

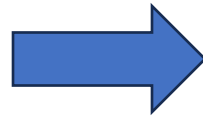
Proteins...

... in endless forms most beautiful

Tim Herman

Proteins fold in water....

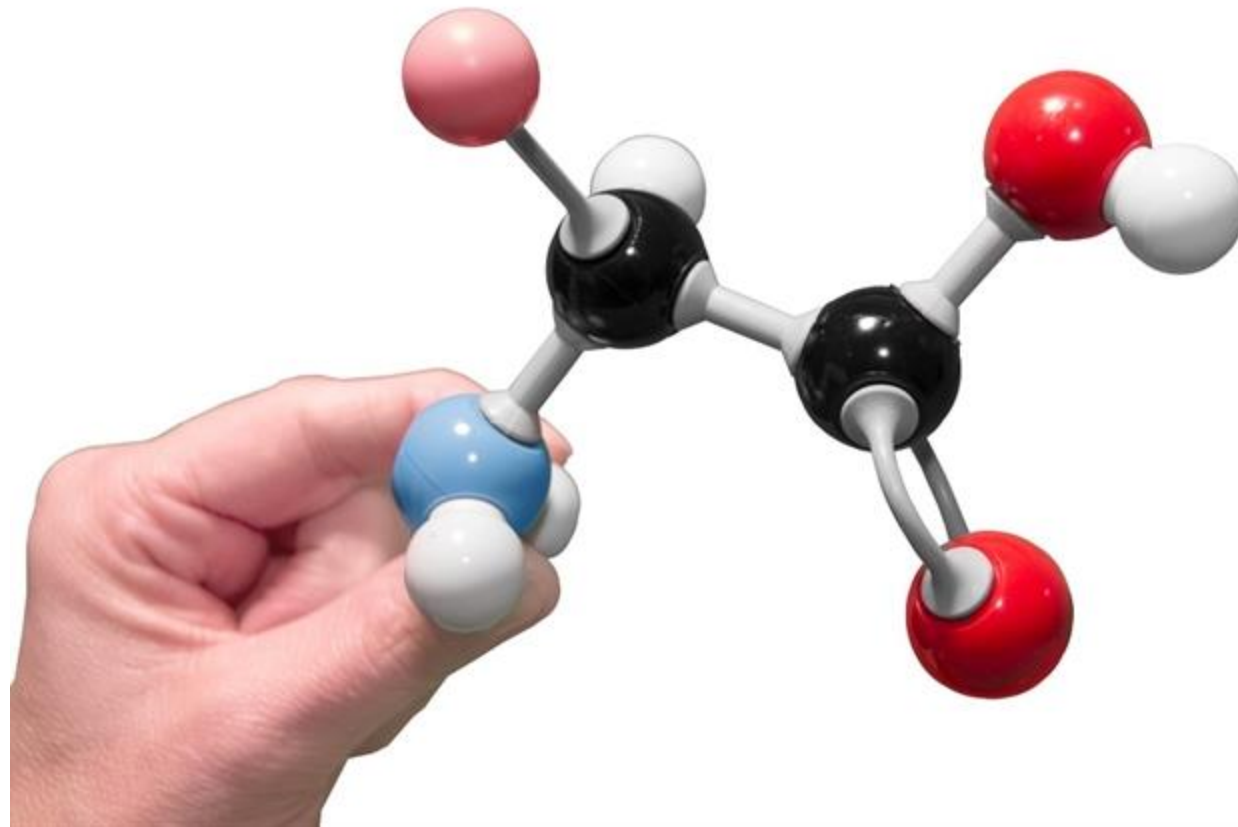
The principles of chemistry explored in the Water Kit...



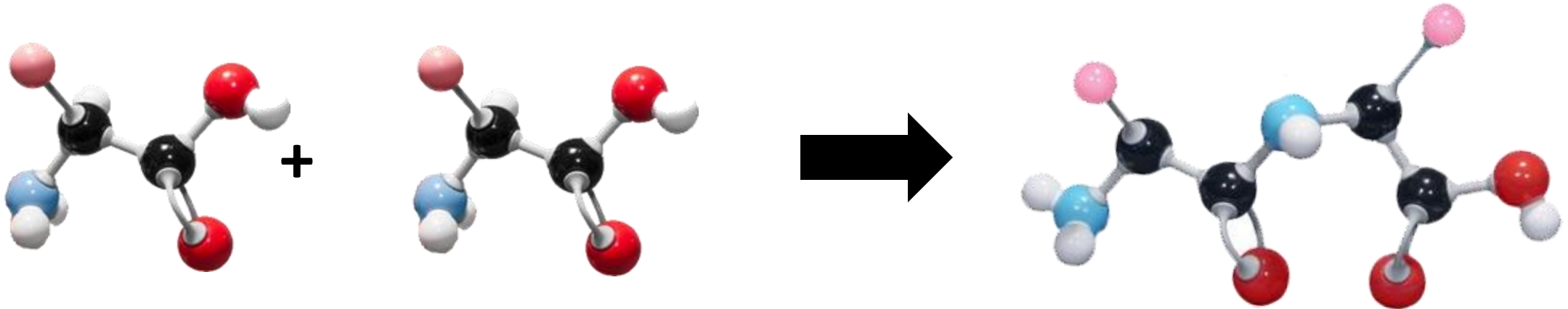
...will be applied to the amino acid sidechains ... in proteins

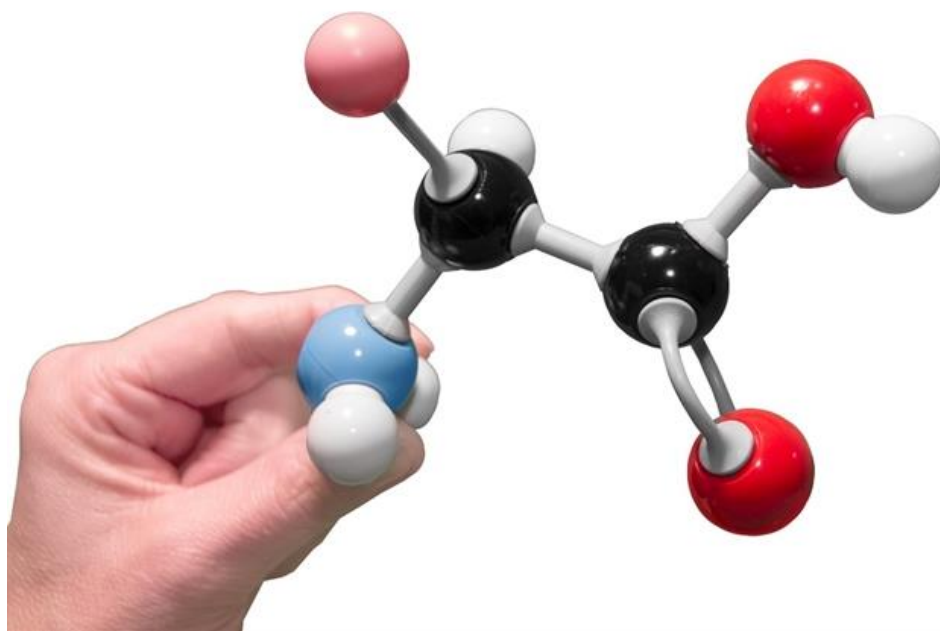


MolyMod Amino Acid Building Blocks

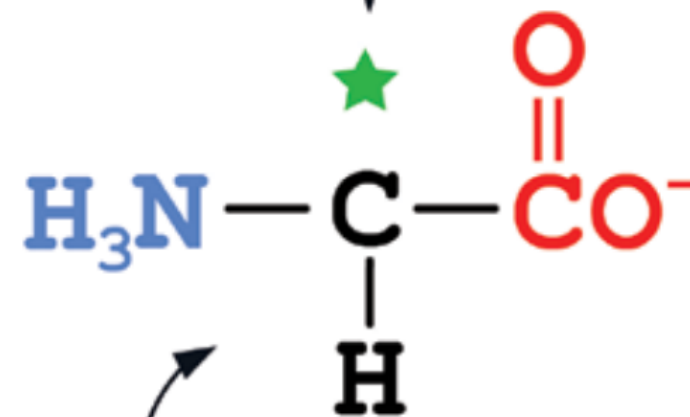


How do amino acids form proteins? (or in this case, a dipeptide?)

