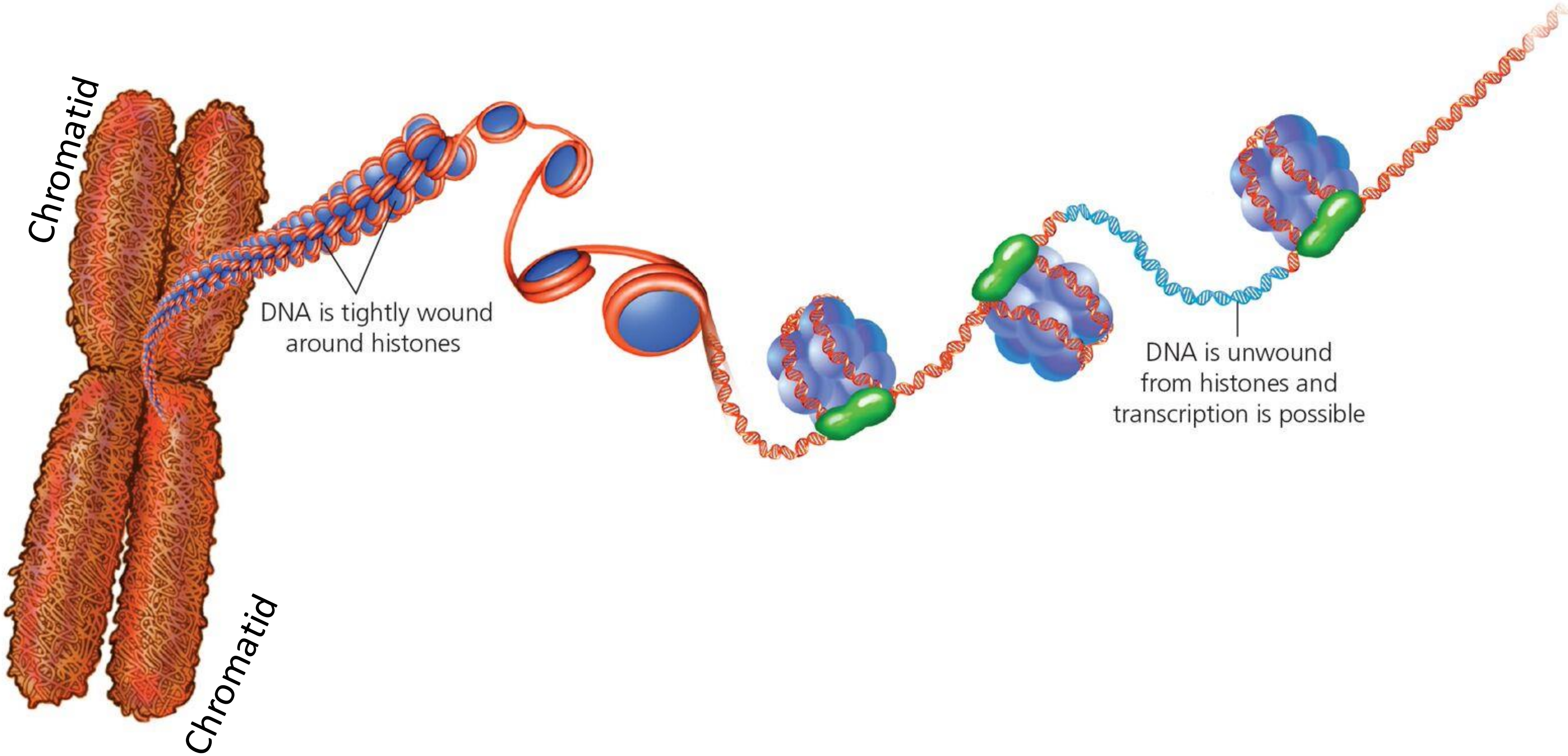
← Sister chromatids! →



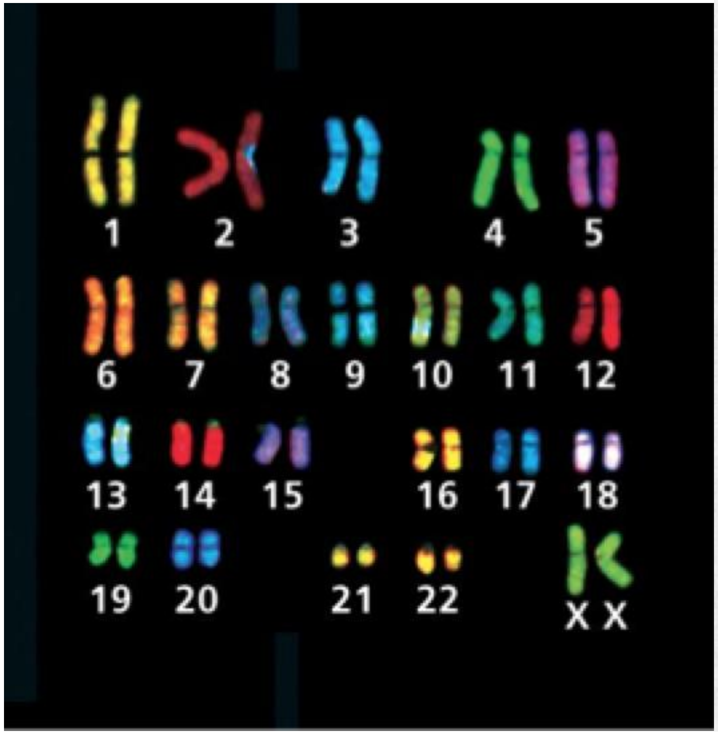
My attempt to show these two strands attached! (They are actually more coiled up than I show here.)

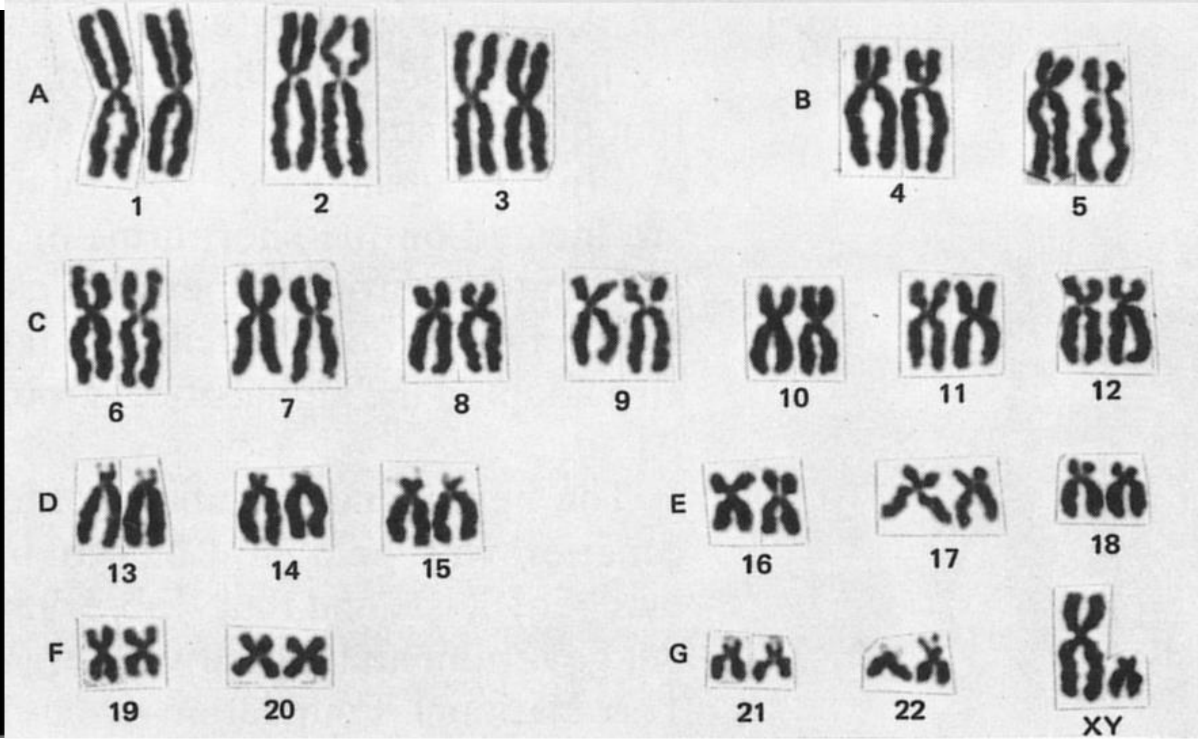
Sister chromatids are two giant tightly coiled strands of DNA.

"Identical Sister Chromatids"



What is going on here?
(We often see both kinds of images.)

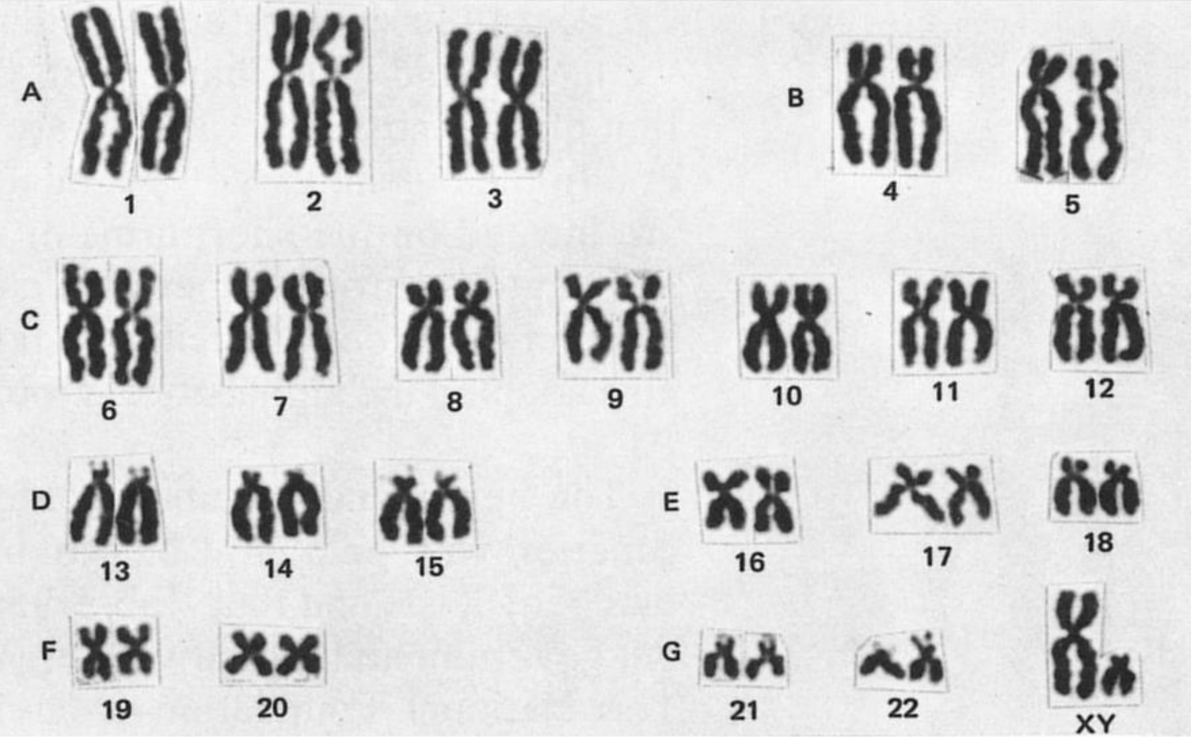




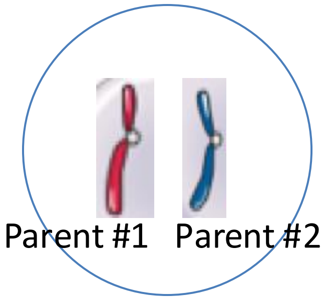
https://www.mun.ca/biology/scarr/Human_Karyotype.html

How do cells divide and distribute this copied DNA into two “daughter” cells while guaranteeing that each cell gets two of each type of chromosome?

