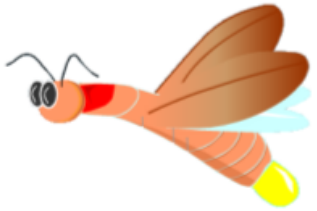
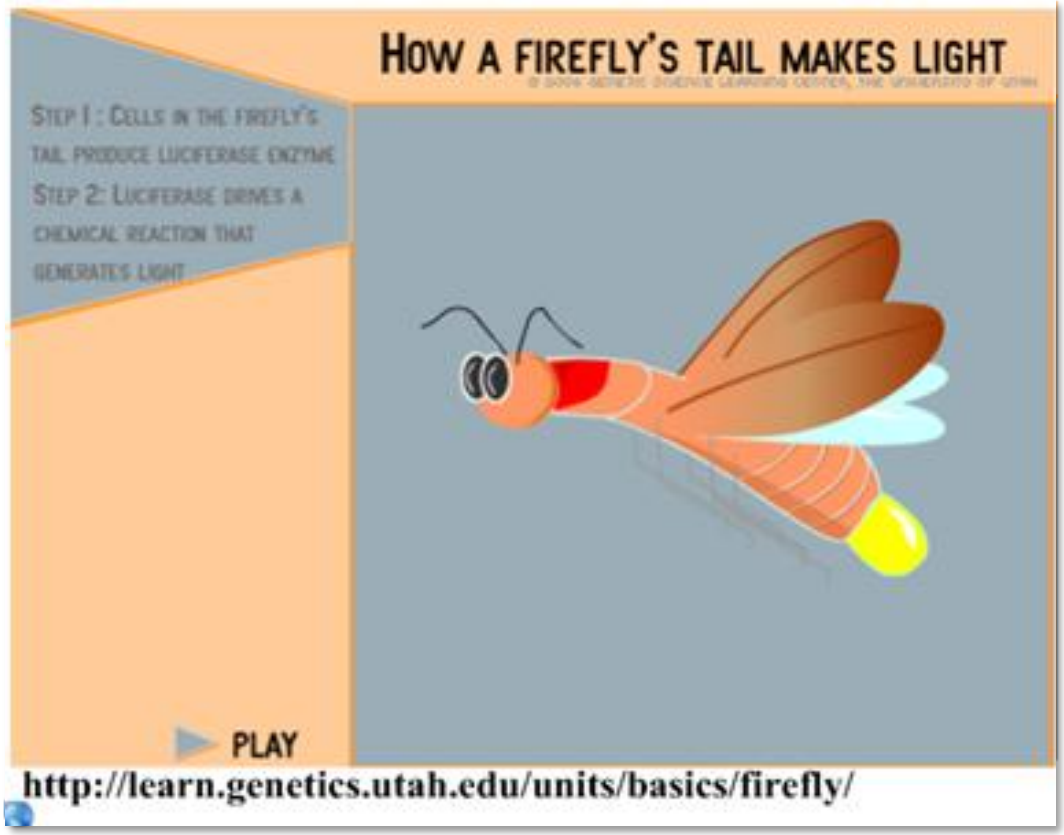


Transcription and Translation (Core)

Stephen Taylor
Bandung International School

Put it into perspective: What is the purpose transcription and translation?



Genes are instructions for proteins or messages. The cell needs to take this instruction and carry it out.

In transcription, the gene is converted into a mRNA messenger which is posted to the ribosomes.

The ribosomes then translate the message into a polypeptide. The sequence of amino acids is determined by the gene, and in turn determines the properties of the finished protein.

enzymes

structural proteins

hormones

gas carriers

immunoglobulins

membrane pumps

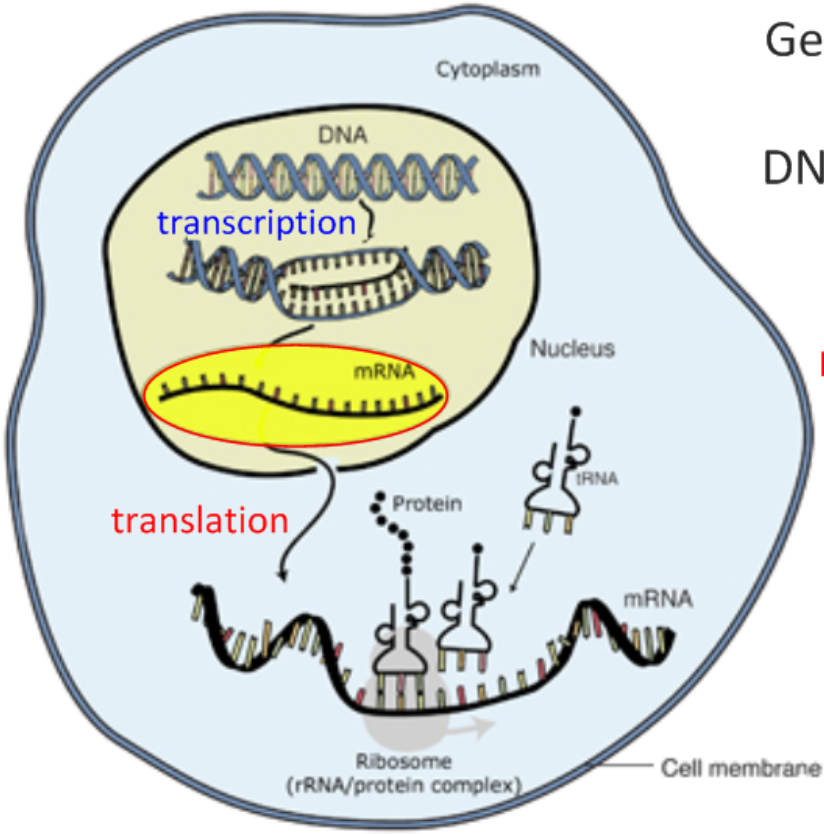
The Central Dogma of Genetics

transcription translation

DNA → RNA → polypeptide

nucleus Cytoplasm

gene message product



Genes are simply codes for making polypeptides.

DNA is stored in the nucleus, yet the polypeptide is produced in the cytoplasm (by ribosomes).

mRNA (messenger RNA) is a message from the nucleus to the ribosome - instructions for how to put the polypeptide together.

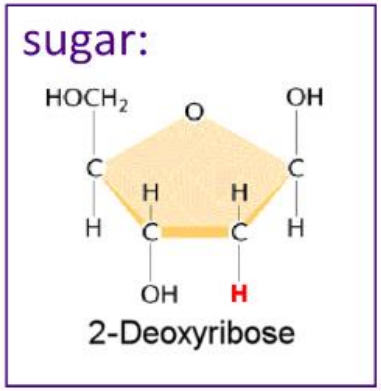
The genetic code is the sequence of bases on mRNA - this tells the ribosome which amino acids to use.

