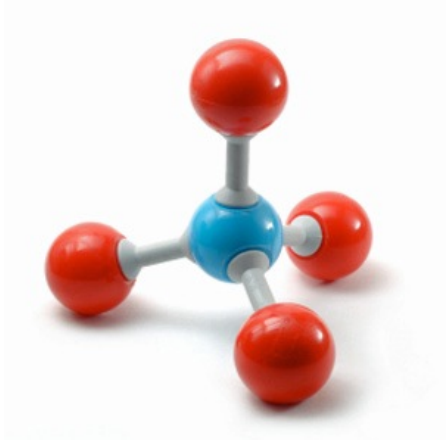
Ch16

Amino Acids

Amino Acids and proteins we make from them.

A whole new scale of biomolecule.

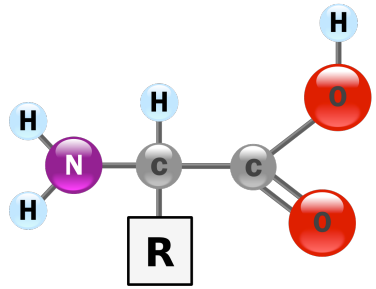


version 1.0

Ch16

Amino Acids

- Talking about Proteins
  - A whole new scale
  - Protein Function
- Amino Acids
  - Structure
    - α Carbon
    - Zwitterion
  - 20 Primary Amino Acids
    - Polar and Nonpolar
    - Acidic and Basic
  - Drawing Amino Acids
  - D/L Stereoisomers
  - Sources
    - Essential Amino Acids



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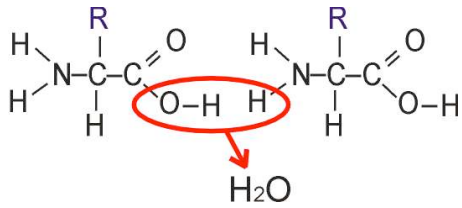
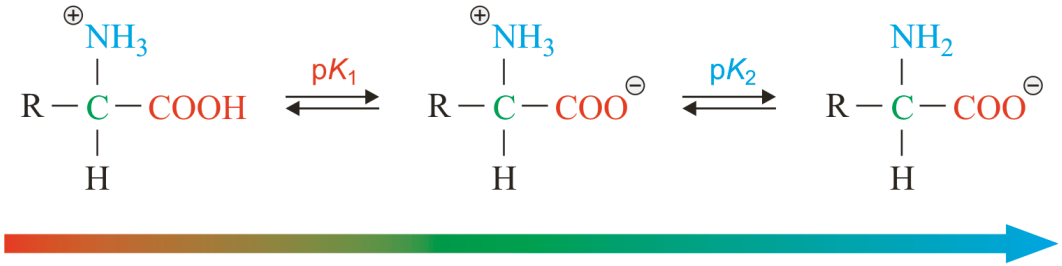
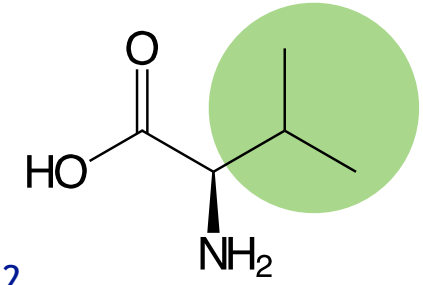
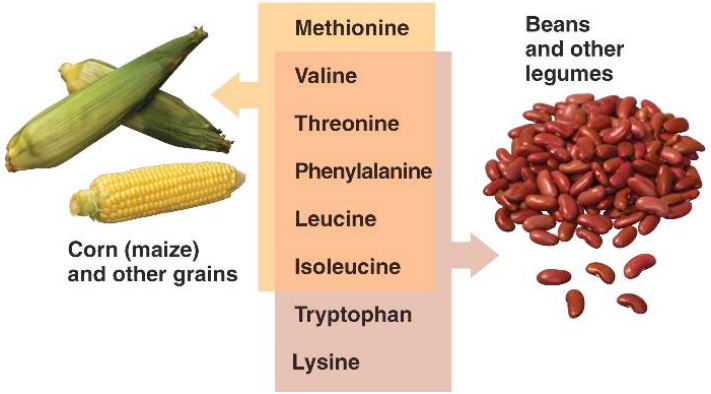
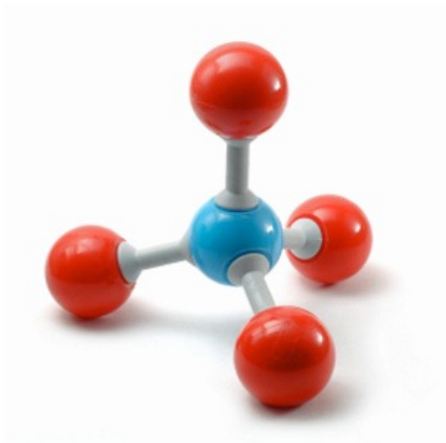