Seems like it could get messy…
Need a very organized process!



They use Mitosis!



Reality check: There would actually be lots of chromosomes and they would actually be smaller than this since they would all have to fit in this cell.

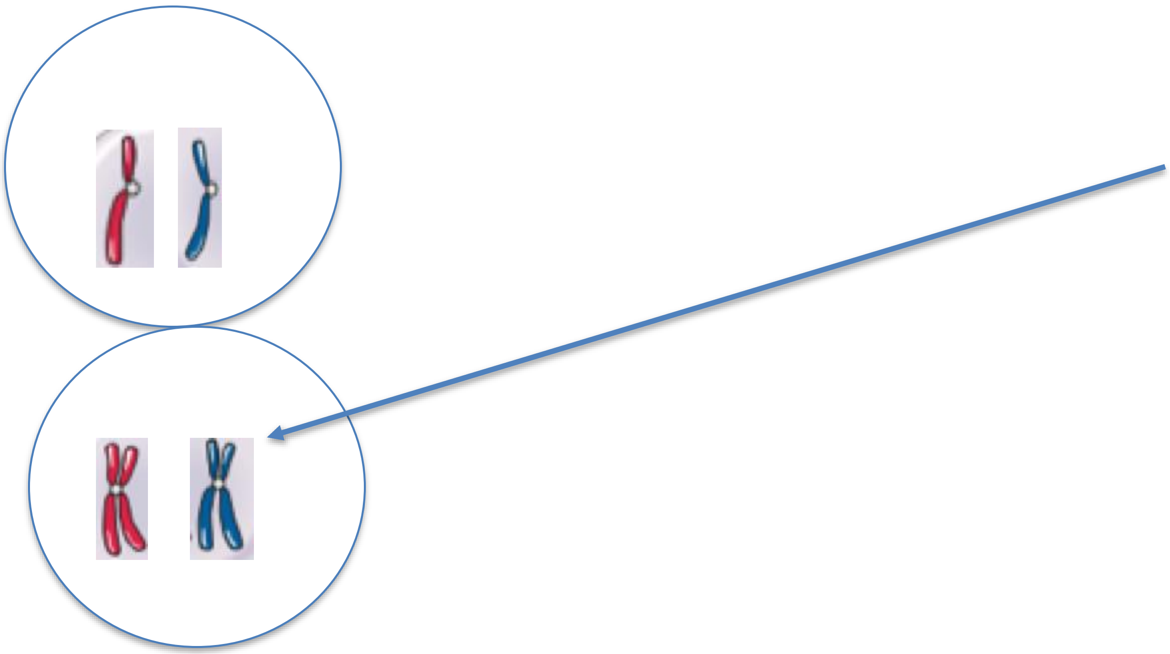
Start with one cell with one homologous **pair** of chromosomes!

This means it is diploid!

To make 2 cells from one cell what has to happen first?

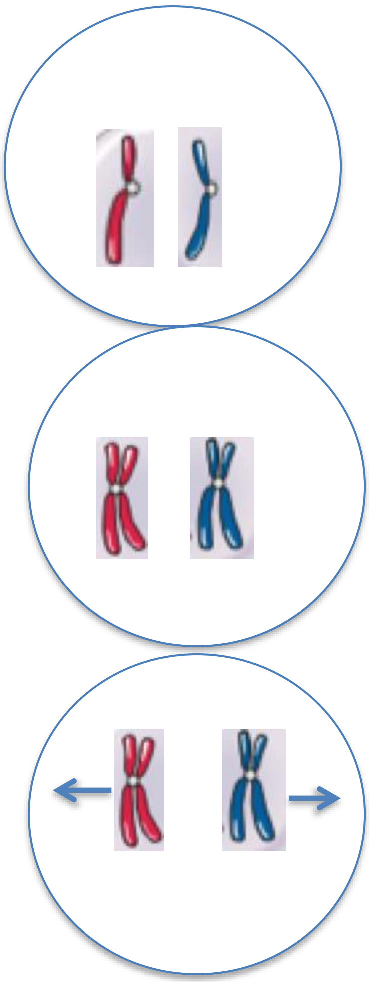
Replication!

Mitosis



What just happened??

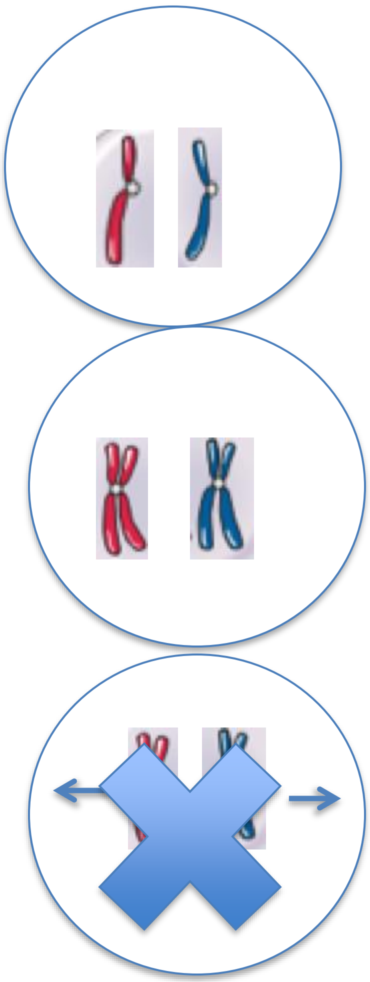
Mitosis



Is this a good way to get to two diploid cells??

If you did it that way the daughter cells would not be genetically identical to the starting cell.

Mitosis



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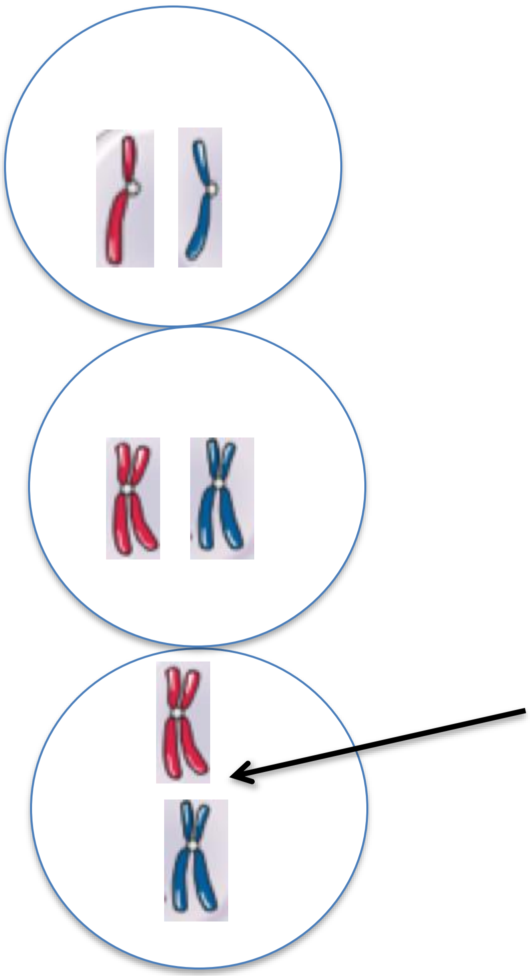
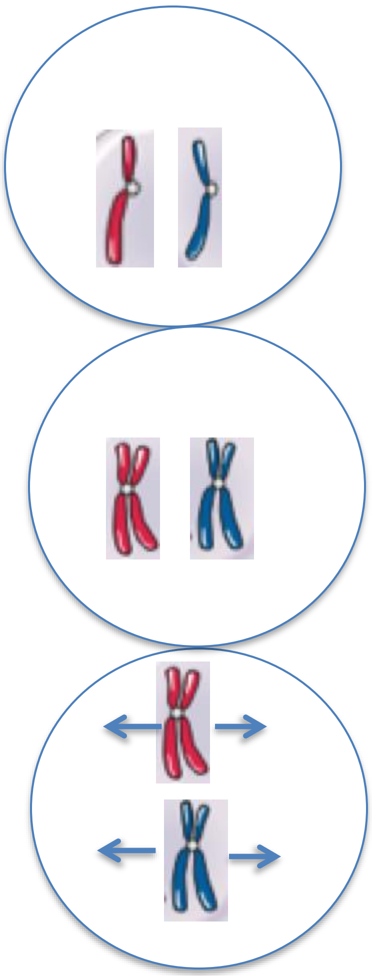
Mitosis



Instead they line up in middle!
(happens to be called metaphase)

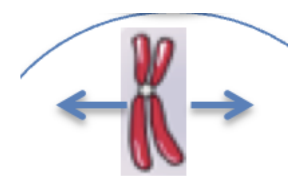
Mitosis



Are these sister chromatids that are “separating or pulling apart”?

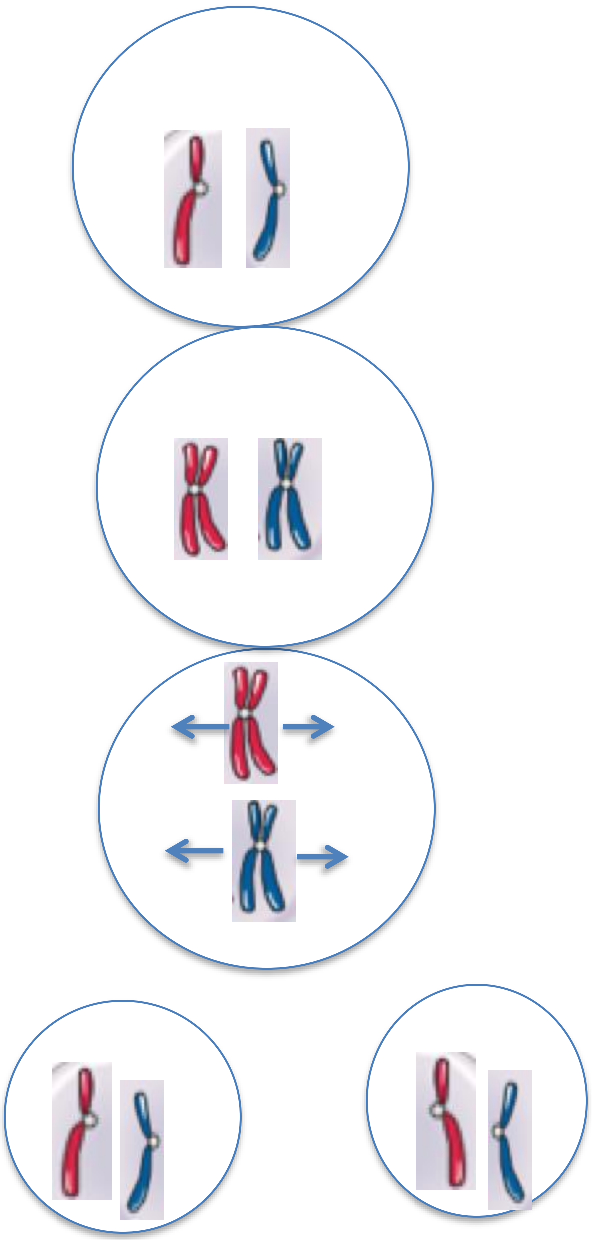
or

Are these homologous chromosomes that are “separating or pulling apart”?