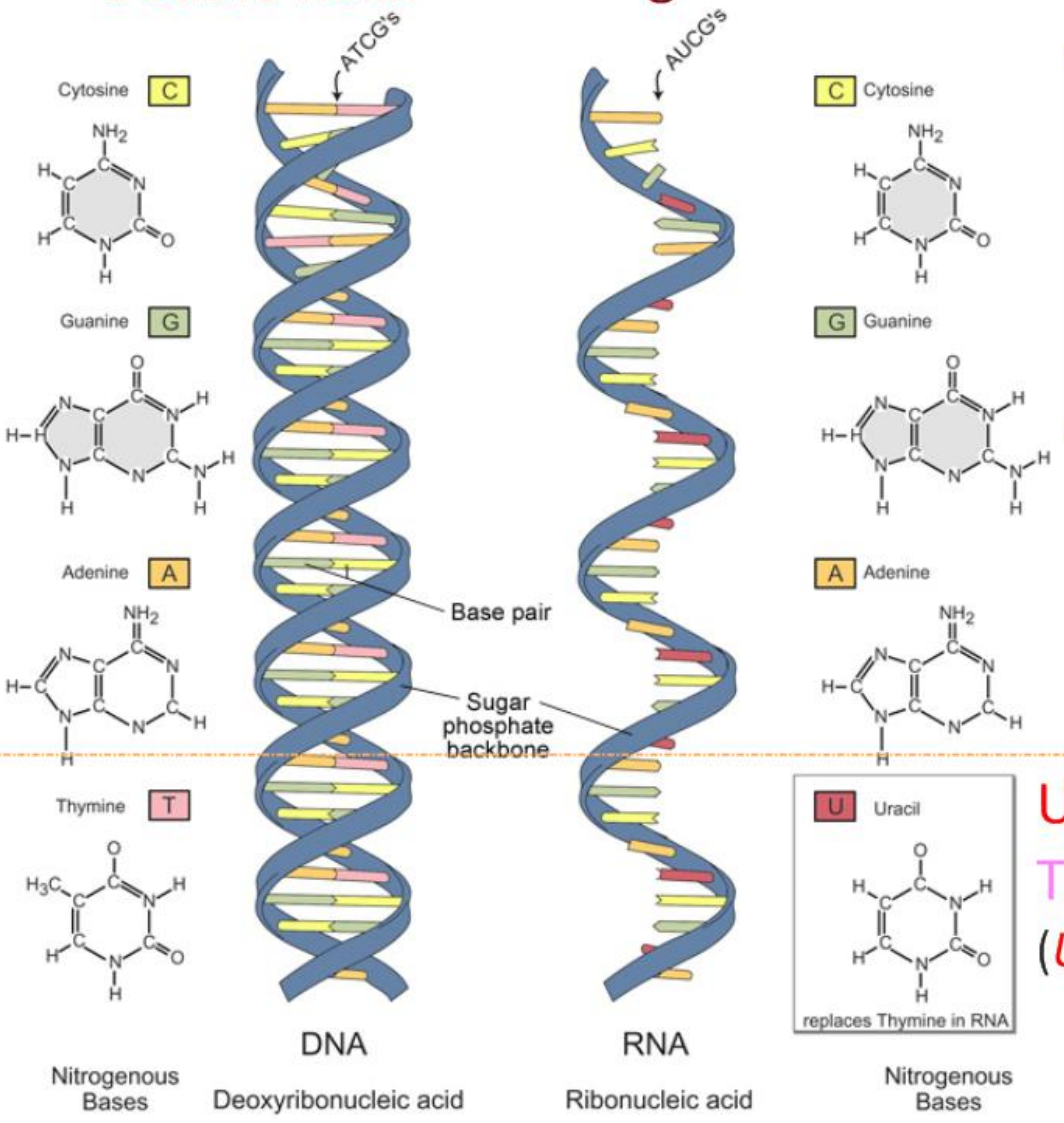
http://www2.geneticsolutions.com/PageReq?id=1530:1873&InPopUp=true

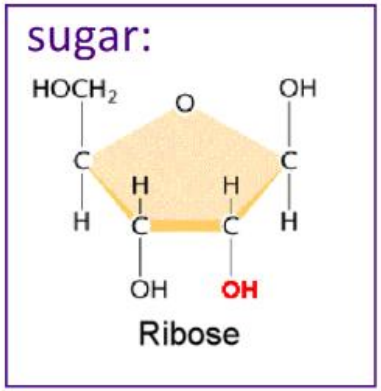
Image adapted from National Human Genome Research Institute

Deoxyribonucleic acid
double helix

Ribonucleic acid
single strand







Uracil replaces Thymine

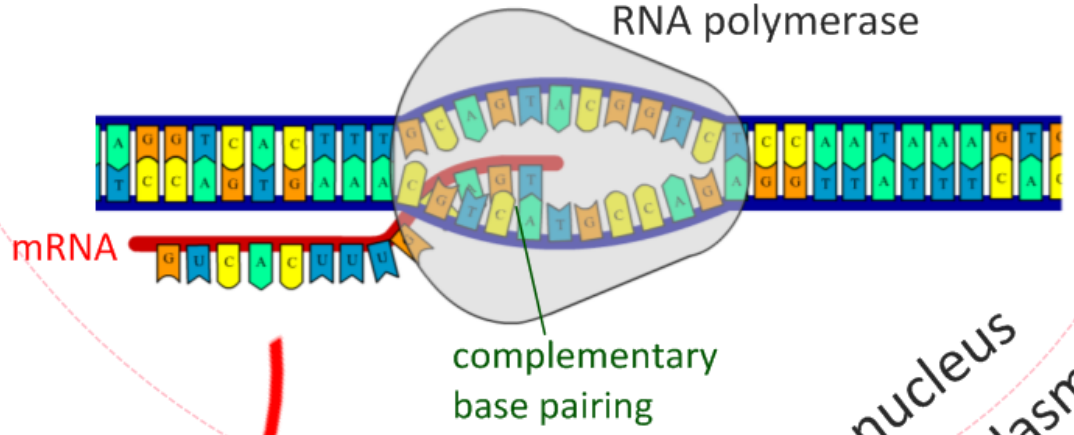
(*U complements A*)

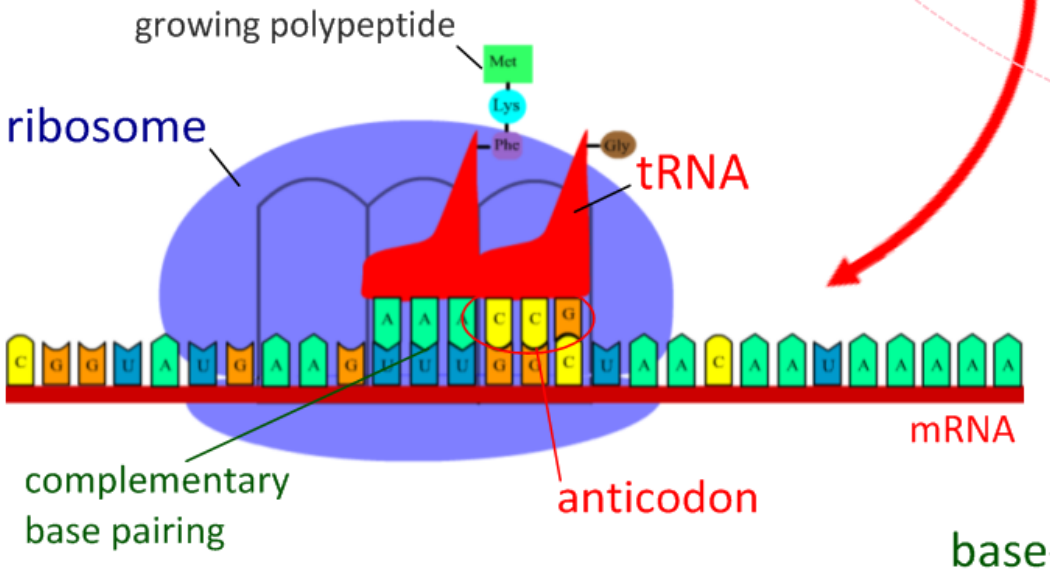
Image adapted from: National Human Genome Research Institute.
http://www2.geneticsolutions.com/PageReq?id=1530:1873&InPopUp=true

Protein Synthesis: Transcription and Translation

Transcription:

RNA polymerase makes a mRNA molecule that is complementary to the DNA.