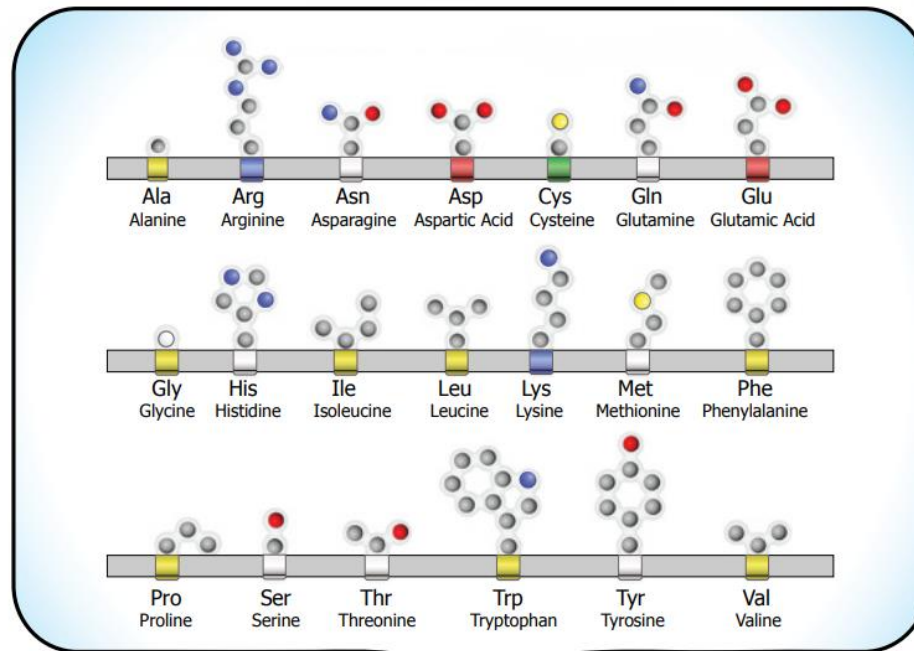




20 Different
Side Chains



Common Backbone



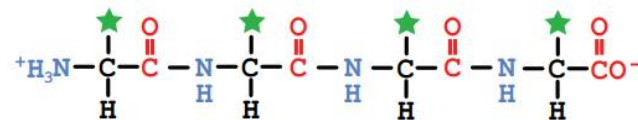
20 Different Side Chains
Attach Here

Amino
Group

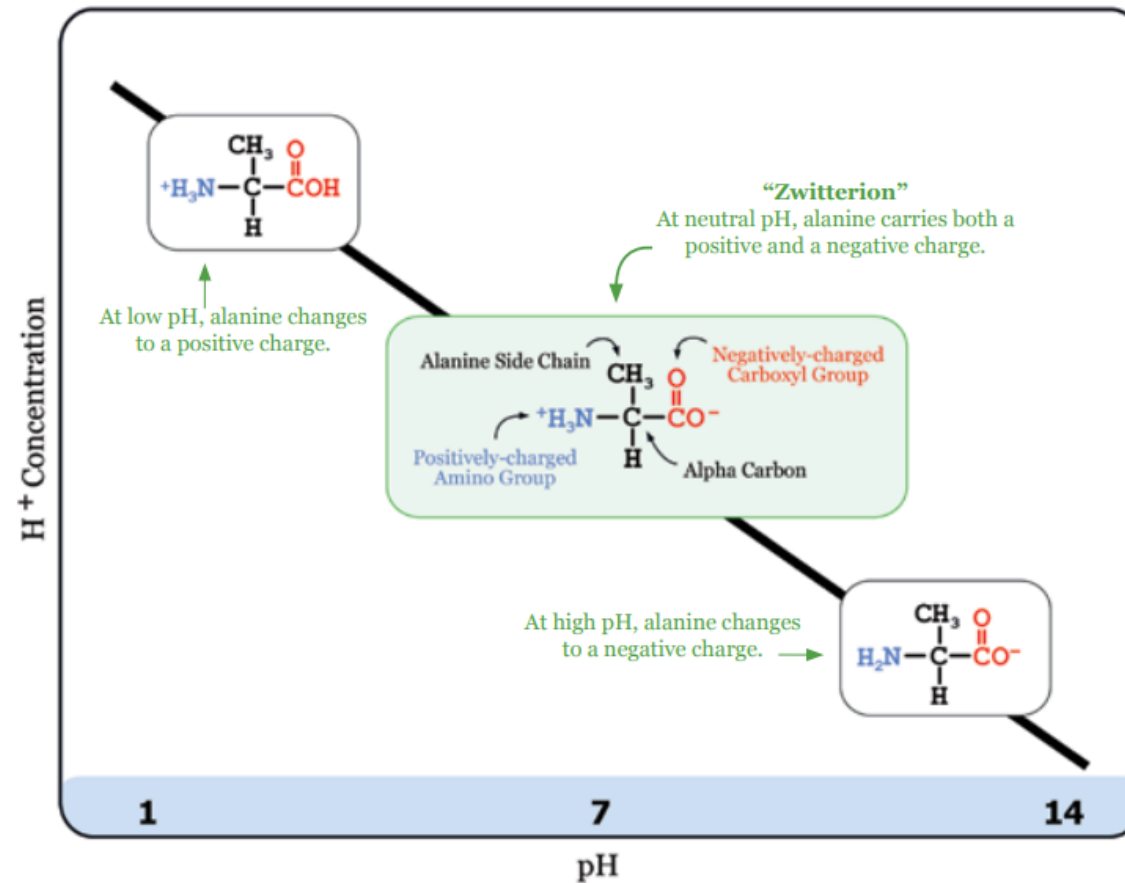


Alpha Carbon

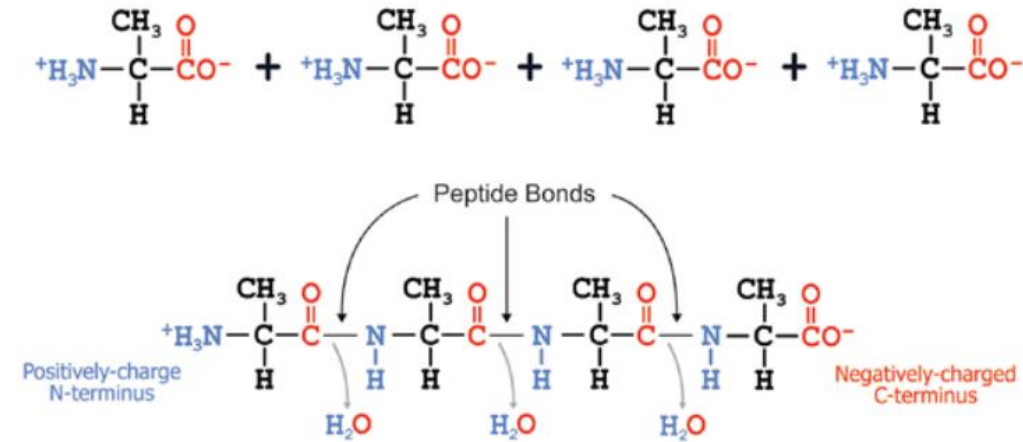
Carboxylic
Acid Group



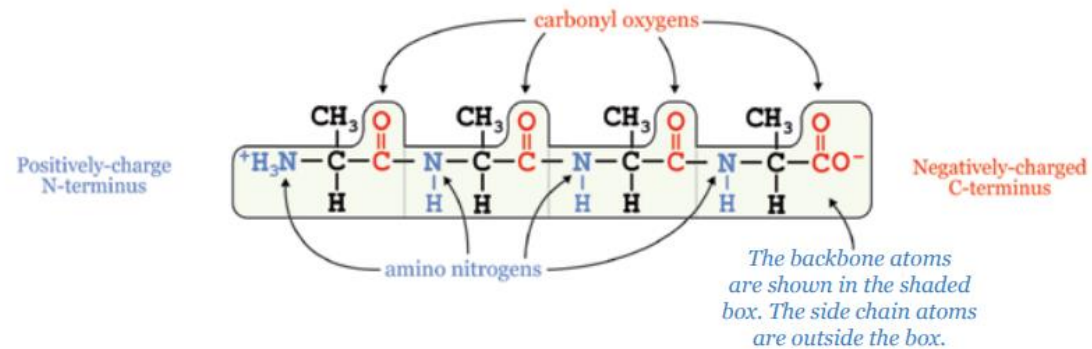
A polypeptide composed of 4 amino acids.



3. In a protein, the backbone amino group of the N-terminal amino acid is **positively-charged**, and the backbone carboxyl group of the C-terminal amino acid is **negatively charged**. All other backbone charges have been **neutralized** by peptide bond formation.



Note that the formation of each peptide bond results in the production of a water molecule. This is an example of a condensation reaction, also called dehydration synthesis.



Amino Acid Side Chain Chart®

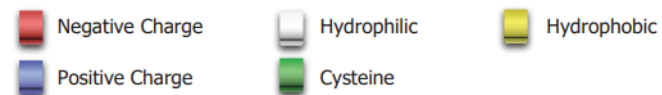
Name	Amino Acid	Side Chain	Name	Amino Acid	Side Chain	Name	Amino Acid	Side Chain	Name	Amino Acid	Side Chain