They are sister chromatids!

Mitosis



Mitosis

One cell to two cells

Diploid to diploid

So where is mitosis happening?

cell type	turnover time
small intestine epithelium	2-4 days
stomach	2-9 days
blood Neutrophils	1-5 days
white blood cells Eosinophils	2-5 days
gastrointestinal colon crypt cells	3-4 days
cervix	6 days
lungs alveoli	8 days
tongue taste buds (rat)	10 days
platelets	10 days
bone osteoclasts	2 weeks
intestine Paneth cells	20 days
skin epidermis cells	10-30 days
pancreas beta cells (rat)	20-50 days
blood B cells (mouse)	4-7 weeks
trachea	1-2 months
hematopoietic stem cells	2 months
sperm (male gametes)	2 months
bone osteoblasts	3 months
red blood cells	4 months
liver hepatocyte cells	0.5-1 year
fat cells	8 years
cardiomyocytes	0.5-10% per year
central nervous system	life time
skeleton	10% per year
lens cells	life time
oocytes (female gametes)	life time

http://book.bionumbers.org/how-quickly-do-different-cells-in-the-body-replace-themselves/

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4. Making proteins (transcription and translation)!

Why do cells need to make proteins?

Function	Description	Example
Antibody	Antibodies bind to specific foreign particles, such as viruses and bacteria, to help protect the body.	Immunoglobulin G (IgG)
Enzyme	Enzymes carry out almost all of the thousands of chemical reactions that take place in cells. They also assist with the formation of new molecules by reading the genetic information stored in DNA.	Phenylalanine hydroxylase
Messenger	Messenger proteins, such as some types of hormones, transmit signals to coordinate biological processes between different cells, tissues, and organs.	Growth hormone
Structural component	These proteins provide structure and support for cells. On a larger scale, they also allow the body to move.	Actin
Transport/storage	These proteins bind and carry atoms and small molecules within cells and throughout the body.	Ferritin

FYI…Human cells can make as many as 100,000 different proteins

How are **proteins** “made” from the DNA molecule.

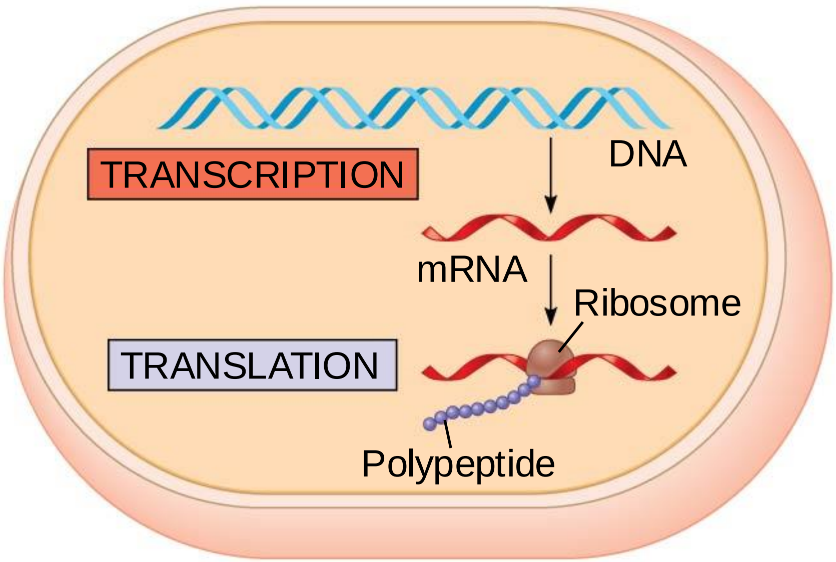
How are genes expressed?

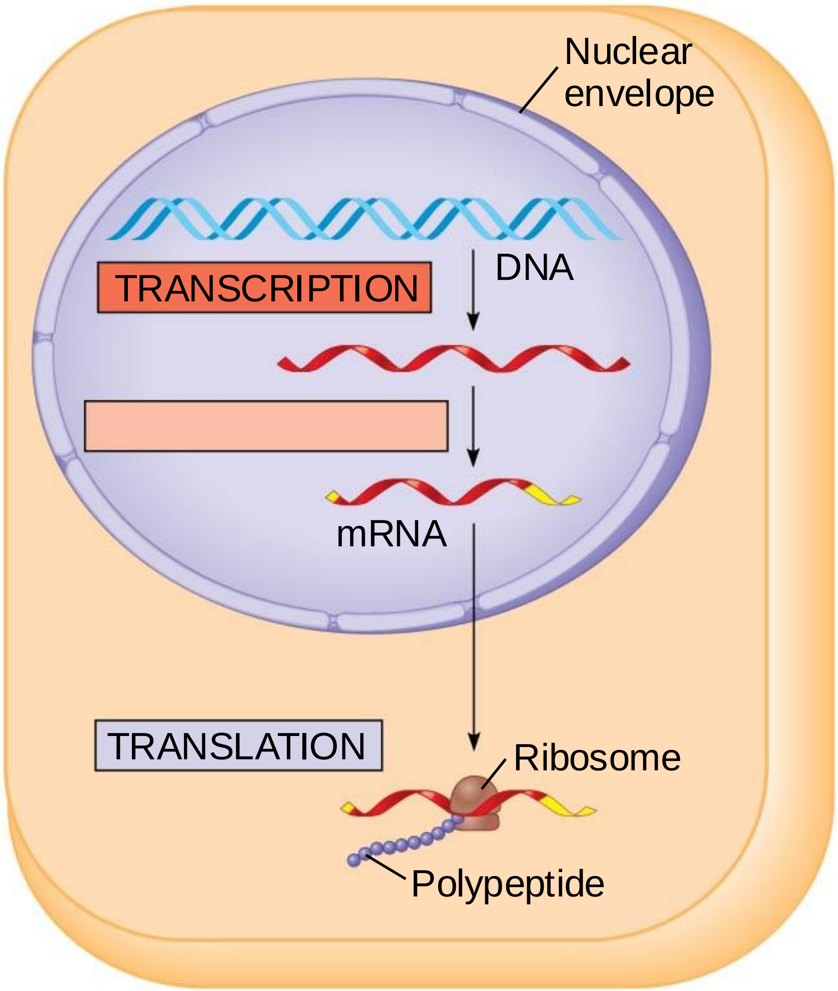
An overview of Transcription and Translation

Which is a Bacterial cell? Which is a Eukaryotic cell?

- What is transcription?
- What is translation?
- What is mRNA?

(Note: RNA has Uracil instead of Thymine!
RNA=C,A,U,G DNA= C,A,T,G)





We are going to focus mostly on Eukaryotic cell transcription and translation (but see Box 5.1).

To make a protein you need to first make some mRNA from DNA (Transcription!)

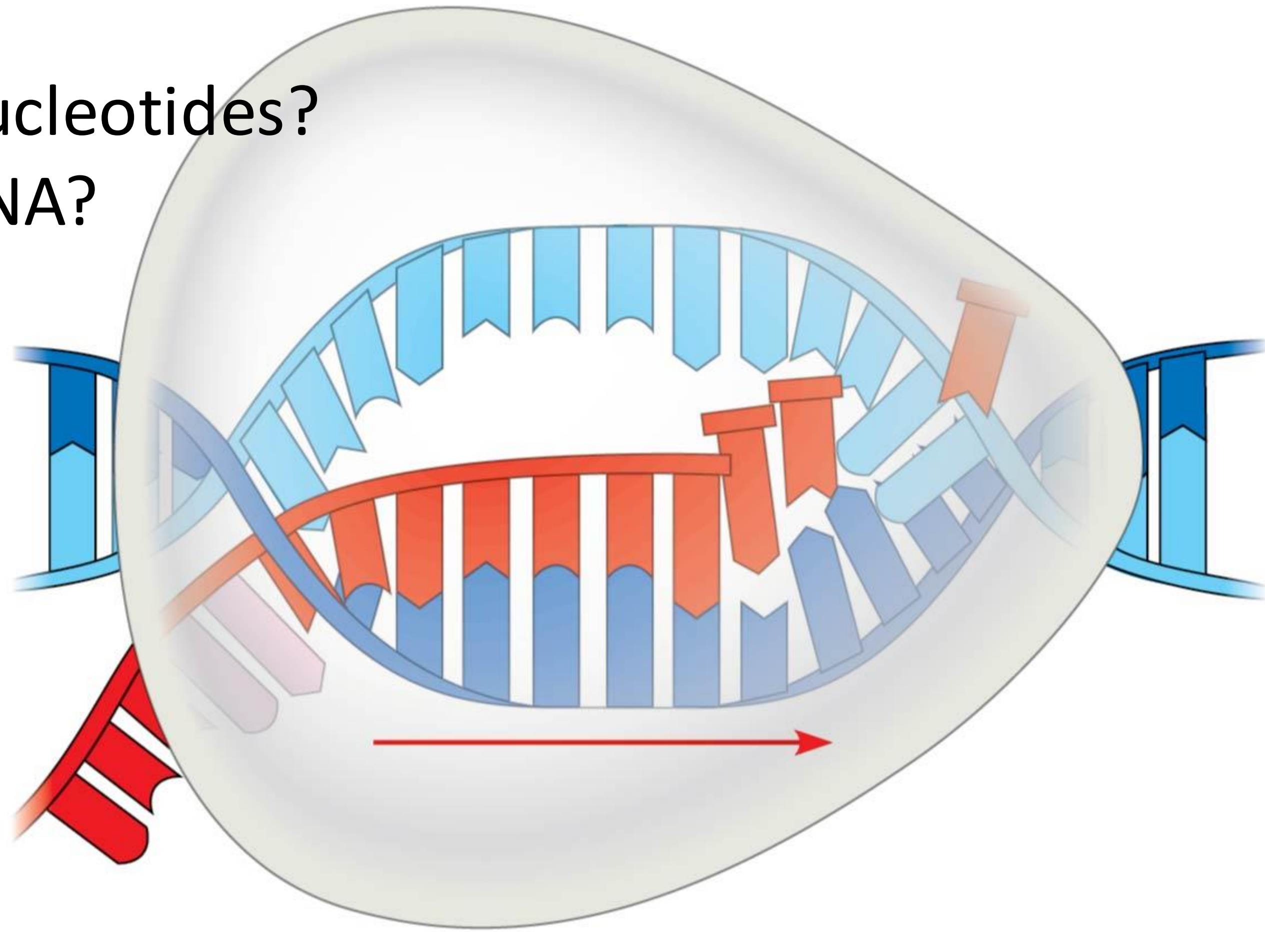
You need a gray blob (RNA polymerase) to add nucleotides!