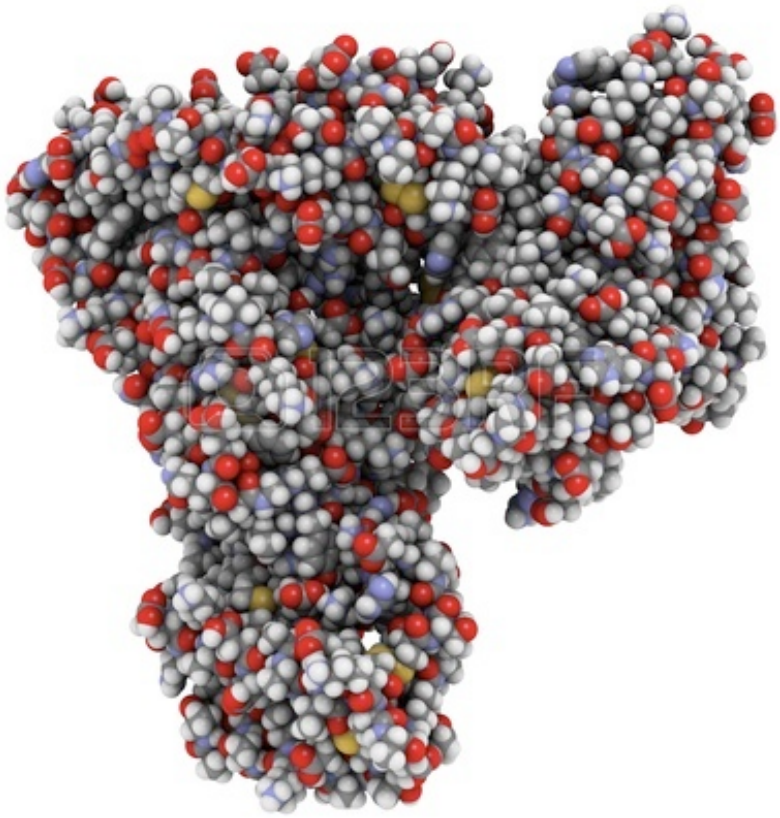
Proteins

Class of Protein	Function	Examples
Structural	Provide structural components	*Collagen* is in tendons and cartilage. *Keratin* is in hair, skin, wool, and nails.
Contractile	Make muscles move	*Myosin* and *actin* contract muscle fibers.
Transport	Carry essential substances throughout the body	*Hemoglobin* transports oxygen. *Lipoproteins* transport lipids.
Storage	Store nutrients	*Casein* stores protein in milk. *Ferritin* stores iron in the spleen and liver.
Hormone	Regulate body metabolism and the nervous system	*Insulin* regulates blood glucose level. *Growth hormone* regulates body growth.
Enzyme	Catalyze biochemical reactions in the cells	*Sucrase* catalyzes the hydrolysis of sucrose. *Trypsin* catalyzes the hydrolysis of proteins.
Protection	Recognize and destroy foreign substances	*Immunoglobulins* stimulate immune responses.