Translation:

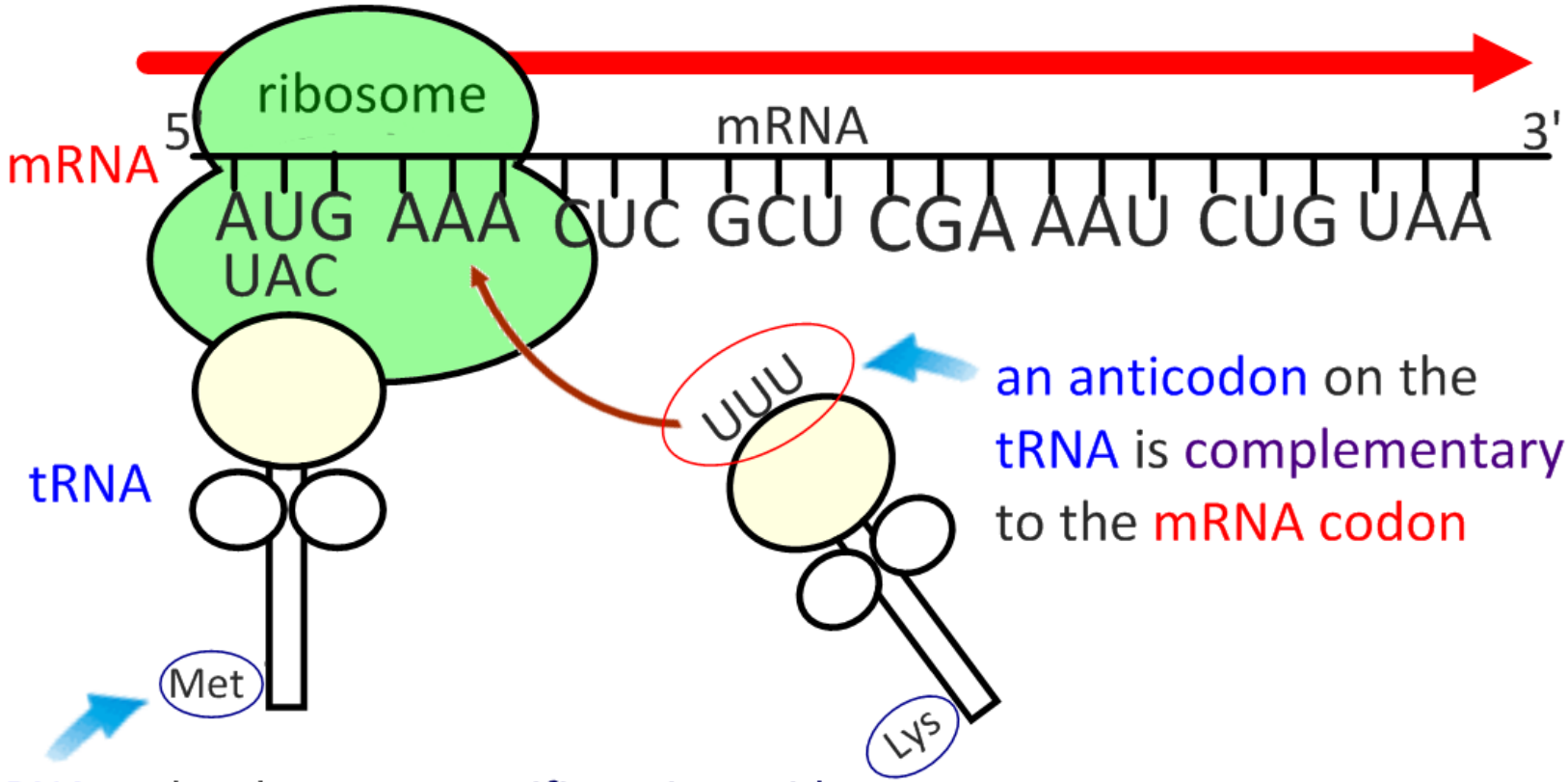
mRNA is posted out of the nucleus and attaches to ribosomes. Ribosomes use complementary base-pairing to 'read' codons on the mRNA.

tRNA (transfer) molecules with corresponding anti-codons bring the correct amino acid.

http://www.stolaf.edu/people/giannini/flashanimat/molgenetics/translation.swf

http://www.stolaf.edu/people/giannini/flashanimat/molgenetics/transcription.swf

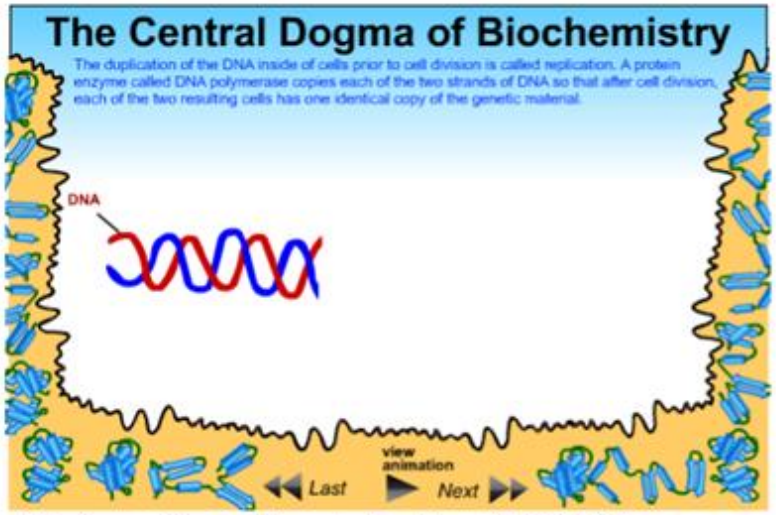
How does the ribosome know which amino acid to add?