What seems to be happening here?

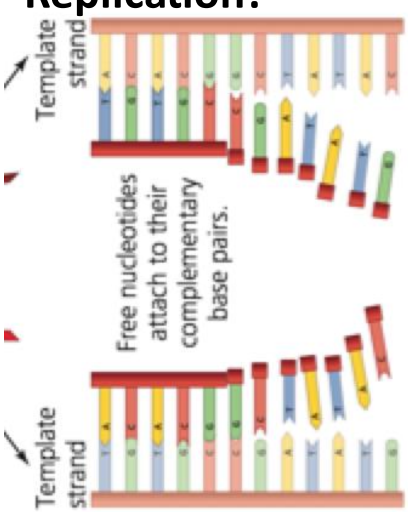
Where is DNA?

Where are **RNA** nucleotides?

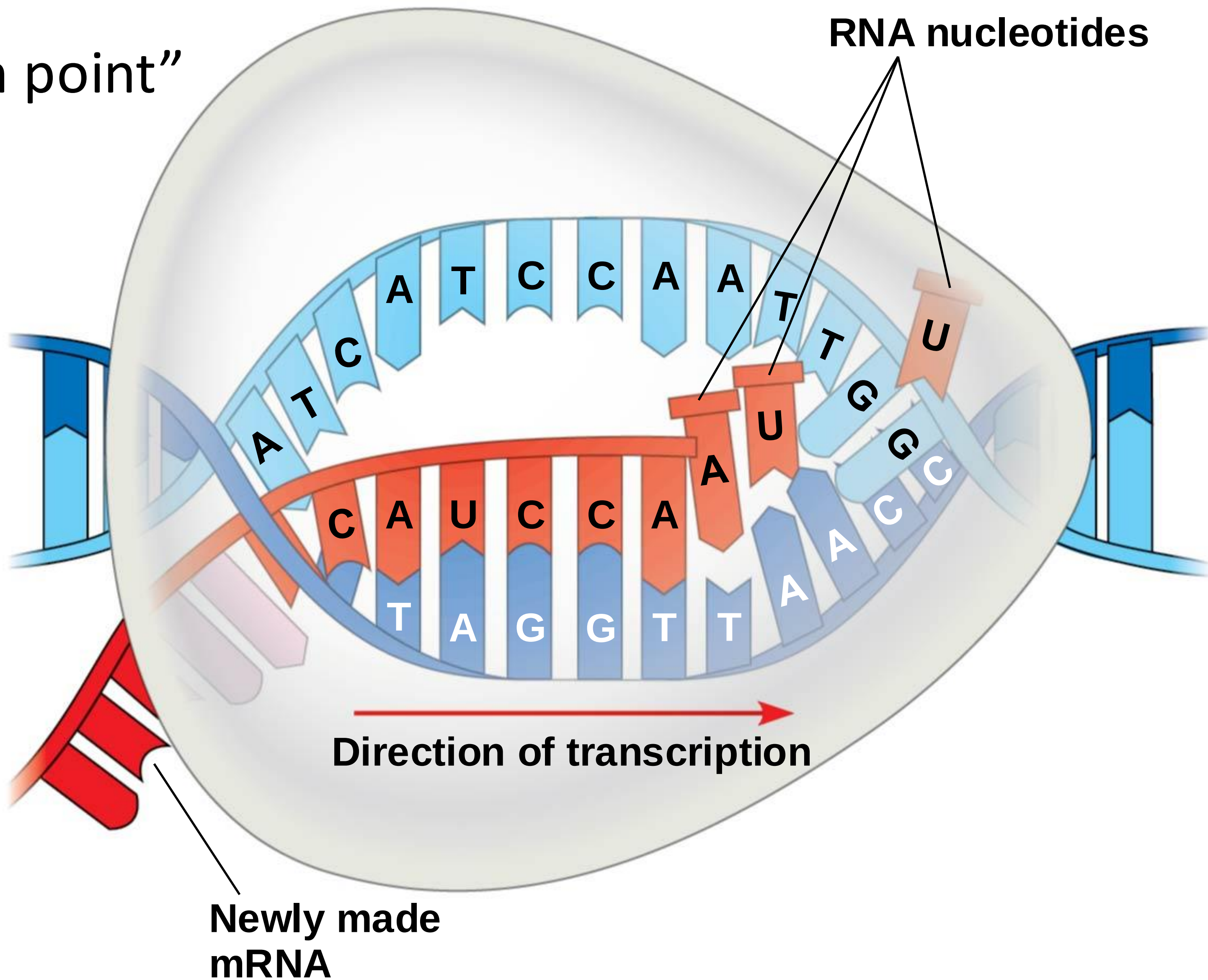
Where is new mRNA?



Reality Check: Making proteins is not the same as Replication!



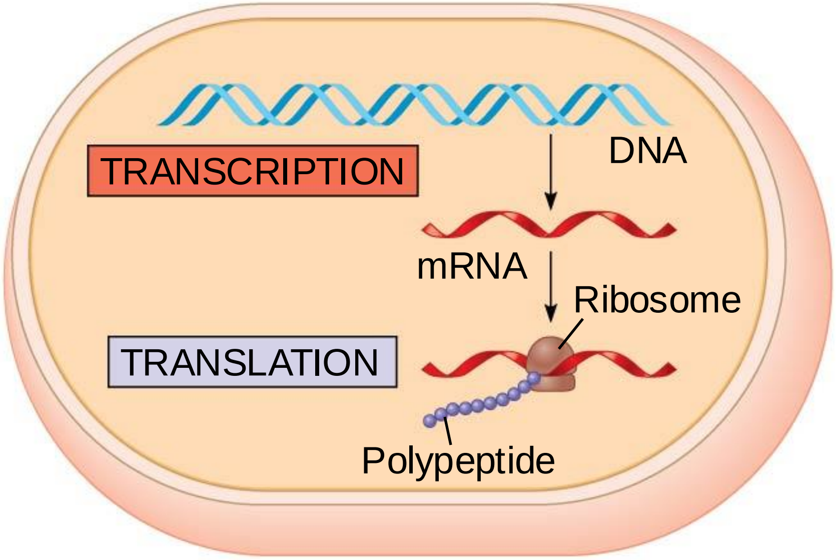
Nucleotides exposed by uncoiling at a "transcription point"

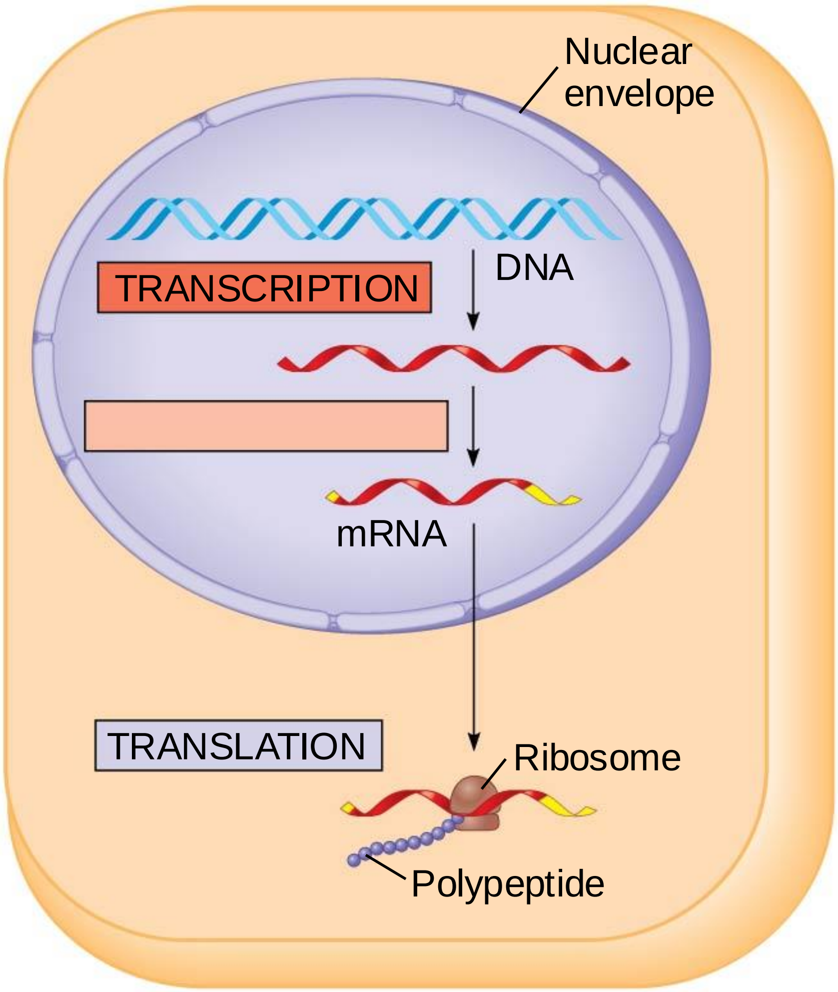


FYI…A single gene ("a region of a chromosome that makes protein") may have multiple transcription points (place on the DNA molecule where transcription is taking place) and multiple gray blobs (RNA polymerases) working on it like "trucks in a convoy"

What does that mean for the product or the protein that is being made or encoded by that gene?

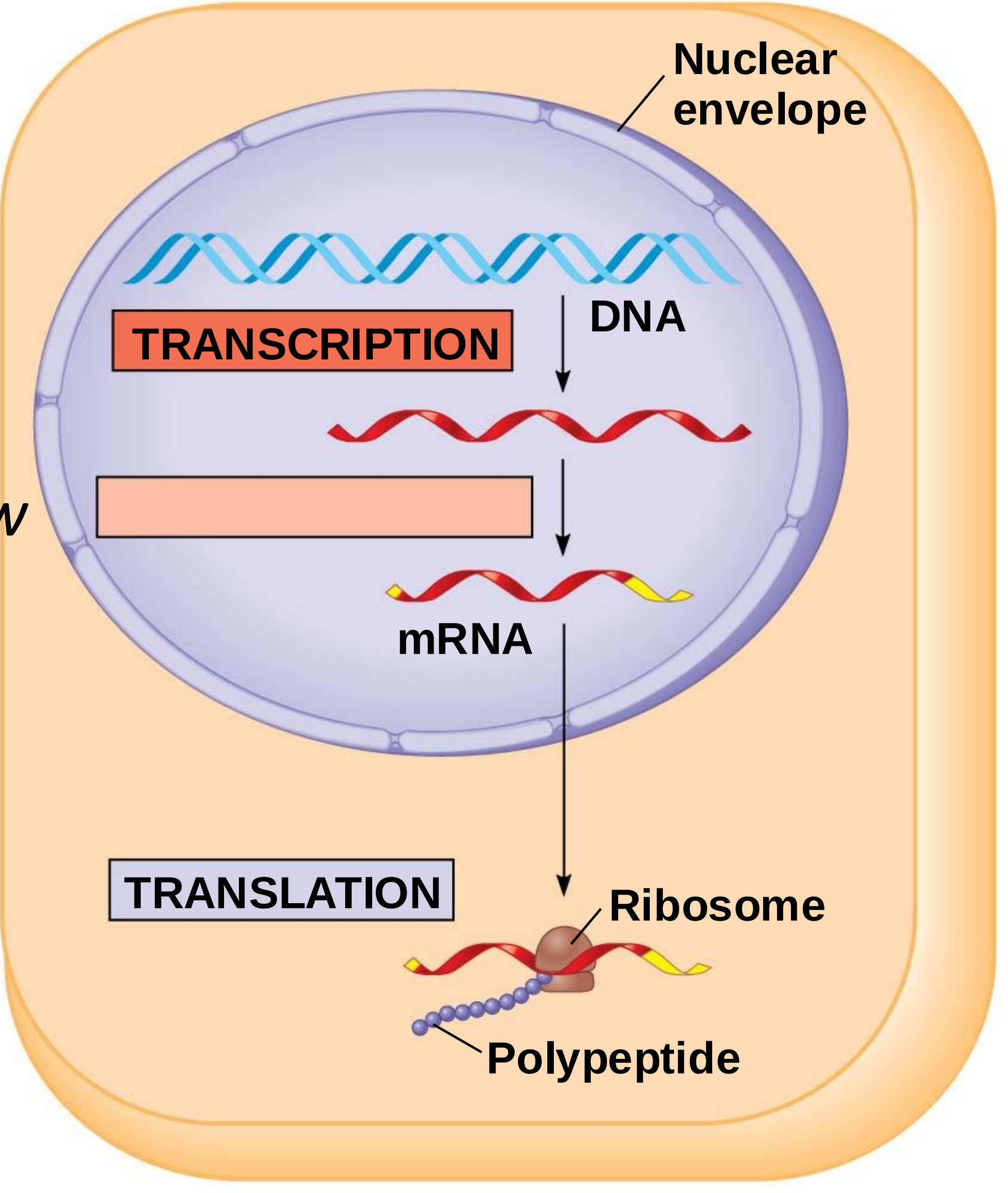
Then mRNA goes somewhere…Where does mRNA go?