Alanine			Glutamine			Leucine			Serine		
Ala			Gln			Leu			Ser		
A	<chem>CC(N)C(=O)O</chem>		Q	<chem>CCC(N)C(=O)O</chem>		L	<chem>CC(C)C(N)C(=O)O</chem>		S	<chem>CC(O)C(N)C(=O)O</chem>	
Arginine			Glutamic Acid			Lysine			Threonine		
Arg	<chem>CCC(N=[NH2+])C(N)C(=O)O</chem>		Glu	<chem>CCC(=O)[O-]C(N)C(=O)O</chem>		Lys	<chem>CCCC[NH3+]C(N)C(=O)O</chem>		Thr	<chem>CC(CO)C(N)C(=O)O</chem>	
R			E			K			T		
Asparagine			Glycine			Methionine			Tryptophan		
Asn	<chem>CC(N)C(=O)N</chem>		Gly	<chem>NC(N)C(=O)O</chem>		Met	<chem>CCSCC(N)C(=O)O</chem>		Trp	<chem>Cc1c[nH]c2ccccc12</chem>	
N			G			M			W		
Aspartic Acid			Histidine			Phenylalanine			Tyrosine		
Asp	<chem>CC(=O)[O-]C(N)C(=O)O</chem>		His	<chem>CC1=CN=CN=C1</chem>		Phe	<chem>CC1=CC=CC=C1</chem>		Tyr	<chem>CC1=CC=C(O)C=C1</chem>	
D			H			F			Y		
Cysteine			Isoleucine			Proline			Valine		
Cys	<chem>SCC(N)C(=O)O</chem>		Ile	<chem>CC(C)C(C)C(N)C(=O)O</chem>		Pro	<chem>C1CCNCC1</chem>		Val	<chem>CC(C)C(N)C(=O)O</chem>	
C			I			P			V		