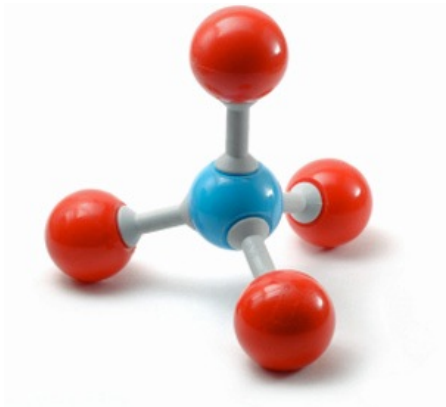
- Proteins do a lot of things, they…
  - Provide structure. Components such as muscle, bone, skin, hair, nails and even the horns of animals are made of protein…
  - Function as enzymes to control chemical reactions such as digestion and cellular metabolism.
  - Act as mechanisms, like how hemoglobin and myoglobin transport oxygen in the blood or how muscle fibers contract to move your arm.

Proteins

- Protein molecules, compared with many of the compounds we have studied, can be … much bigger.



- You're familiar with molecules like:
  - Carbon Dioxide (3 atoms; mm 44 g/mol)
  - Glucose (24 atoms; mm 180 g/mol)
- These are examples of protein molecules:
  - Insulin (483 atoms; mm 5,800 g/mol)
  - Hemoglobin (5,000 atoms; mm 67,000 g/mol)
- Proteins are polymers.
- Proteins are made from amino acids, linked together.



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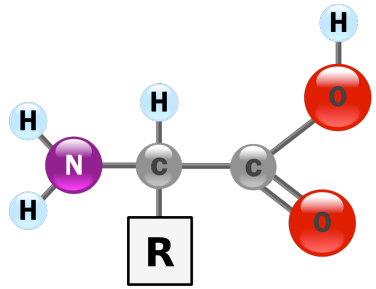

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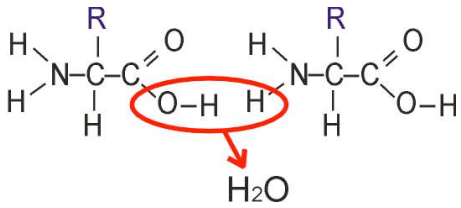
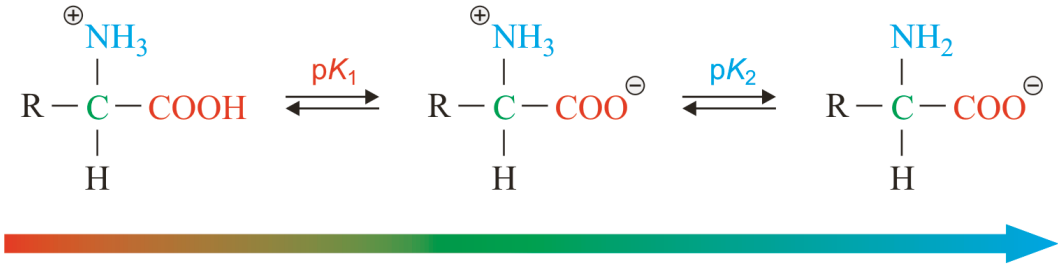
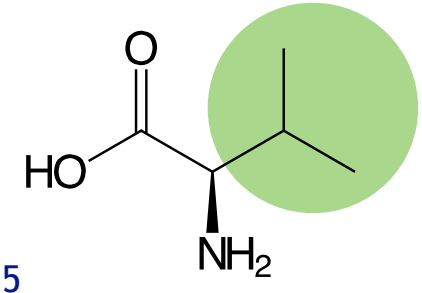
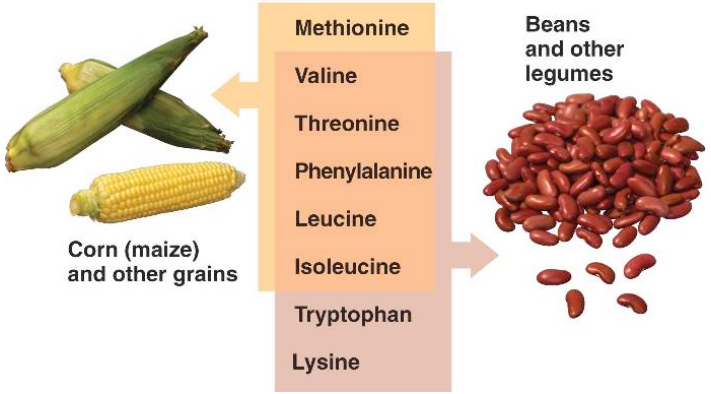
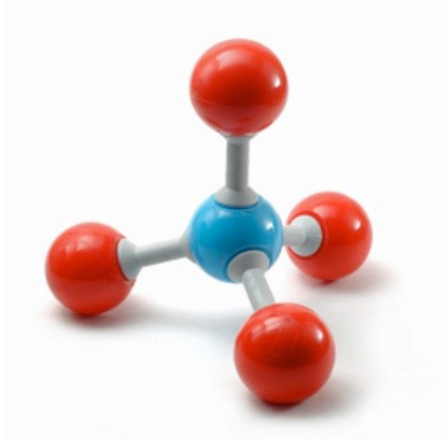