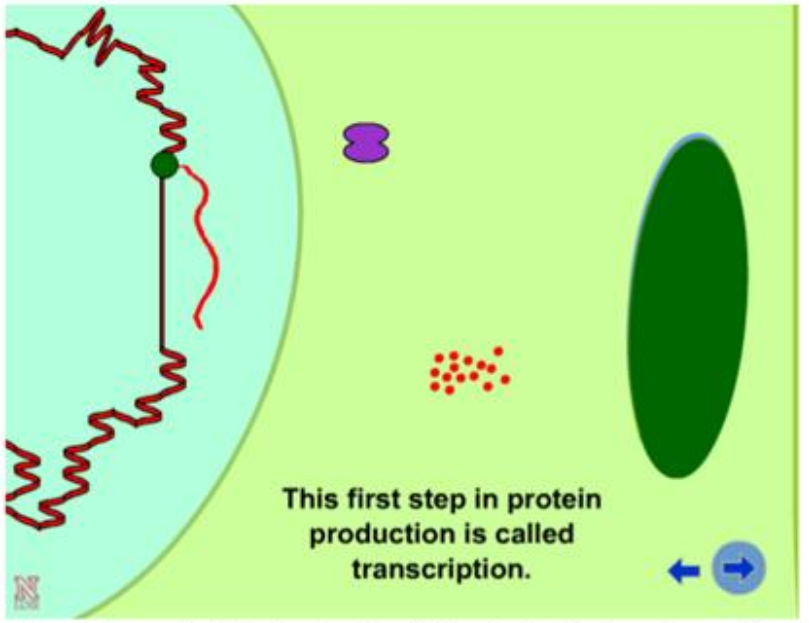
an anticodon on the tRNA is complementary to the mRNA codon

tRNA molecules carry specific amino acids
(they can each carry one type only)

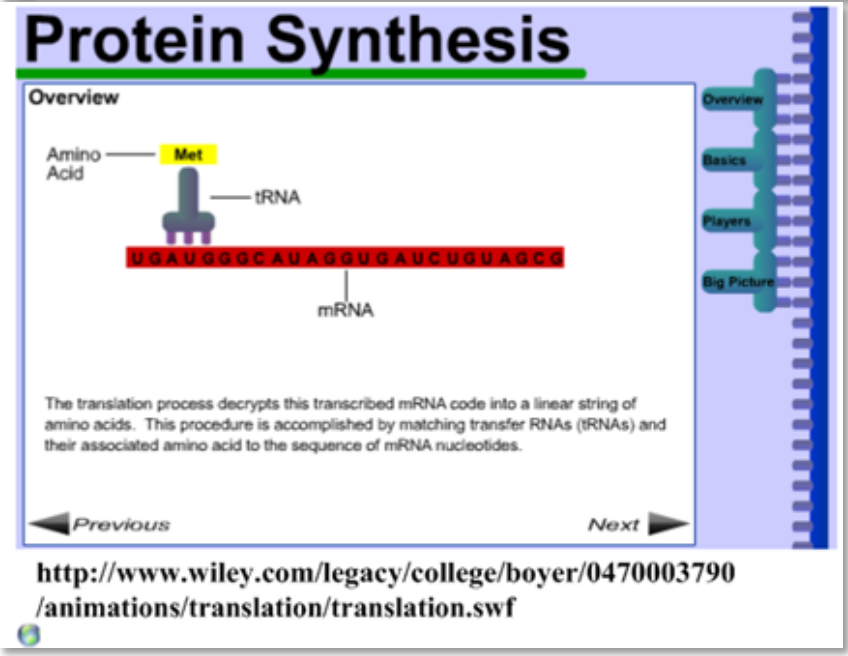
Protein Synthesis Overviews:



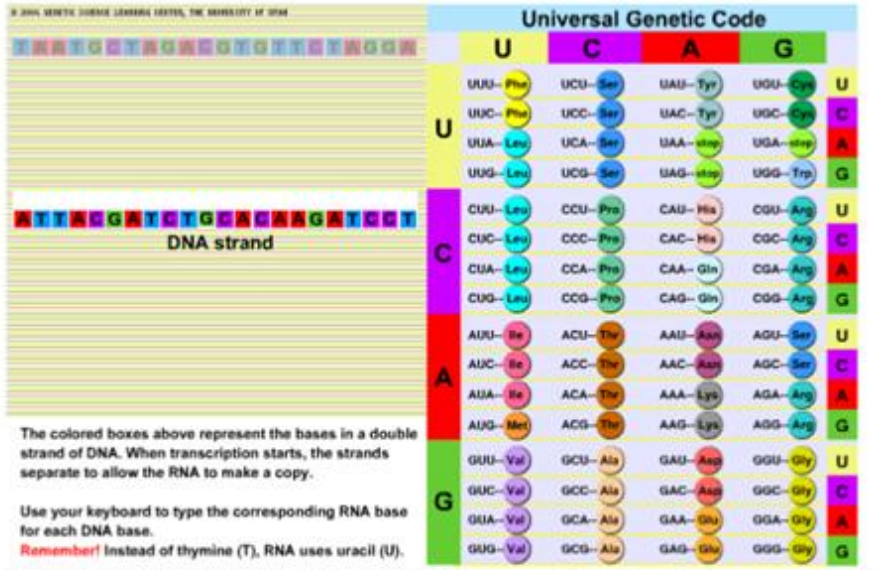
http://www.wiley.com/legacy/college/boyer/0470003790/animations/central_dogma/central_dogma.swf



http://www-class.unl.edu/biochem/gp2/m_biology/animation/gene/gene_a1.html



http://www.wiley.com/legacy/college/boyer/0470003790/animations/translation/translation.swf



http://learn.genetics.utah.edu/content/begin/dna/transcribe/

Can you find the sentences?

bisntnsgvienfhthemanwastooldforthewarendthsonphsvkj

vjabgdkltheboyhadoneredcarandoneoldhatendvjwbvi

skcwthecarwasredandtooldforhernewjobendajvalvhbwov

What do they have in common?

bisntnsgvienfhthemanwastooooldforthewarendthsonphsvkj

vjabgdkltheboyhadoneredcarandoneoldhatendvjwbvi

skcwthecarwasredandtooooldforhernewjobendajvalvhbwov

What do they have in common?

bisntnsgvienfh|the|man|was|too|old|for|the|war|end|thsonphsvkj

vjabgdkl|the|boy|had|one|red|car|and|one|old|hat|end|vjwbvi

skcw|the|car|was|red|and|too|old|for|her|new|job|end|ajvalvhbwov

start with the same word

all finish with 'end' - not in the sentence

all three-letter words

many words & phrases repeated or reused

How is this like the Genetic Code?

bisntnsgvienfh|the|man|was|too|old|for|the|war|end|thsonphsvkj
vjabgdkl|the|boy|had|one|red|car|and|one|old|hat|end|vjwbvi
skcw|the|car|was|red|and|too|old|for|her|new|job|end|ajvalvhbwov

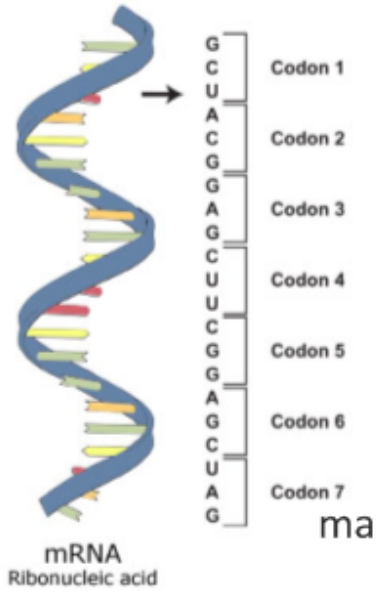


Image adapted from: National Human Genome Research Institute. Talking Glossary of Genetic Terms. Available at: www.genome.gov/Pages/Hyperion/DIR//VIP/Glossary/Illustration/codon.shtml.

http://images1.clinicaltools.com/images/gene/codon.jpg

all three-letter words =

DNA is transcribed in triplets - sequences of three bases.
This gives mRNA codons - sequences of three RNA bases.
mRNA codons make up the genetic code.