Atom Color Key



Amino Acid Property Key

Amino acid clip color and name color indicate property



The Genetic Codon Chart®

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

Amino Acid Properties

Translation Start Codon

Translation Stop Codon

Hydrophobic / Non-polar

Hydrophilic / Polar

Negative Charge

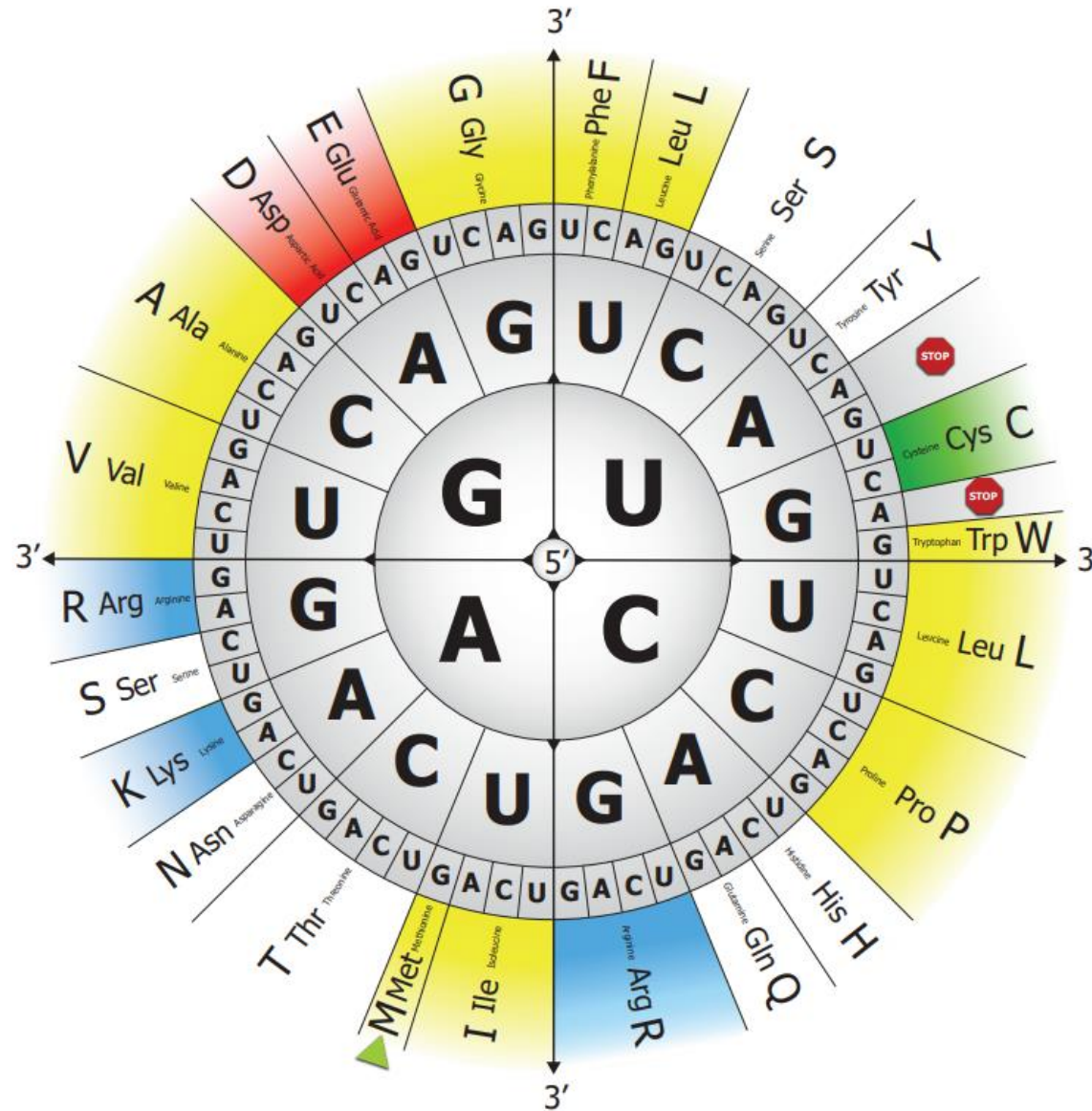
Positive Charge

Cysteine

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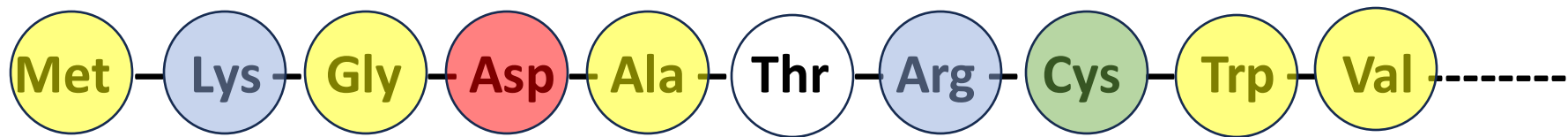
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The Genetic Codon Circle[®]



What is a protein?

*A protein is simply a linear sequence of amino acids...
that folds up into a complex 3D shape...
following basic principles of chemistry ... and physics.*



*How many **15-amino acid proteins** are possible?*

$$\begin{array}{rcl} 20 \times 20 \times 20 \times 20 \times 20 \dots\dots\dots & = & 3 \times 10^{19} \\ 400 & & 30,000,000,000,000,000,000 \\ 8000 & & \\ 160,000 & & \\ 3,200,000 & & \end{array}$$

If an average protein is composed of **200 amino acids**,...
there are 1.6×10^{260} possible proteins

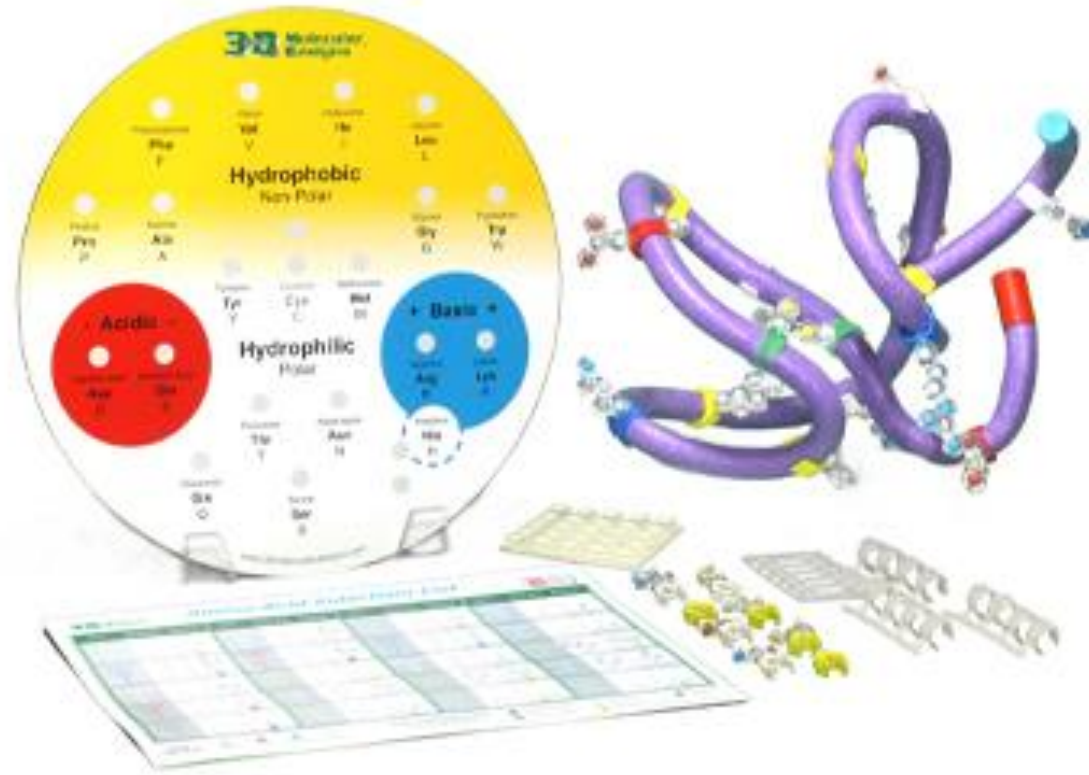
14

[illegible]

14

The Amino Acid Starter Kit

(... a protein folding kit ...)



... the best thing we have ever done.