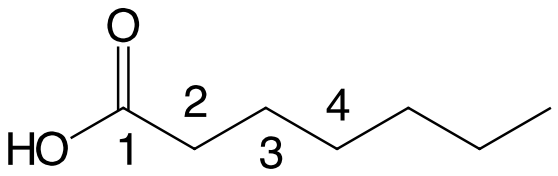


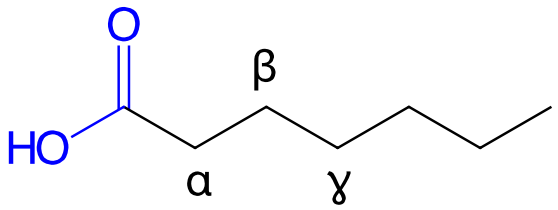


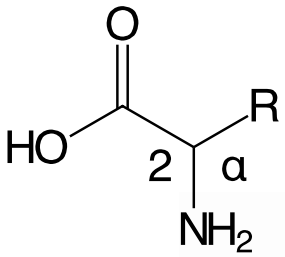


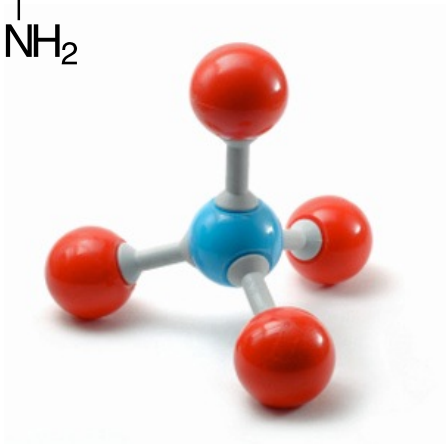
Amino Acid Structure

- Proteins are built from amino acids.
- Amino acids are a carbon backbone with an amine and a carboxylic acid.
- There are a lot of amino acids.
- The human body builds proteins from twenty, that all have the amine in the same position.
- They're named after that common feature:
  - 2-amino acids or α-amino acids
- The twenty α-amino acids we make proteins from are called the primary amino acids.
- They differ by the residue R.