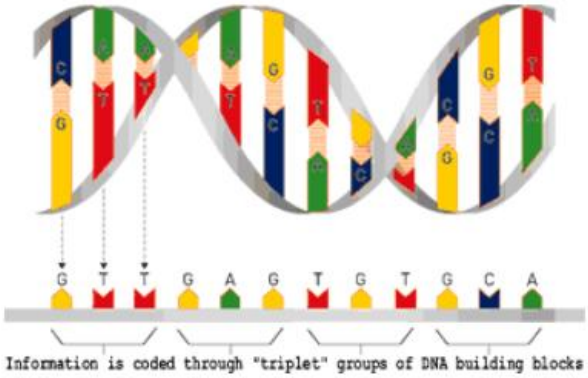
start with the same word = each gene starts with a 'start' codon

all finish with 'end' - not in the sentence = stop codon at end of gene

many words & phrases repeated or reused = there are 64 different combinations but infinite polypeptides. This means that many are reused.

But one big difference: the genetic code has only four letters!

The Genetic Code



DNA
triplets

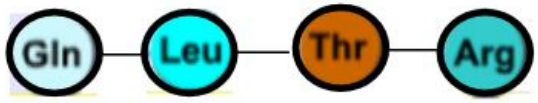
transcription

CAA CUC ACA CGU

mRNA
codons

translation

There are 64 codons but
only 20 amino acids



polypeptide
amino acids

http://www.bbsrc.ac.uk/life/images/dna_garden/dna1/triplet_groups.gif

Universal Genetic Code

	U	C	A	G	
U	UUU-- Phe	UCU-- Ser	UAU-- Tyr	UGU-- Cys	U
	UUC-- Phe	UCC-- Ser	UAC-- Tyr	UGC-- Cys	C
	UUA-- Leu	UCA-- Ser	UAA-- stop	UGA-- stop	A
	UUG-- Leu	UCG-- Ser	UAG-- stop	UGG-- Trp	G
C	CUU-- Leu	CCU-- Pro	CAU-- His	CGU-- Arg	U
	CUC-- Leu	CCC-- Pro	CAC-- His	CGC-- Arg	C
	CUA-- Leu	CCA-- Pro	CAA-- Gln	CGA-- Arg	A
	CUG-- Leu	CCG-- Pro	CAG-- Gln	CGG-- Arg	G
A	AUU-- Ile	ACU-- Thr	AAU-- Asn	AGU-- Ser	U
	AUC-- Ile	ACC-- Thr	AAC-- Asn	AGC-- Ser	C
	AUA-- Ile	ACA-- Thr	AAA-- Lys	AGA-- Arg	A
	AUG-- Met	ACG-- Thr	AAG-- Lys	AGG-- Arg	G
G	GUU-- Val	GCU-- Ala	GAU-- Asp	GGU-- Gly	U
	GUC-- Val	GCC-- Ala	GAC-- Asp	GGC-- Gly	C
	GUA-- Val	GCA-- Ala	GAA-- Glu	GGA-- Gly	A
	GUG-- Val	GCG-- Ala	GAG-- Glu	GGG-- Gly	G

http://learn.genetics.utah.edu/units/basics/transcribe/

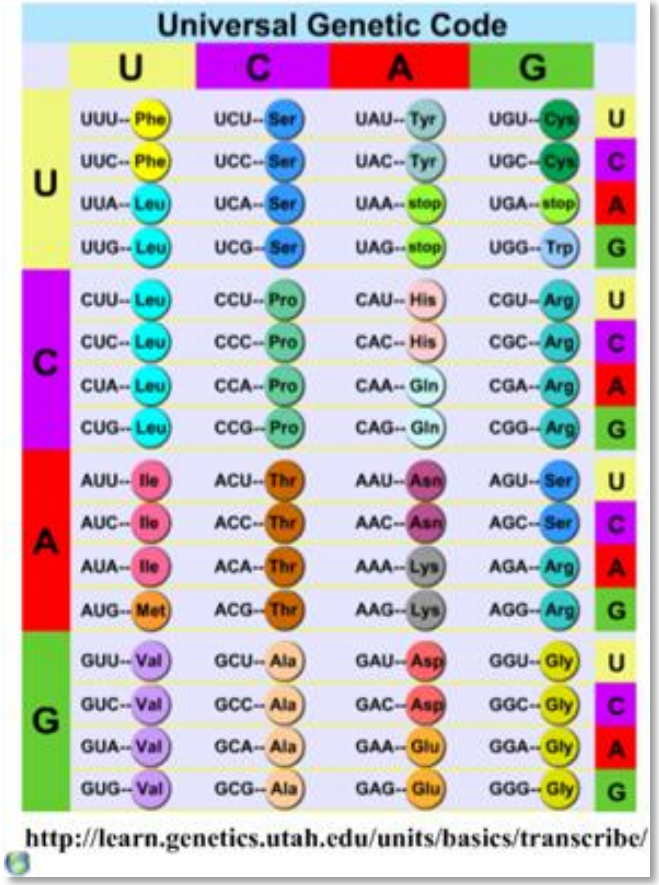
The Genetic Code

Is universal:

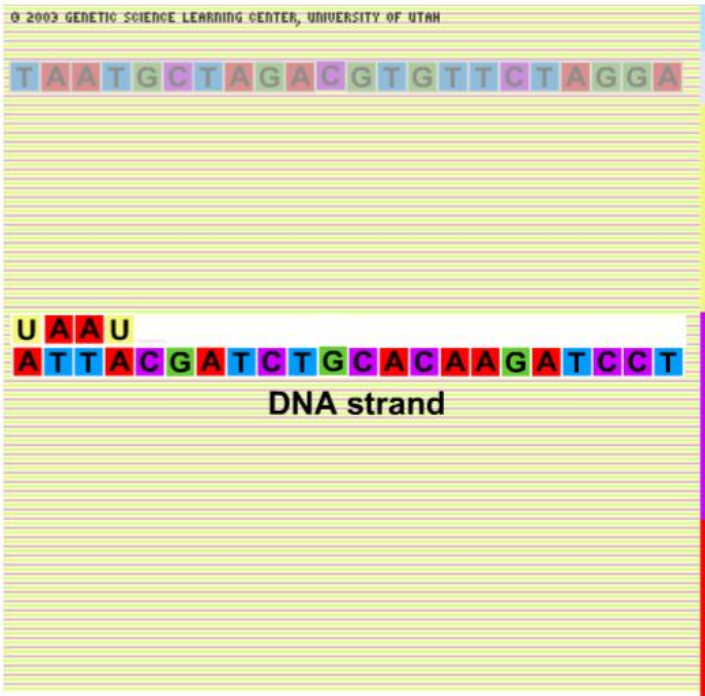
- All living things use the same code
- All living things have the same bases
- Codons code for the same amino acids no matter what the organism.