Linus
Pauling

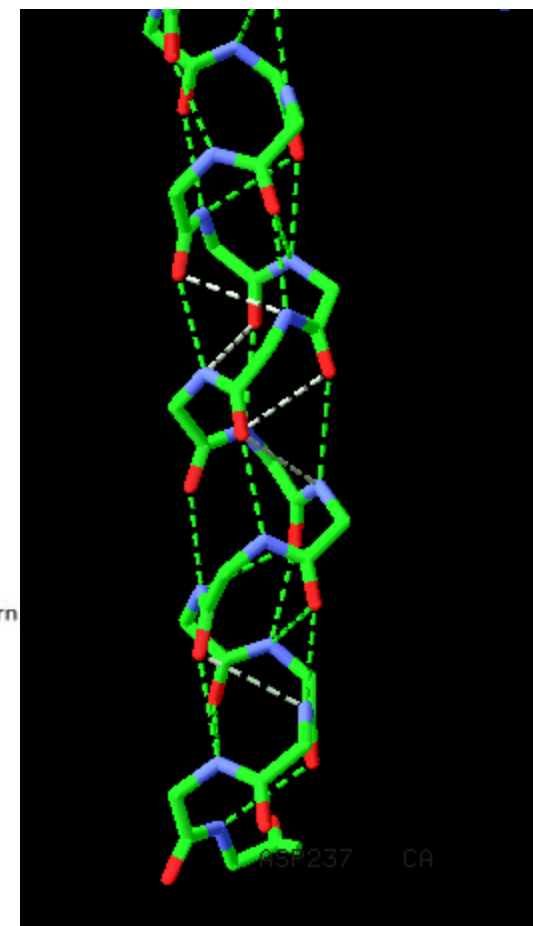
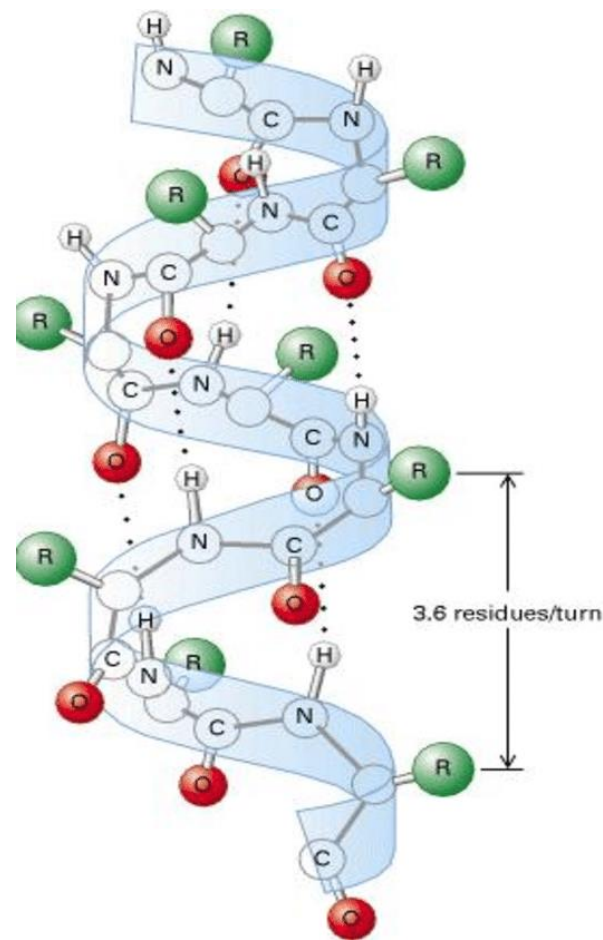
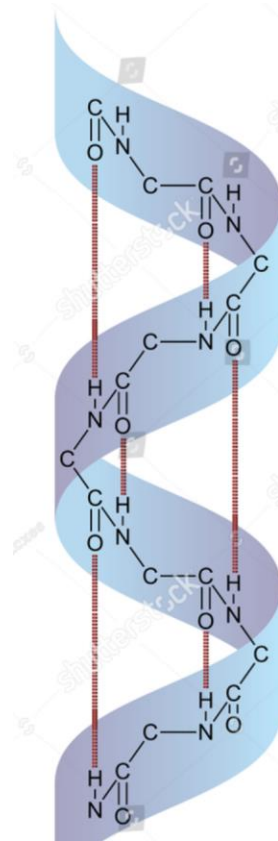
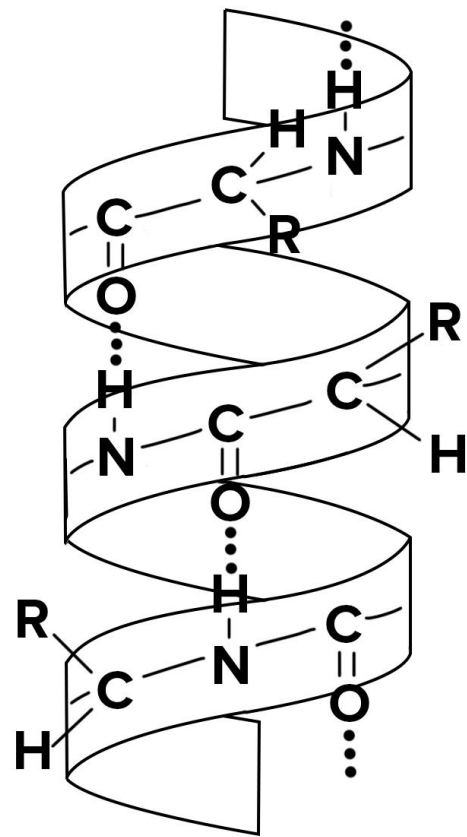


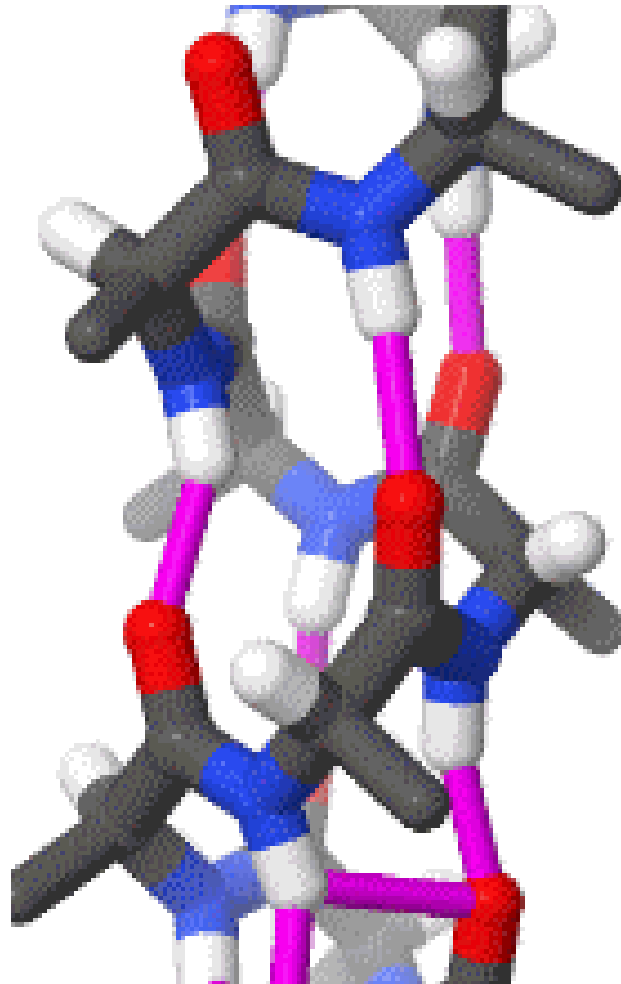
Robert
Corey



CPK coloring scheme...
(Corey / Pauling / Kolton)

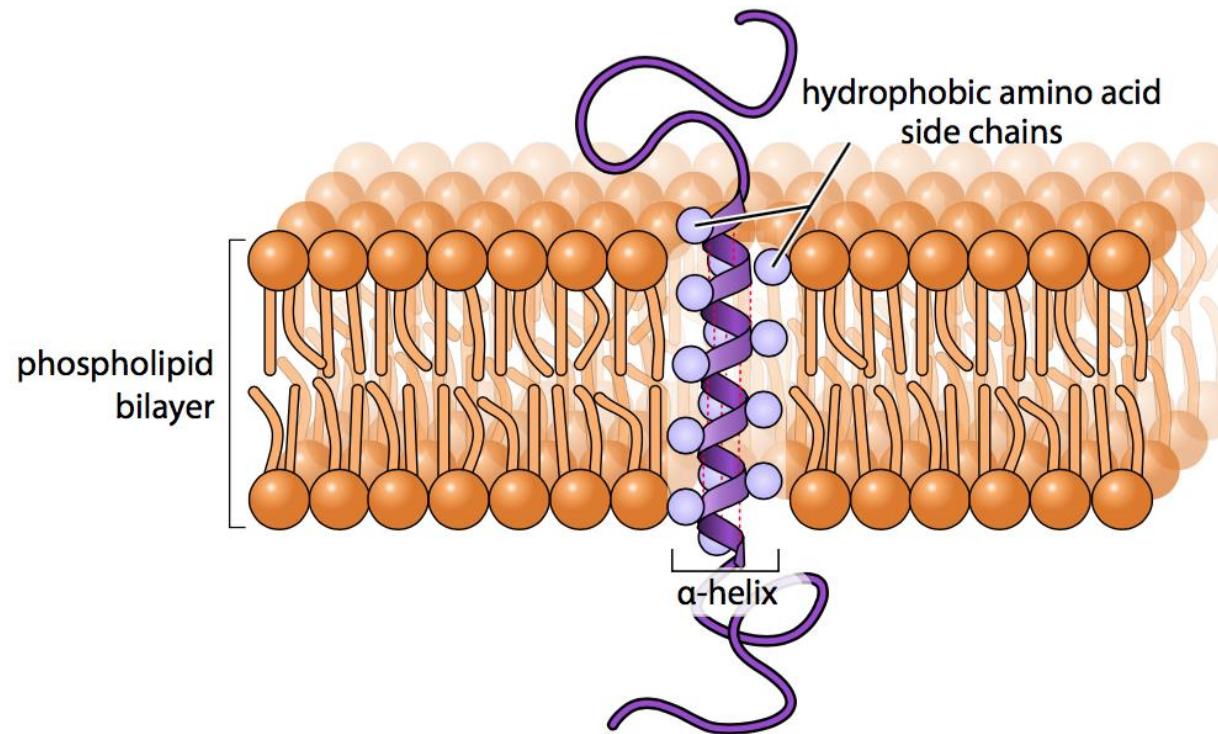
Pauling, L., Corey, R. B. & Branson, H. R. (1951)
Proc. Natl. Acad. Sci. USA **37**, 205–211.