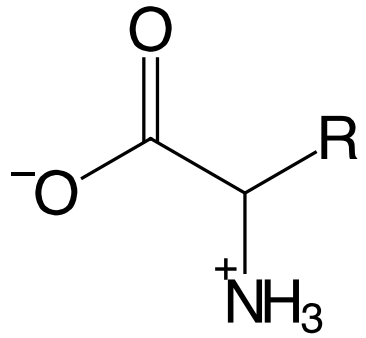


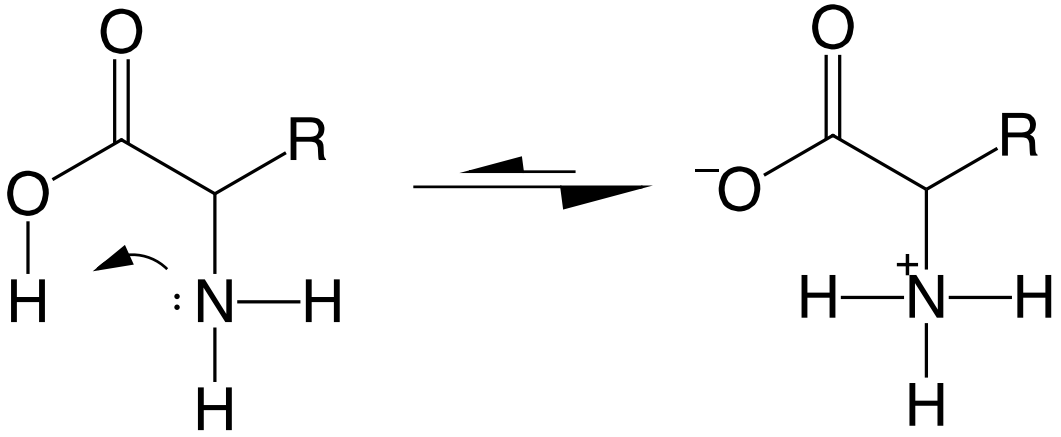


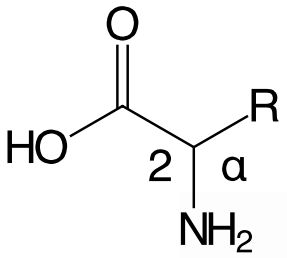


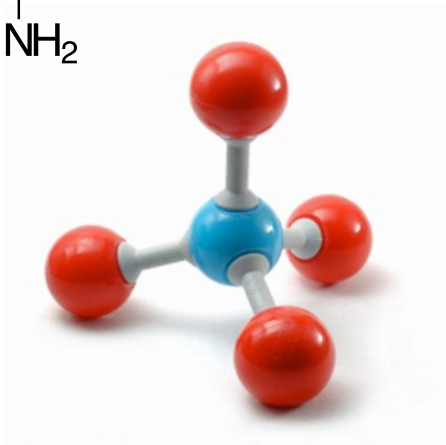
Amino Acid Structure

- α-Amino acids have a melting point in the 200-300° C range.
  - This is really high for organic compounds of this size.
  - The reason for this is α-amino acids have an acid and base in the same molecule, right next to each other.
- Amino acids commonly form a zwitterion.
- A zwitterion is a neutral molecule with both a positive and a negative electrical charge.
- Zwitterions are sometimes also called inner salts.









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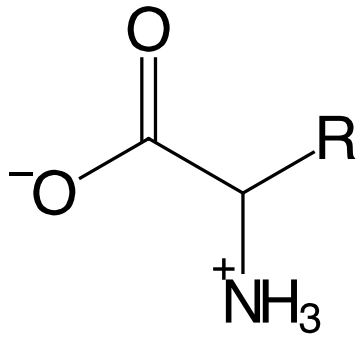
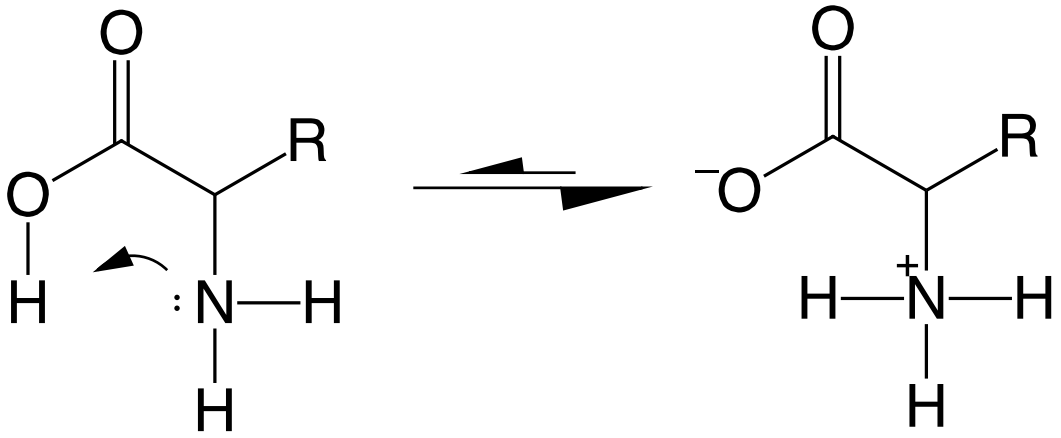
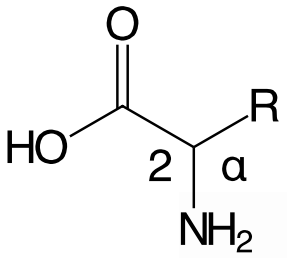
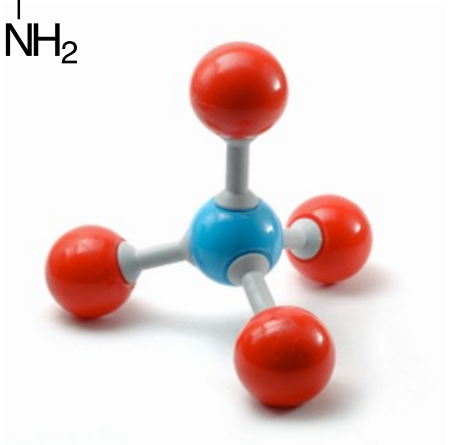