*"While DNA stays safe and secure in nucleus, mRNA takes the chances, venturing out into the cell's cytoplasm and mingles with a whole new crew of construction enzymes and protein-making factories called **ribosomes**. "*

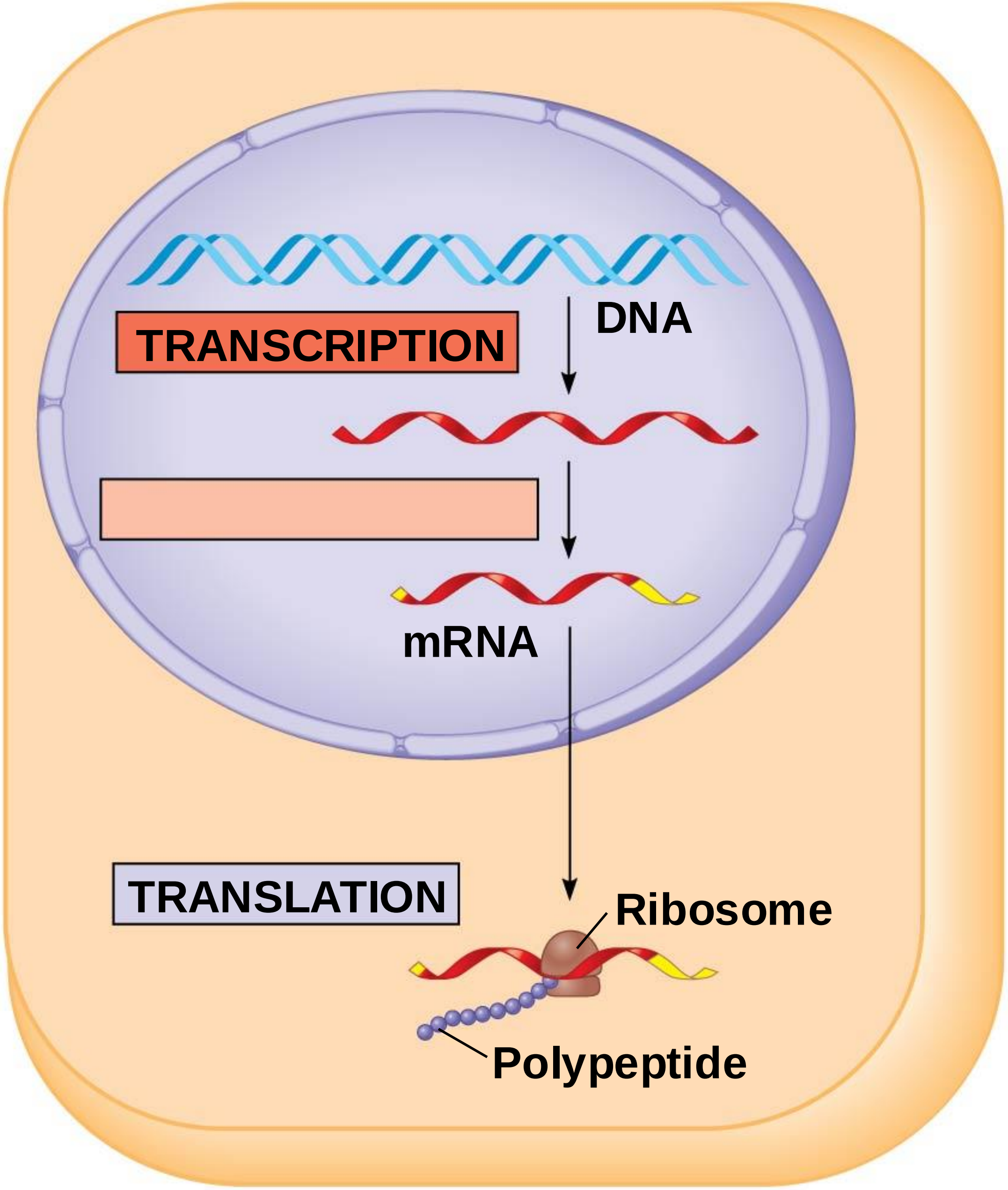
How do we go from mRNA to a protein or polypeptide?



(b) Eukaryotic cell

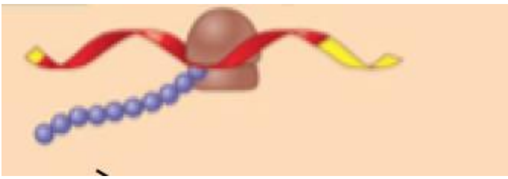
Translation!

mRNA gets "threaded through" the ribosome to make a polypeptide (string of amino acids, i.e. the purple beads)

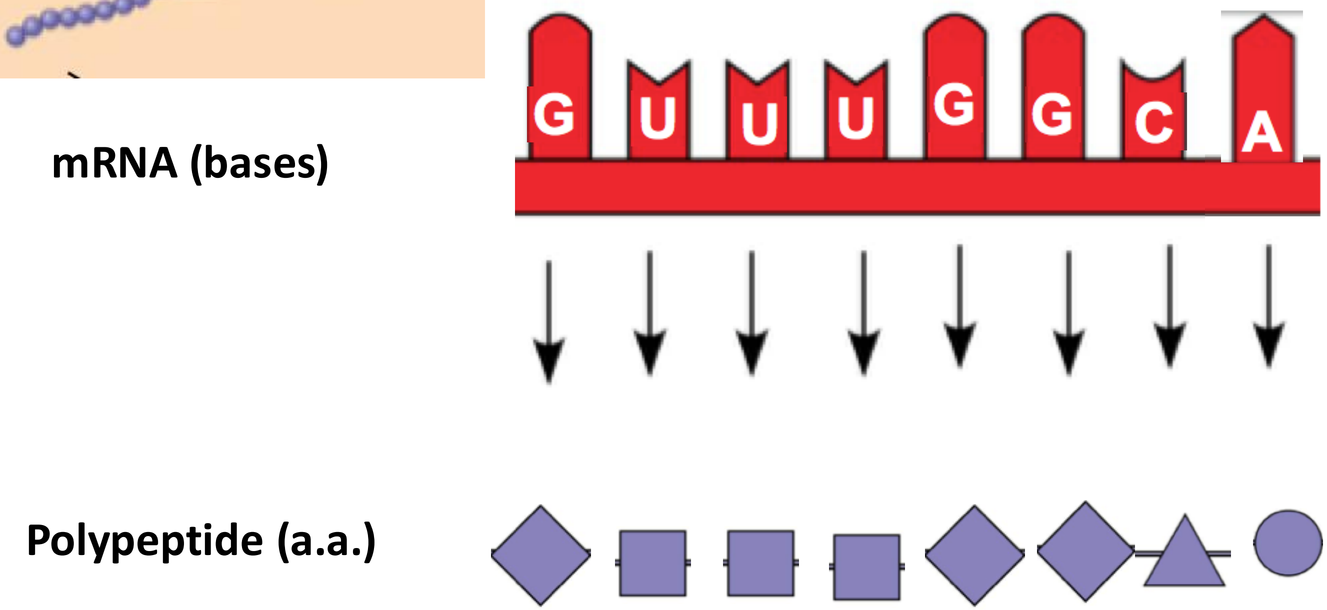


(b) Eukaryotic cell

Lets look a little more closely at that "red ribbon" of mRNA!



Each purple bead is an amino acid which when strung together make a polypeptide.

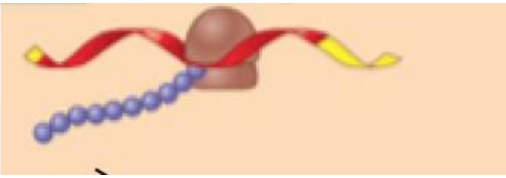


Note Uracil in mRNA instead of Thymine!

Is this image correct???????

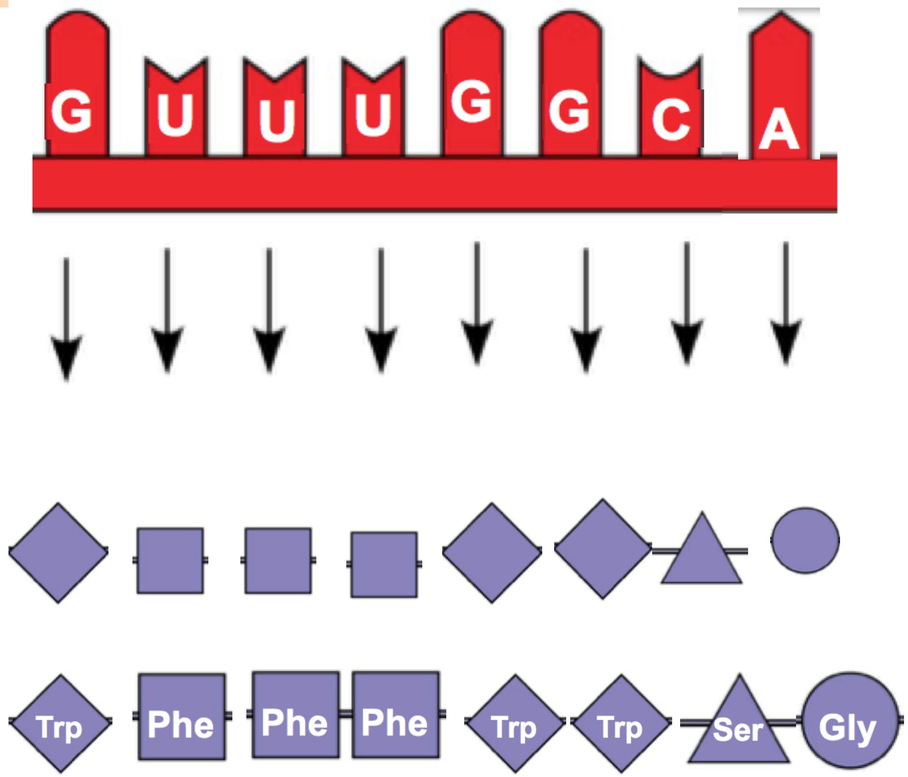
Does each individual base match with a different amino acid? If this was the case we could have only 4 amino acids!