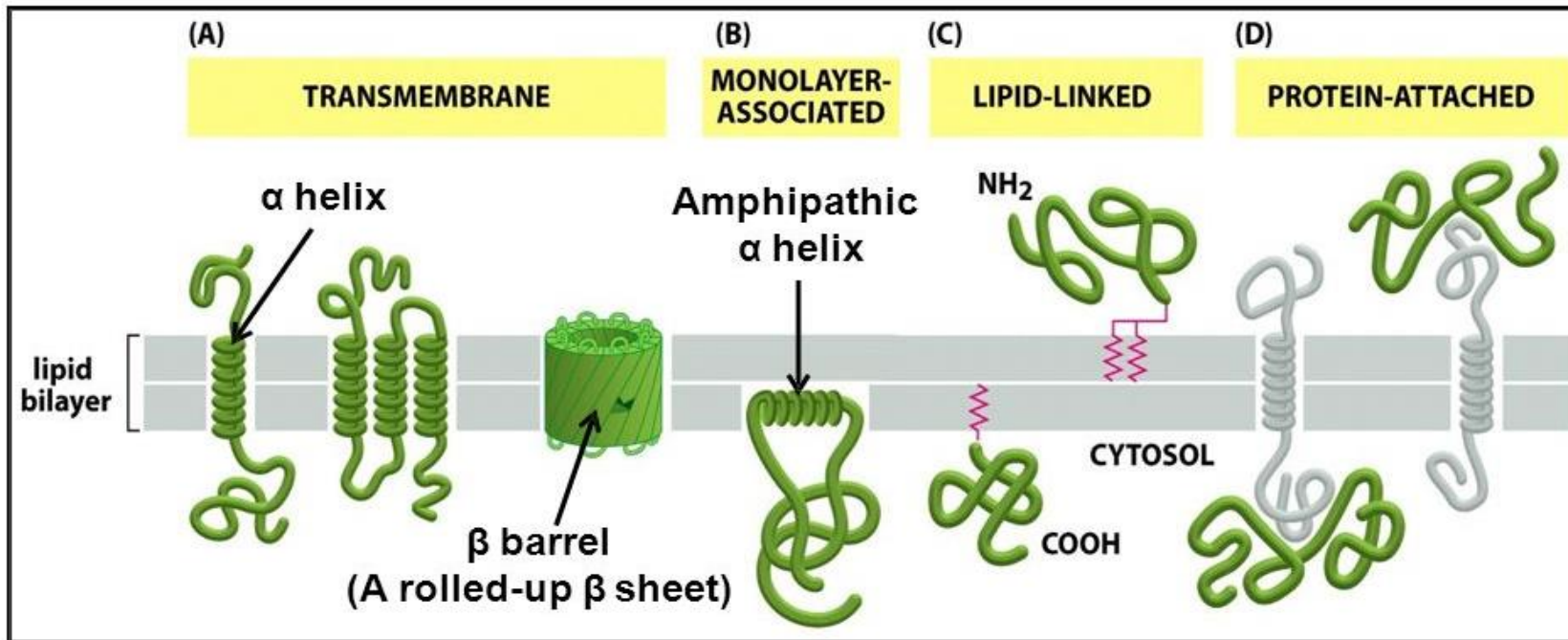


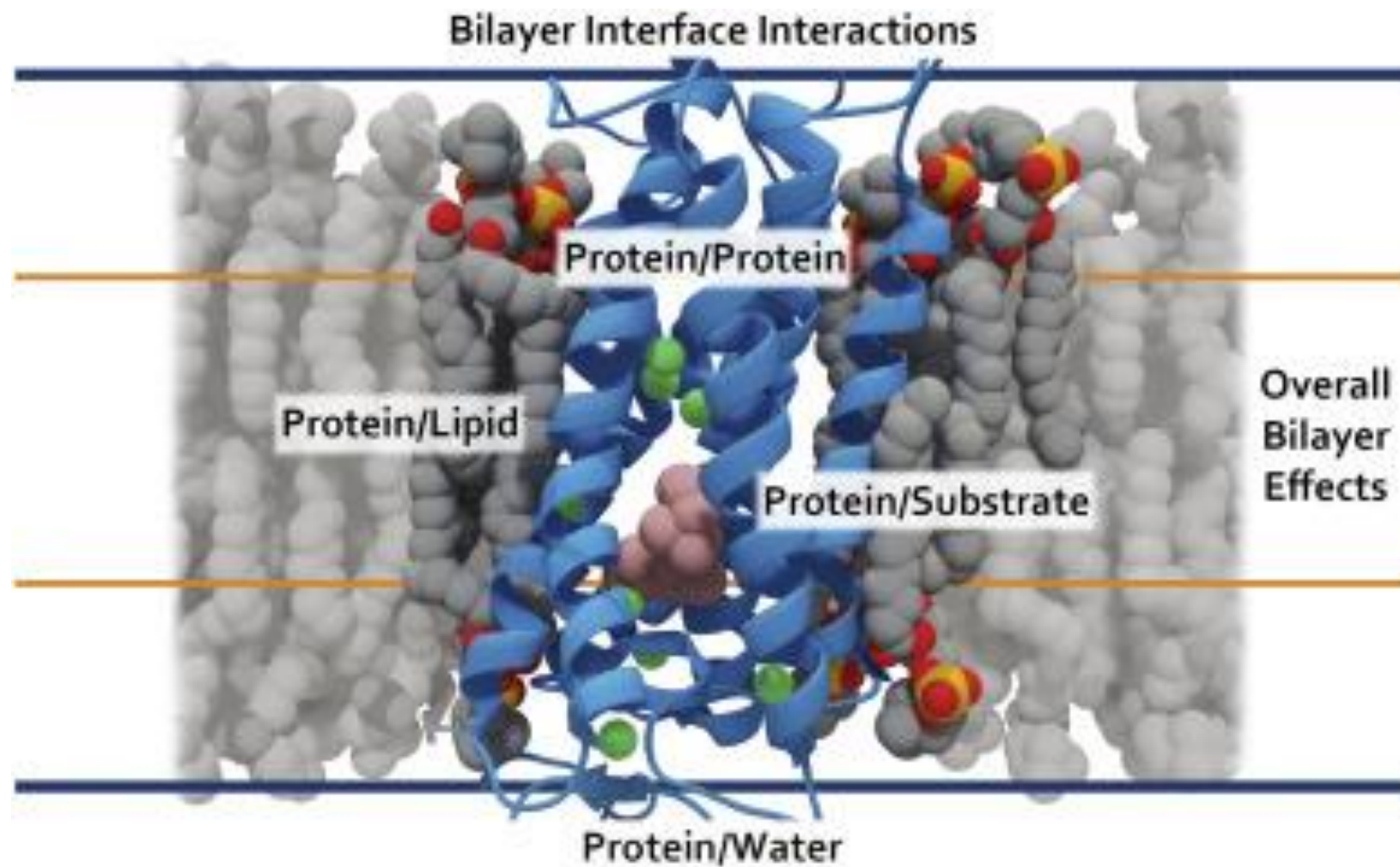


https://en.wikipedia.org/wiki/Alpha_helix