Is degenerate:

- There are 64 codons but only 20 amino acids (plus stop)
- The same amino acid may be coded for by more than one codon.
- Reduced impact of base-substitution mutation, as amino acid produced could still be the same.



Transcribe and translate!



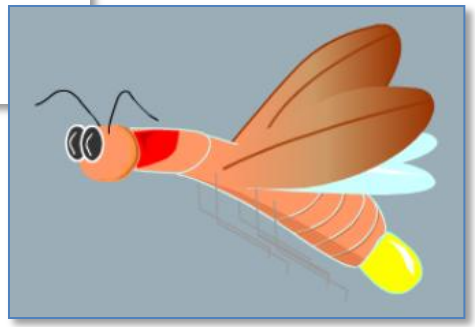
The colored boxes above represent the bases in a double strand of DNA. When transcription starts, the strands separate to allow the RNA to make a copy.

Use your keyboard to type the corresponding RNA base for each DNA base.
Remember! Instead of thymine (T), RNA uses uracil (U).

Universal Genetic Code

	U	C	A	G	
U	UUU-- Phe	UCU-- Ser	UAU-- Tyr	UGU-- Cys	U
	UUC-- Phe	UCC-- Ser	UAC-- Tyr	UGC-- Cys	C
	UUA-- Leu	UCA-- Ser	UAA-- stop	UGA-- stop	A
	UUG-- Leu	UCG-- Ser	UAG-- stop	UGG-- Trp	G
C	CUU-- Leu	CCU-- Pro	CAU-- His	CGU-- Arg	U
	CUC-- Leu	CCC-- Pro	CAC-- His	CGC-- Arg	C
	CUA-- Leu	CCA-- Pro	CAA-- Gln	CGA-- Arg	A
	CUG-- Leu	CCG-- Pro	CAG-- Gln	CGG-- Arg	G
A	AUU-- Ile	ACU-- Thr	AAU-- Asn	AGU-- Ser	U
	AUC-- Ile	ACC-- Thr	AAC-- Asn	AGC-- Ser	C
	AUA-- Ile	ACA-- Thr	AAA-- Lys	AGA-- Arg	A
	AUG-- Met	ACG-- Thr	AAG-- Lys	AGG-- Arg	G
G	GUU-- Val	GCU-- Ala	GAU-- Asp	GGU-- Gly	U
	GUC-- Val	GCC-- Ala	Glutamic acid	GGC-- Gly	C
	GUA-- Val	GCA-- Ala	GAA-- Glu	GGA-- Gly	A
	GUG-- Val	GCG-- Ala	GAG-- Glu	GGG-- Gly	G

Have a go… http://learn.genetics.utah.edu/units/basics/transcribe/



http://learn.genetics.utah.edu/content/begin/dna/firefly/

Transcribe this DNA strand into mRNA:

DNA: A C G T T A C G G A T T A C A G T C C C A A A C T A C

mRNA:

Transcribe this DNA strand into mRNA:

DNA: A C G T T A C G G A T T A C A G T C C C A A A C T A C

mRNA: U G C A A U G C C U A A U G U C A G G G U U U G A U G

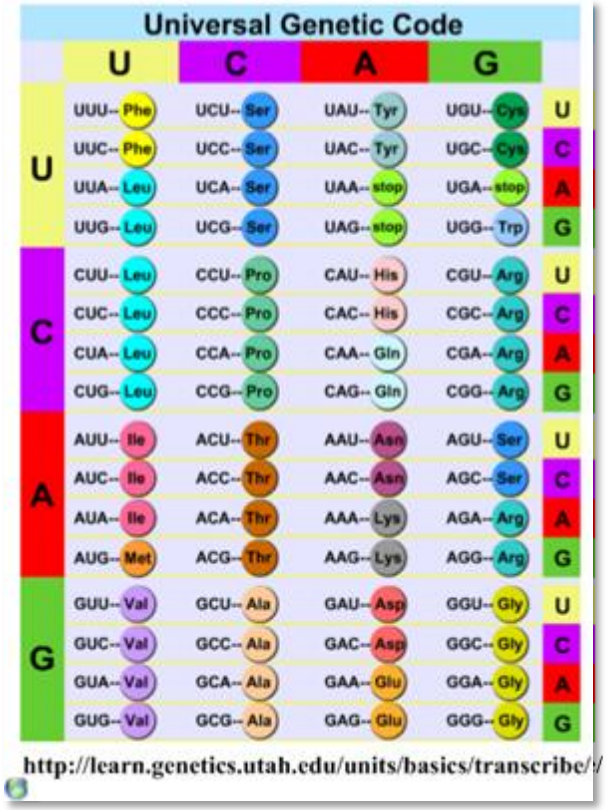
Don't forget: on mRNA, Uracil takes the place of Thymine

Uracil is complementary to Adenine

Now translate the mRNA into a polypeptide:

DNA: A C G T T A C G G A T T A C A G T C C C A A A C T A C

mRNA: U G C A A U G C C U A A U G U C A G G G U U U G A U G



Remember: the 'Met' codon is 'Start'

There are 20 amino acids and a Stop codon:

Phe Leu Ile Met Val Ser Pro Thr Ala Tyr

His Gln Asn Lys Asp Glu Cys Trp Arg Gly Stop

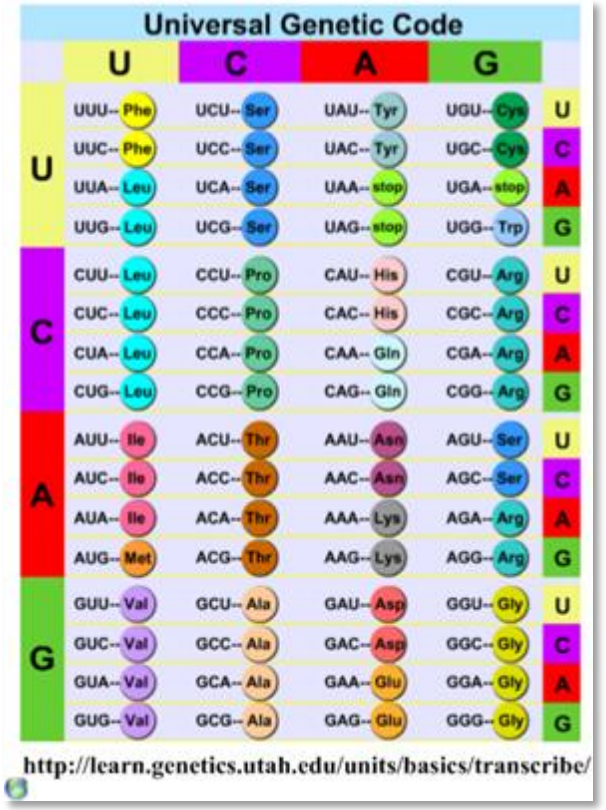
How many amino acids in the polypeptide?:

DNA: A C G T T A C G G A T T A C A G T C C C A A A C T A C

mRNA: U G C A A U G C C U A A U G U C A G G G U U U G A U G

Met Pro Asn Val Arg Val Stop

The 'Met' codon is always the first.