Lets look a little <u>more</u> closely!



mRNA

polypeptide



4 bases

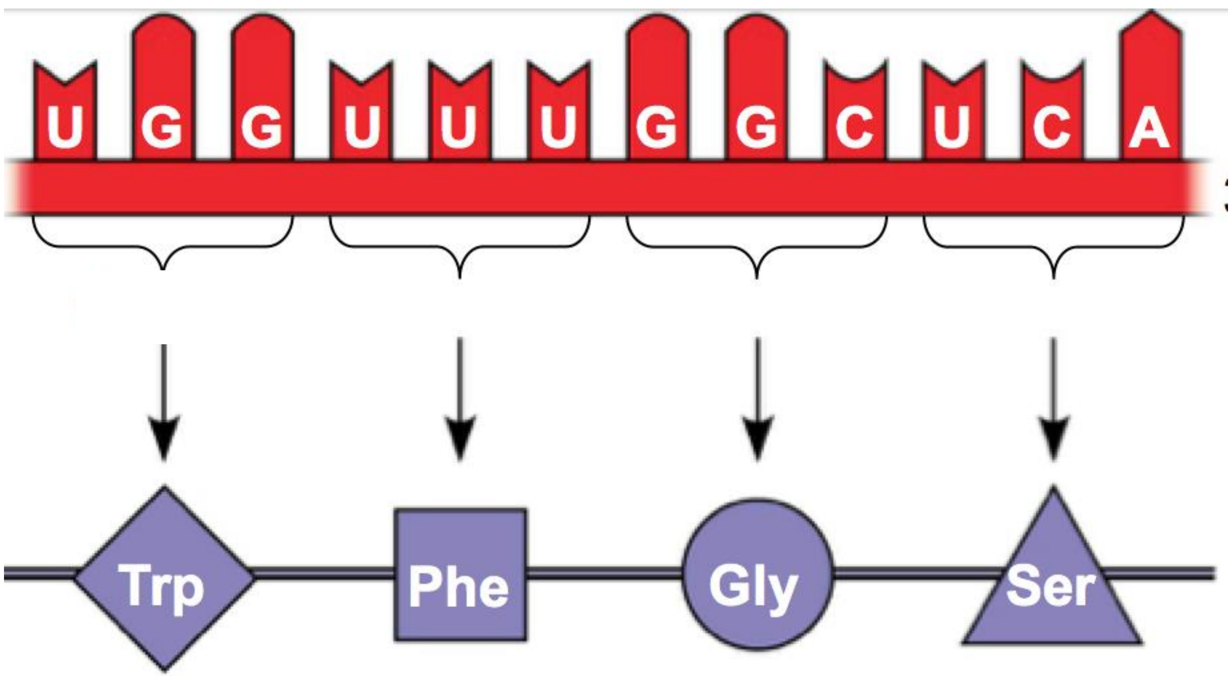
↓

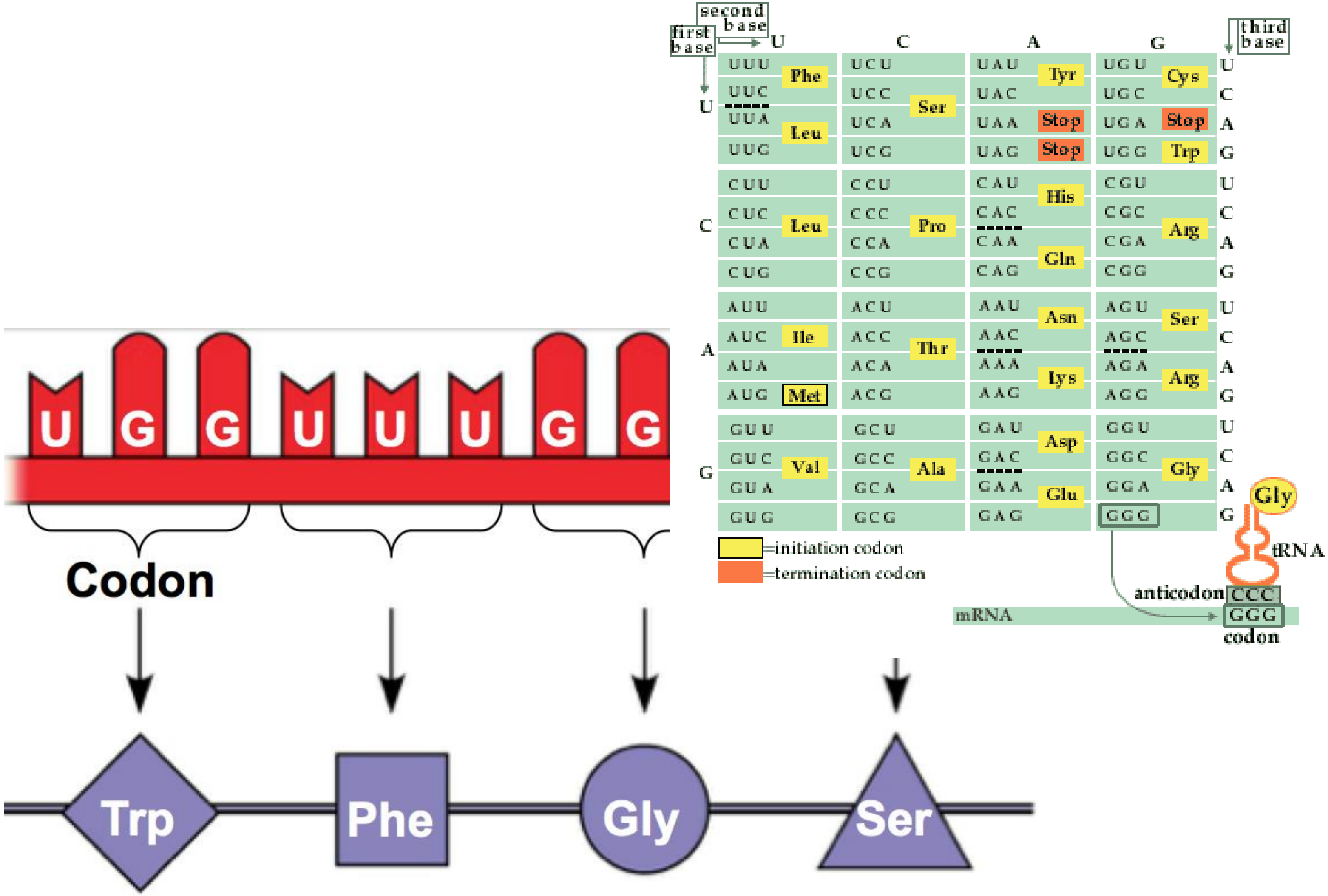
4 amino acids?

Is this correct?

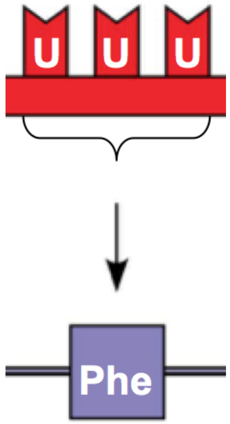
This 1-1 system is **<u>not</u>** what was selected for in our deep evolutionary history. You might consider why?

Instead this is what evolved…

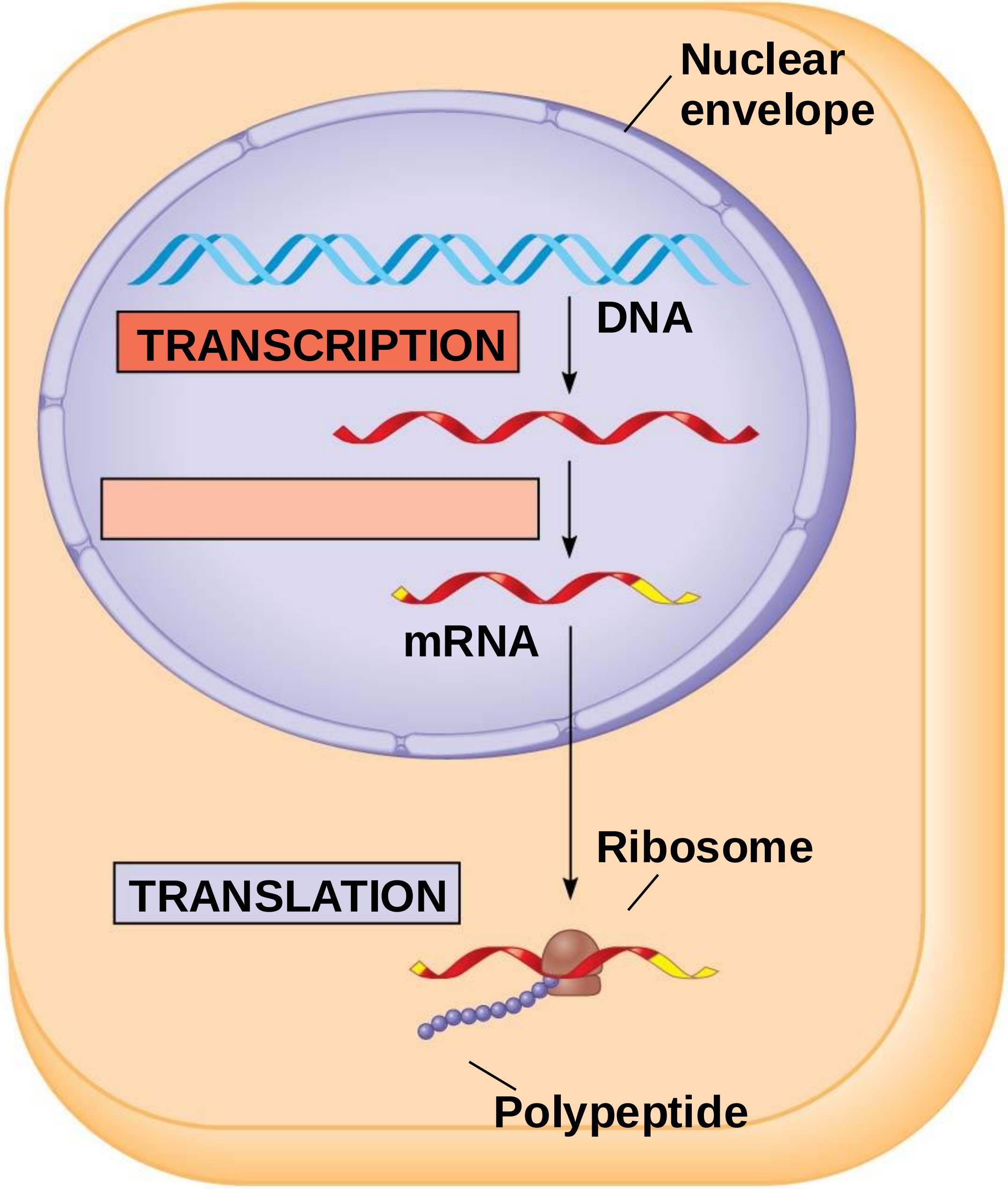




This way you can have many more amino acids-AND thus many more different combinations of amino acids which results in enormous **Protein Diversity (yay)**