A Transmembrane Alpha Helix



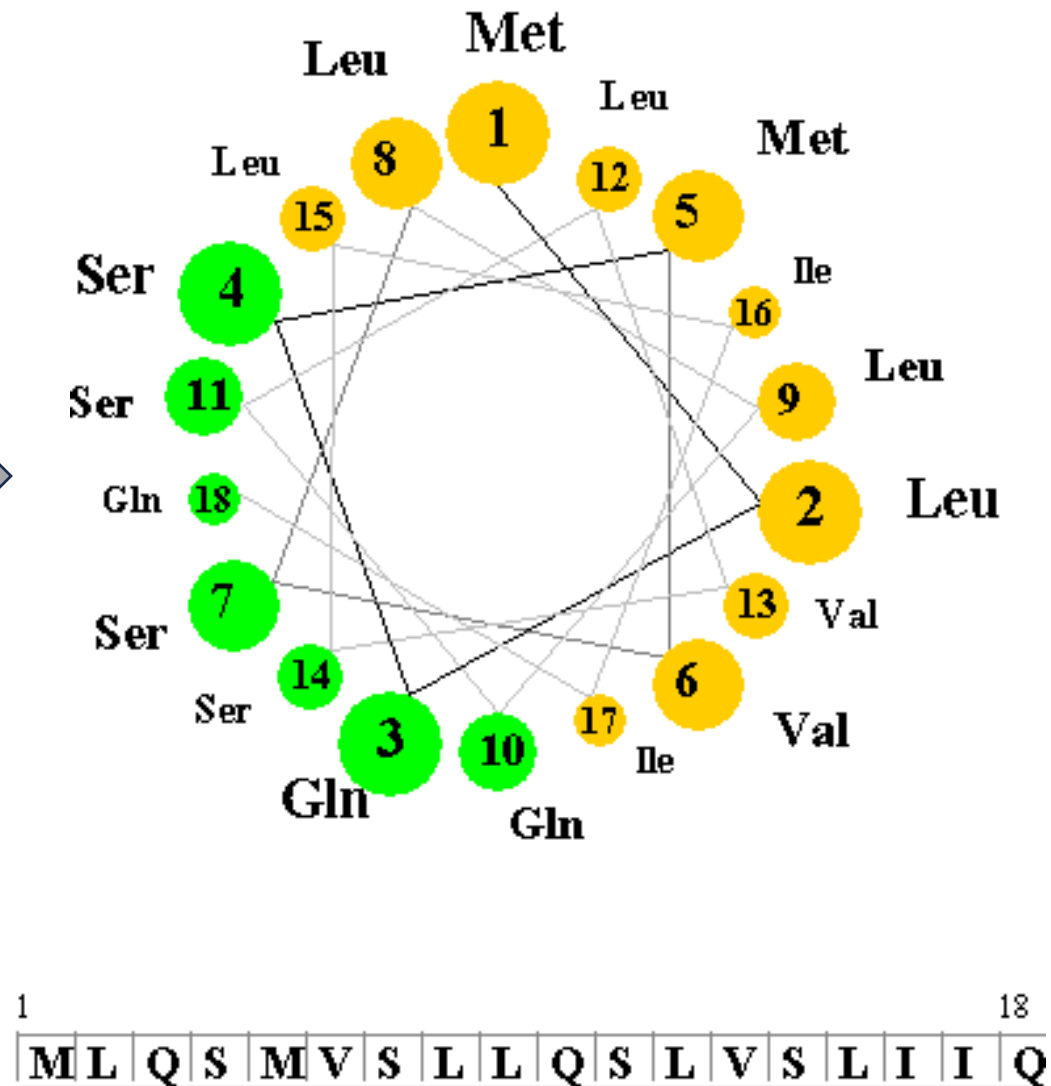




Amphipathic Alpha Helices...