There are 20 amino acids and a Stop codon:

Phe Leu Ile Met Val Ser Pro Thr Ala Tyr

His Gln Asn Lys Asp Glu Cys Trp Arg Gly Stop

Things to remember about the genetic code:

DNA: A C G T T A C G G A T T A C A G T C C C A A A C T A C

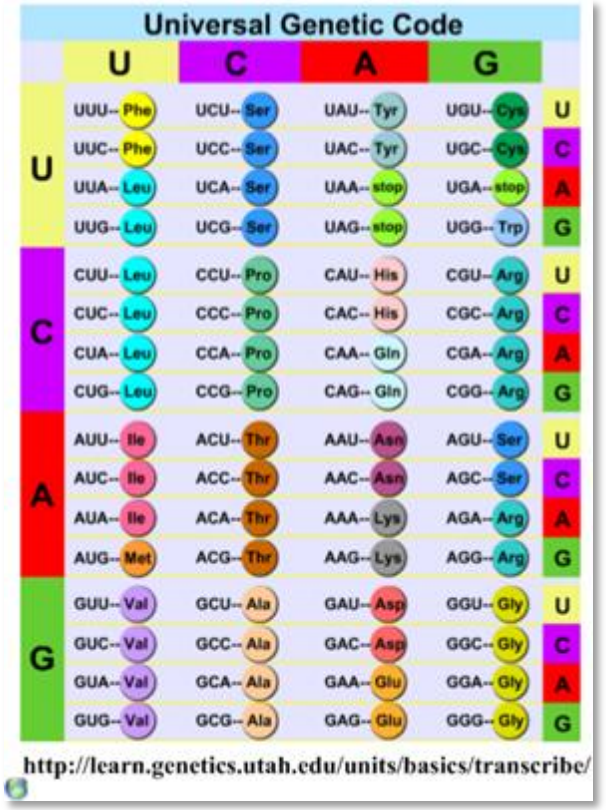
this gene = 21 base pairs

giving 7 codons

mRNA: U G C A A U G C C U A A U G U C A G G G U U U G A U G

Met Pro Asn Val Arg Val Stop

6 amino acids in the polypeptide plus stop



The 'Met' codon is always the first.

Number of amino acids = codons - 1

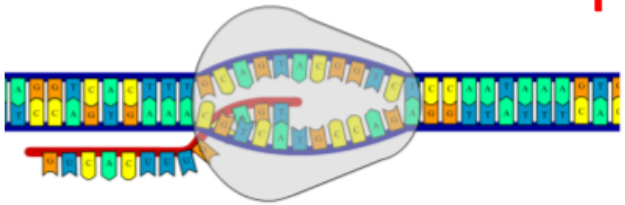
or = (base pairs/3) -1

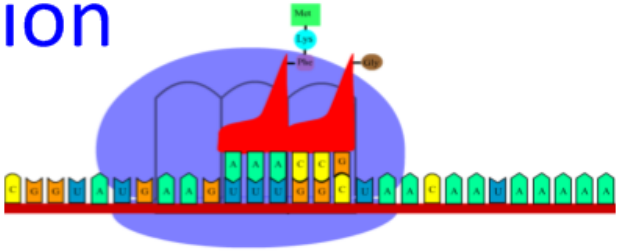
There are 20 amino acids and a Stop codon:

Phe Leu Ile Met Val Ser Pro Thr Ala Tyr

His Gln Asn Lys Asp Glu Cys Trp Arg Gly Stop

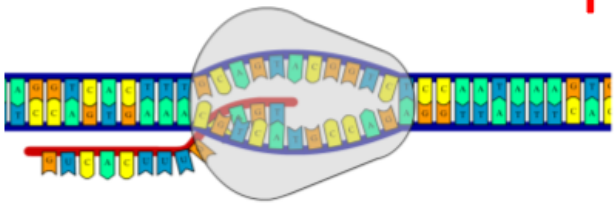
Transcription vs Translation

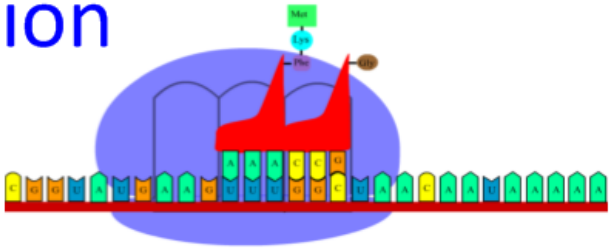




DNA	Input	
	Genetic code	codons
	Output	
nucleus	Location	
	Molecules used	ribosomes
RNA nucleotides		

Transcription vs Translation

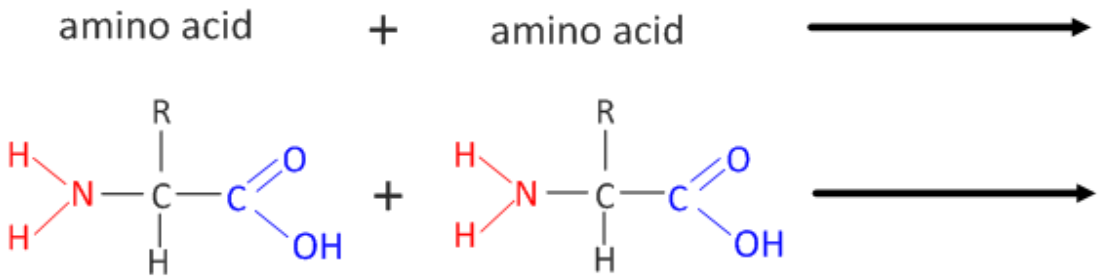




DNA	Input	mRNA
triplets	Genetic code	codons
mRNA	Output	polypeptide
nucleus	Location	ribosomes (RER/ cytoplasm)
RNA polymerase RNA nucleotides	Molecules used	ribosomes tRNA amino acids

How are the amino acids joined together to make a polypeptide?

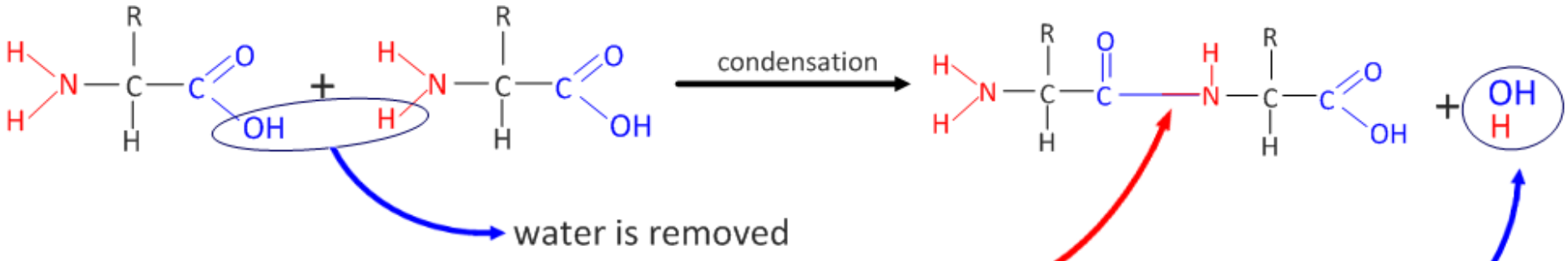
Revision: Carbohydrates, Lipids and Proteins.