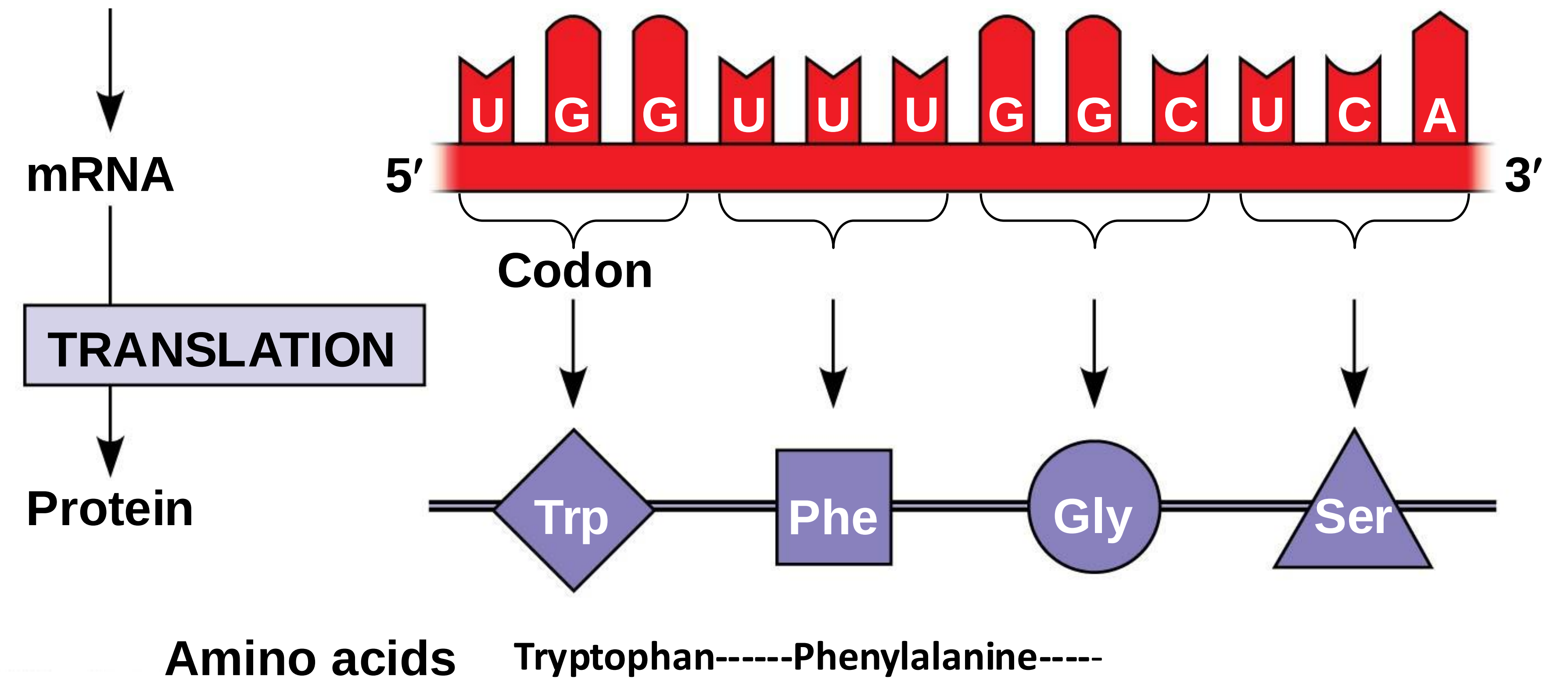


At **ribosome** each set of **three** mRNA nucleotides (a codon) is matched to a particular amino acid.



(b) Eukaryotic cell

So for example…
Here is the mRNA we just made out in the cytoplasm.
It will get threaded through the ribosome.
As each codon gets pulled through it is matched with a single amino acid.



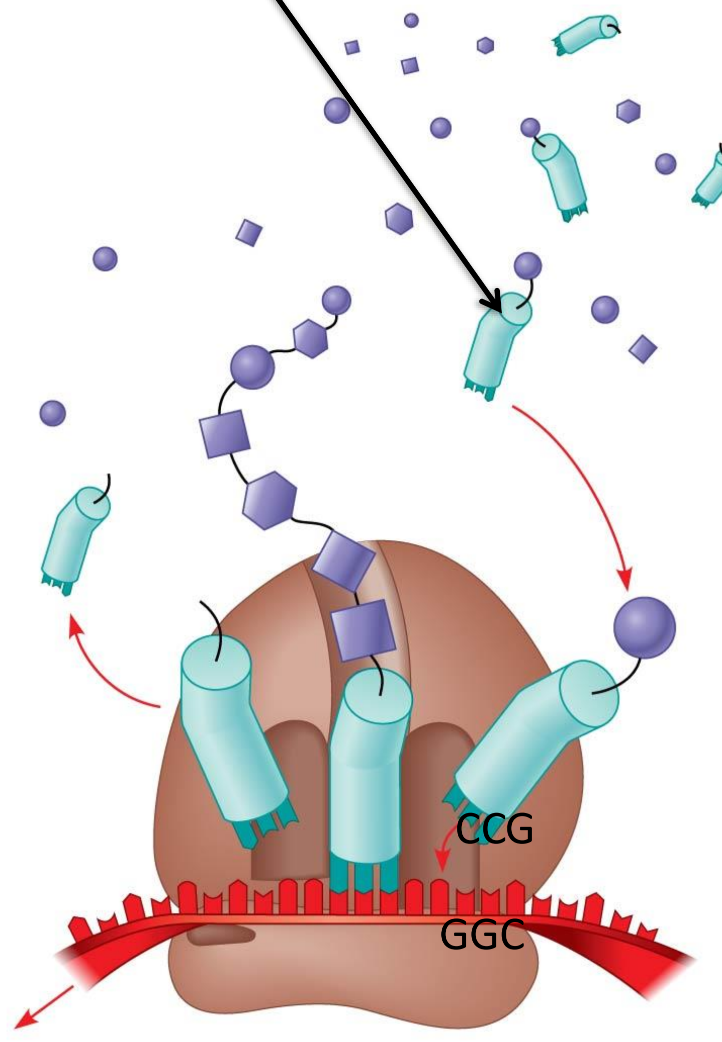
Now even more closely! How does it work?

Another kind of RNA (transfer RNA or tRNA) is out in cytoplasm hanging around holding amino acids!

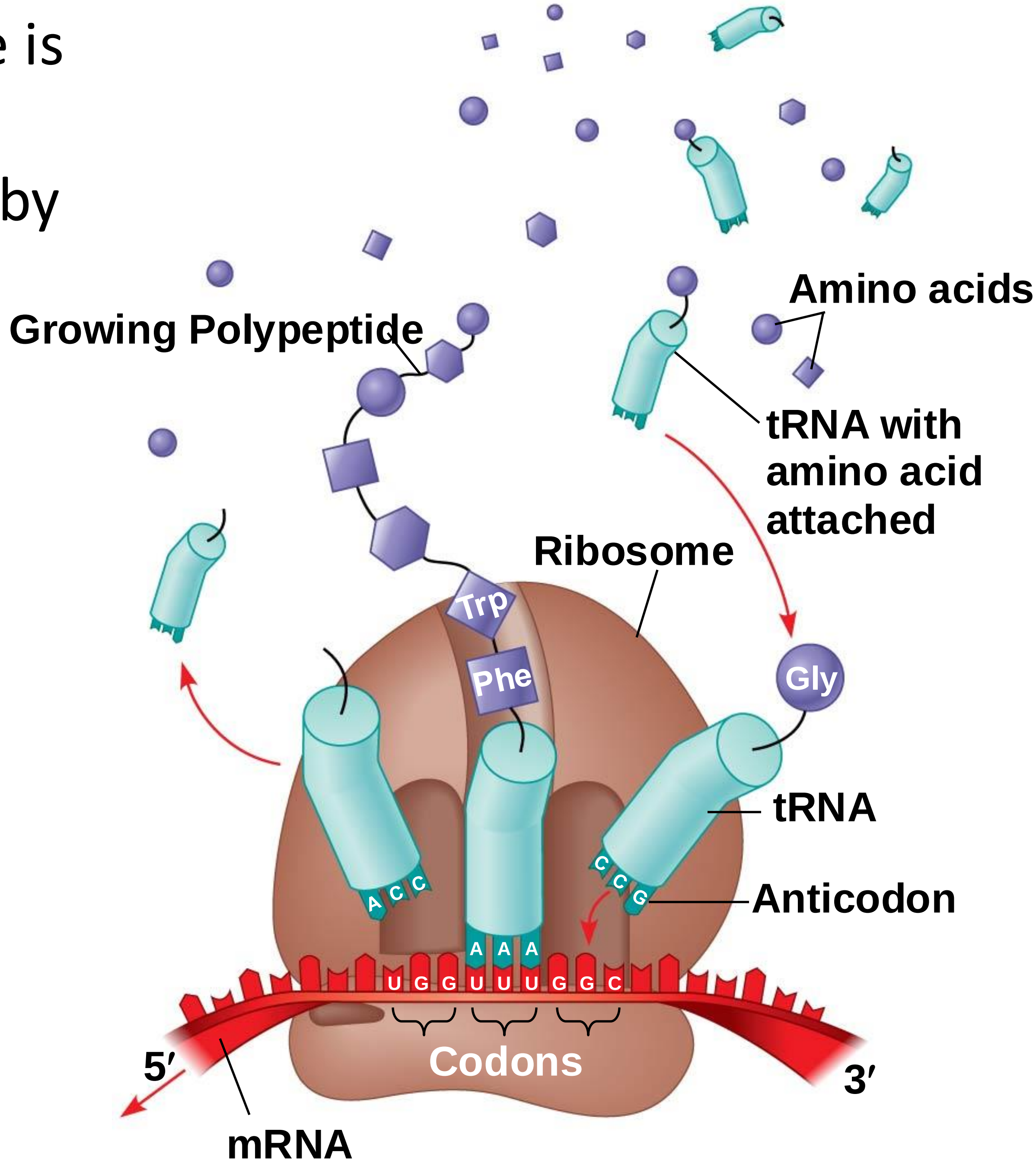
tRNA has dark teal "anticodon" at one end and a specific amino acid at other

if mRNA **codon** is GGC **tRNA anticodon** to match will be CCG

and would have grabbed glycine as its amino acid



Growing polypeptide is held by ribosome as tRNAs sweep in one by one attaching their amino acid to the growing polypeptide chain.



The entire mRNA strand will not be translated!!!!