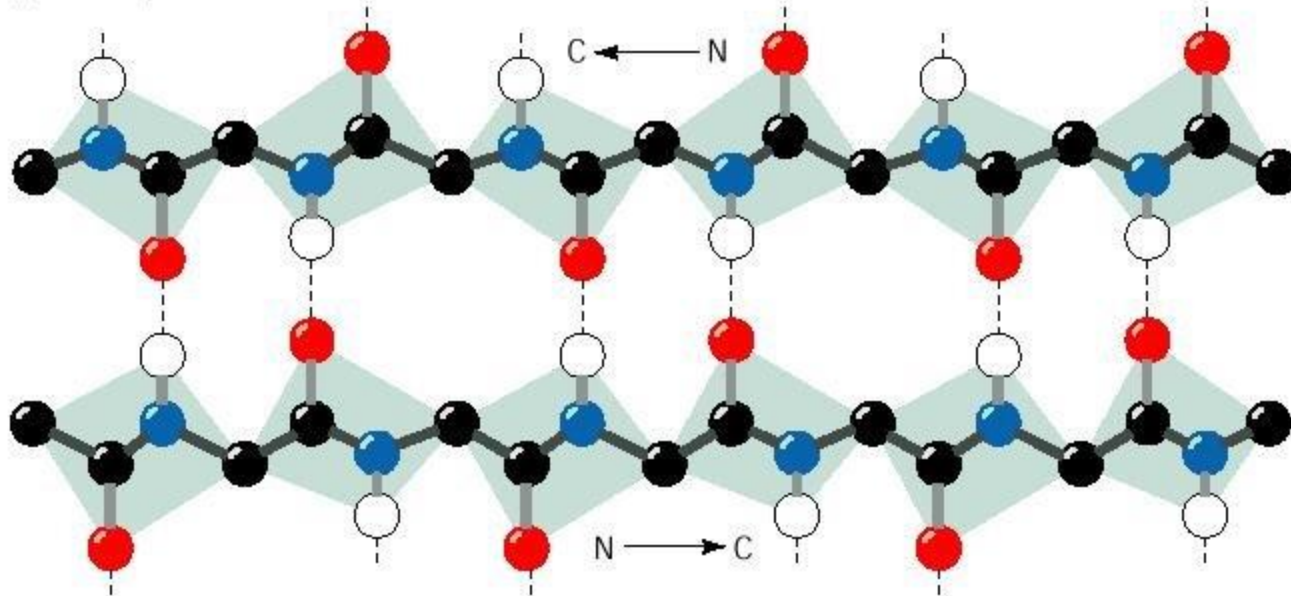
A Helical-Wheel plot

Remember,... 3.4 residues/turn

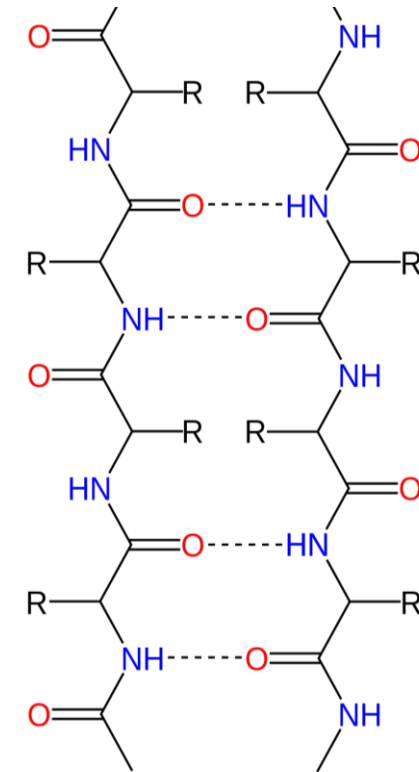


The Beta Sheet

(a) Antiparallel

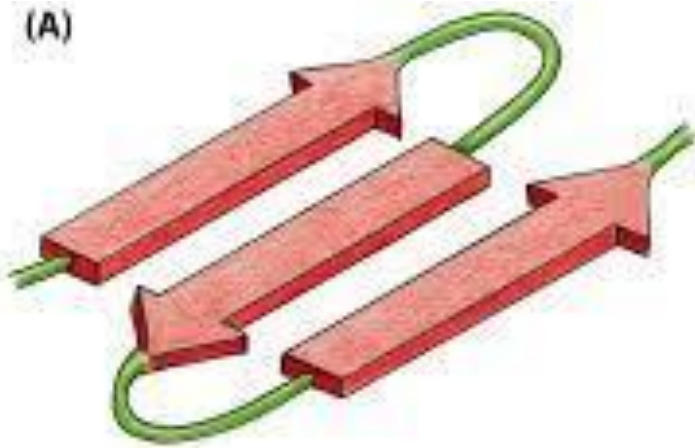


http://cmgm.stanford.edu/biochem201/Slides/Protein%20Structure/Anti_parallel%20Beta-Strands.JPG

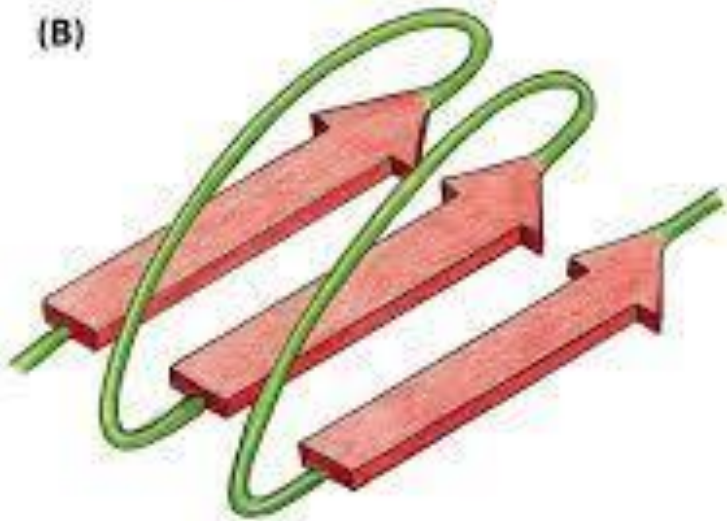


Antiparallel

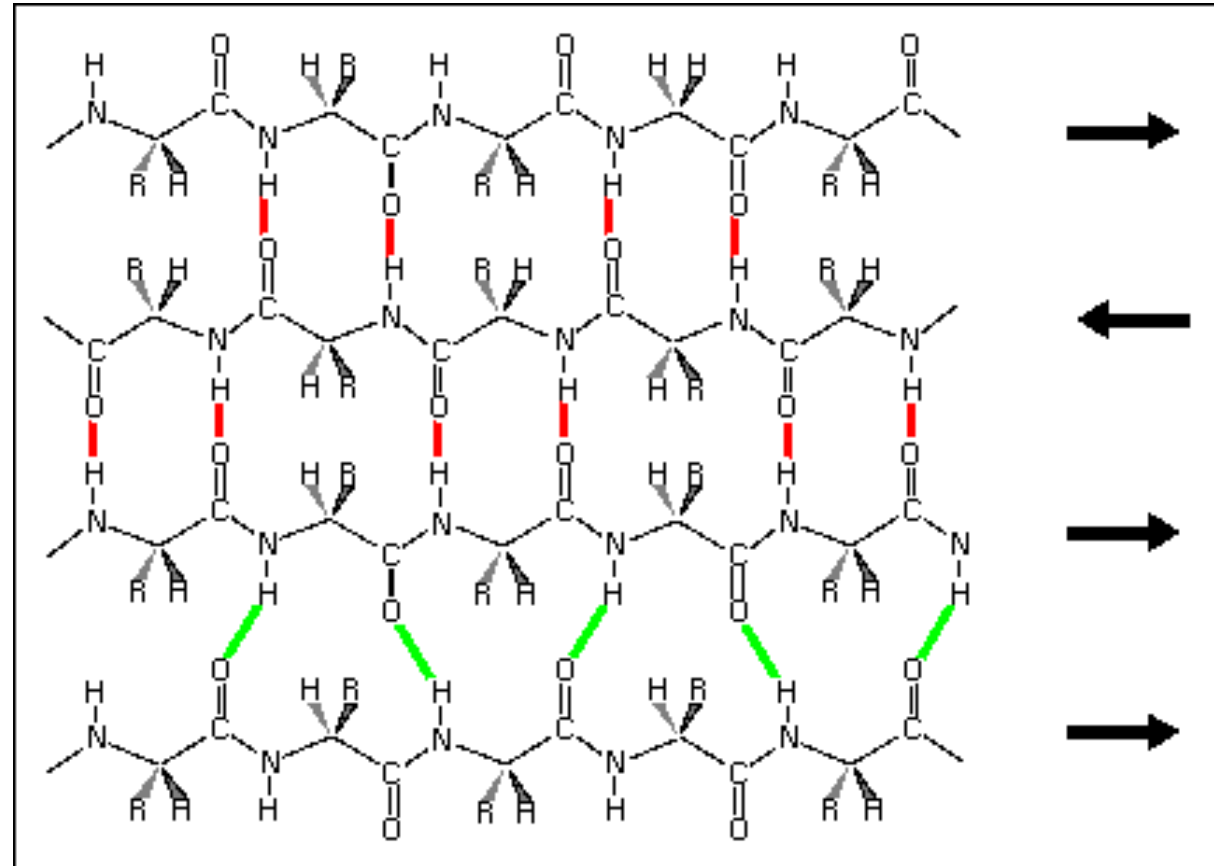
(A)



(B)



Parallel



But now that everything has changed



The Amino Acid Starter Kit is the best thing we have ever done!

And yet,... **all models are wrong** ... (some models are useful.)

So,... what's wrong with this very useful model?

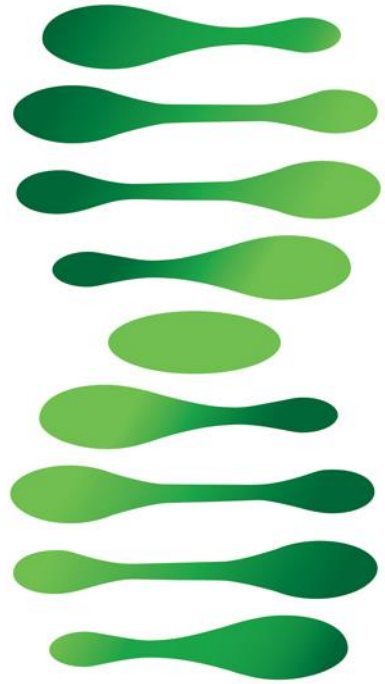
1.

2.

3.

4.





Transforming Science Learning