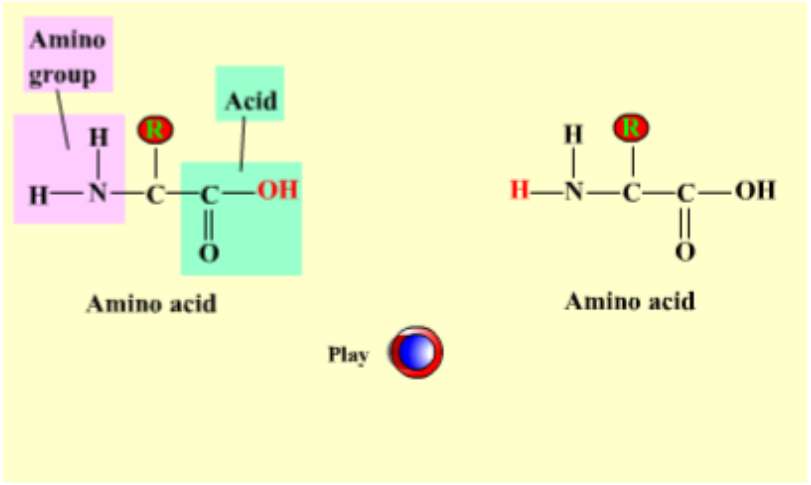
How are the amino acids joined together to make a polypeptide?

Revision: Carbohydrates, Lipids and Proteins.

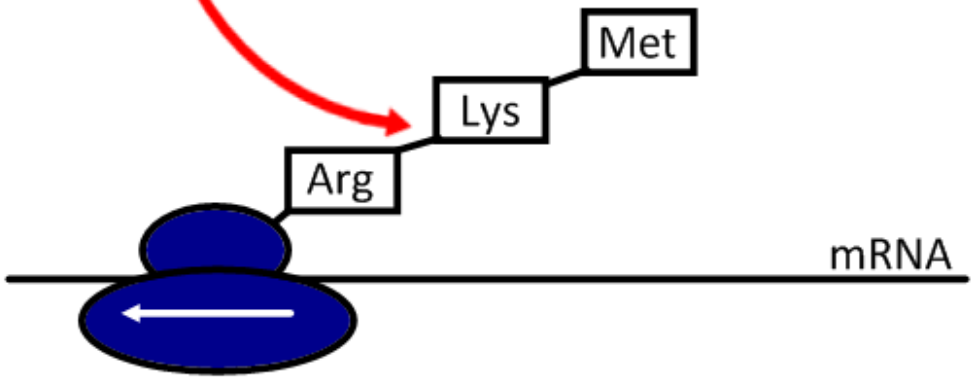
amino acid + amino acid → dipeptide + water (condensation)



Condensation forms a peptide bond:



http://www2.nl.edu/jste/proteins.htm



The *One Gene, One Polypeptide* hypothesis

Another example of a paradigm shift in Biology

At first, it was thought that *one gene would always make one enzyme*, and then it was modified to *one gene, one polypeptide* as the result of the work of Beadle and Tatum.

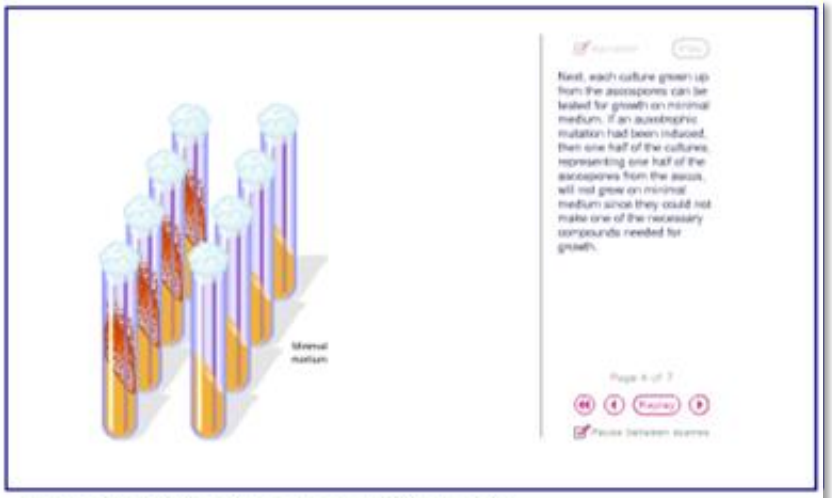
Of course, there are different versions of many genes, known as alleles. So is it really *one allele, one protein*?

However, as research has continued, we have found more and more exceptions to the new rule:

1. Some genes control the expression of others
   (no polypeptide produced)

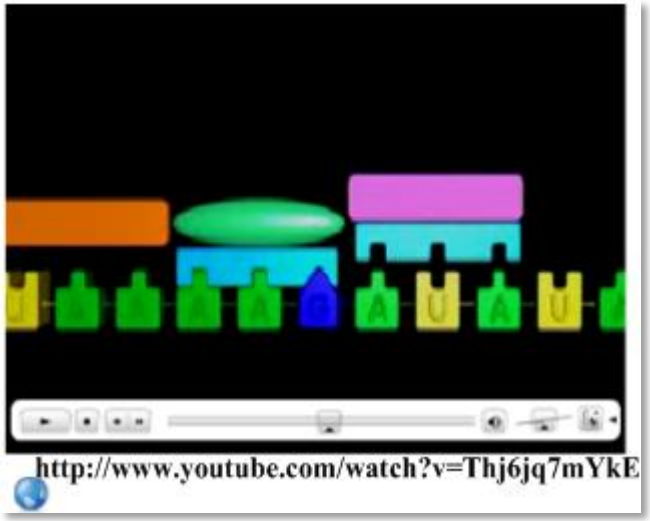
2. Some genes code for RNA which does not produce a polypeptide
   (no 'START' codon - function unknown)

Beadle and Tatum:



http://artstudios.com/A04A.swf

Simplistic blood group example:



http://www.youtube.com/watch?v=Thj6jq7mYkE

Quick Questions:

1. A mRNA strand has 27 codons. How many amino acids in the polypeptide?

2. A gene is 6009 base pairs long. How many amino acids in the polypeptide?

3. What do the codons UUA, CUA and CUG have in common?

Quick Questions:

1. A mRNA strand has 27 codons. How many amino acids in the polypeptide?

26 (number of codons minus one - stop codon)

2. A gene is 6009 base pairs long. How many amino acids in the polypeptide?

2002 $\frac{6009}{3}$ = codons minus one (stop codon)

3. What do the codons UUA, CUA and CUG have in common?

They all code for the same amino acid (Leucine)
This is an example of the degenerate nature of the genetic code.

For more IB Biology resources:

http://sciencevideos.wordpress.com