What happens is…

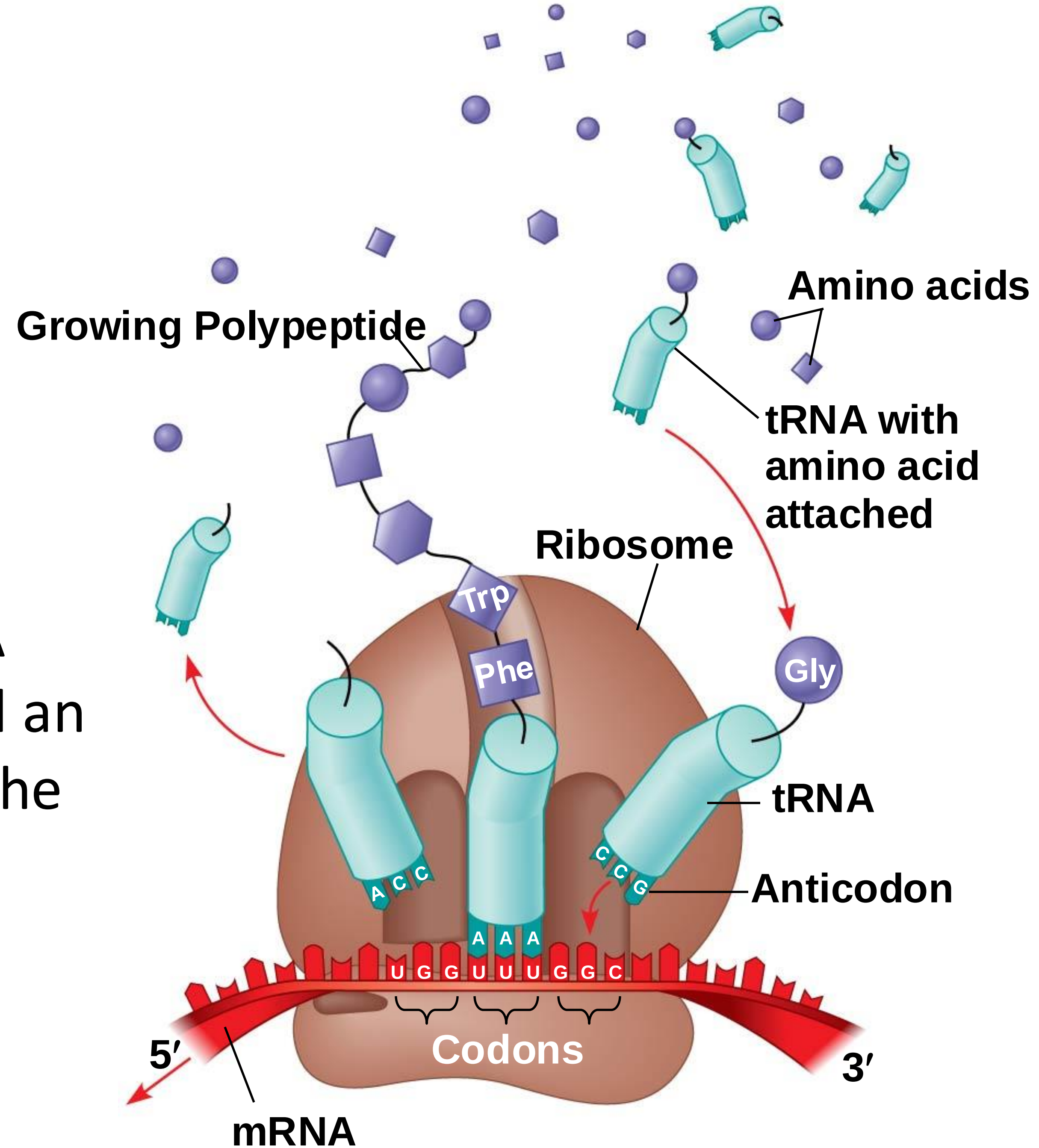
- mRNA-gets conveyed thru the ribosome until a start codon is encountered (always AUG)

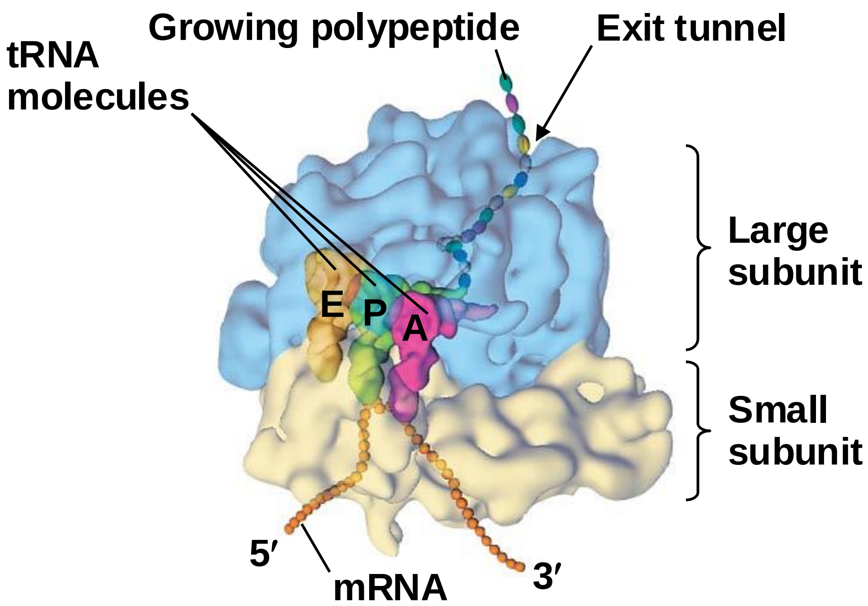
- Start codon establishes **reading frame** (every set of three after that is then defined as a codon)

- Once start codon is encountered, tRNA hauls amino acids to the ribosome

What if there was a mutation in the DNA molecule that added an extra nucleotide to the mRNA (red ribbon)?

Would disrupt the **reading frame**!

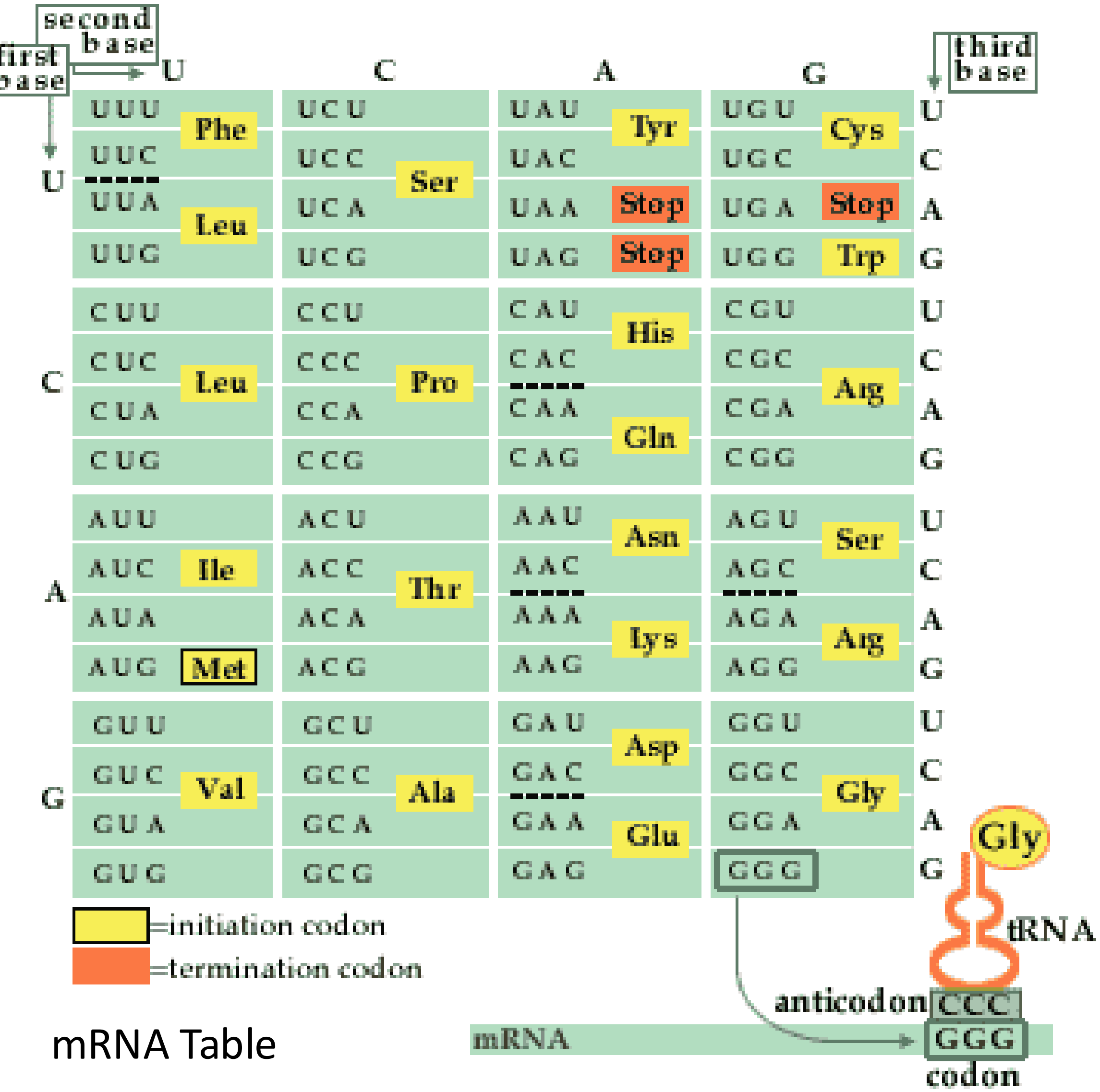




More about ribosomes…

- Are tons of these within the cell
- Made up of yet another kind of RNA (ribosomal RNA)

How many different kinds of RNA are there?
(mRNA, tRNA, rRNA)



mRNA Table

How do we read these codon tables?

64 possible codons

[4 possible bases (A, G, C, U) and 3 bases per codon so 4^3]

- 3 stop codons
- 1 start codon

BUT THERE are not 60 different amino acids because multiple codons match with each a.a.

“**wobble**” = 3rd “slot” is more “flexible”

GGU, GGC, GGA an GGG will **all** match to Glycine

AGA, AGG will both code for Arginine

Picture from your text of Ribosomes translating mRNA into protein. (purple ribbon of mRNA instead of red ribbon)

1st base in Codon	U	C	A	G	3rd base in Codon
	2nd base in Codon				
U	Phe	Ser	Tyr	Cys	U
	Phe	Ser	Tyr	Cys	C
	Leu	Ser	**STOP**	**STOP**	A
	Leu	Ser	**STOP**	Trp	G
C	Leu	Pro	His	Arg	U
	Leu	Pro	His	Arg	C
	Leu	Pro	Gln	Arg	A
	Leu	Pro	Gln	Arg	G
A	Ile	Thr	Asn	Ser	U
	Ile	Thr	Asn	Ser	C
	Ile	Thr	Lys	Arg	A
	Met	Thr	Lys	Arg	G
G	Val	Ala	Asp	Gly	U
	Val	Ala	Asp	Gly	C
	Val	Ala	Glu	Gly	A
	Val	Ala	Glu	Gly	G

Start