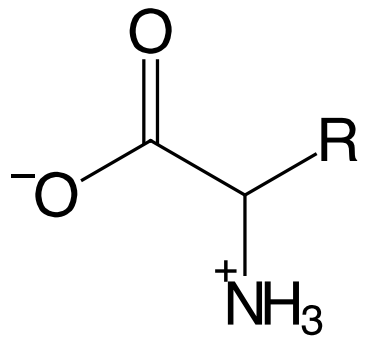




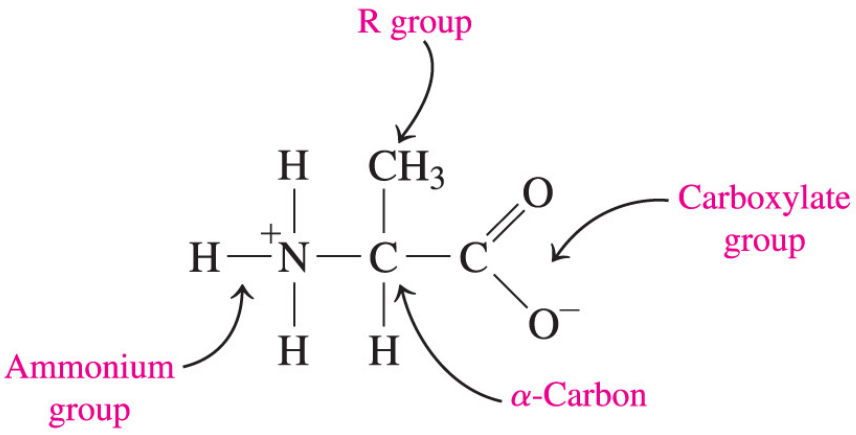


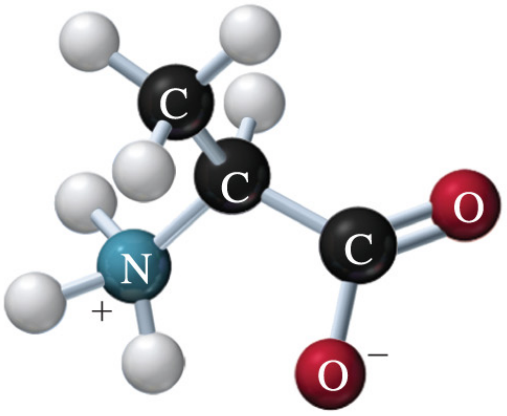
Amino Acid Structure

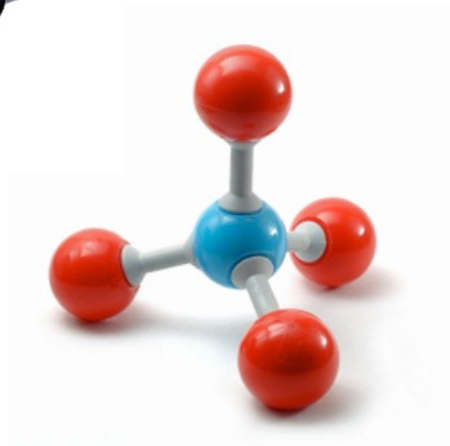
- In biological systems, amino acids are written as the zwitterion.
  - the central atom is the α-carbon bonded to:
    - an ammonium group ($-NH_3^+$)
    - a carboxylate group ($-COO^{1-}$)
    - a hydrogen atom
    - and a R group or side chain



- Differences in the R group produce the different α-amino acids.

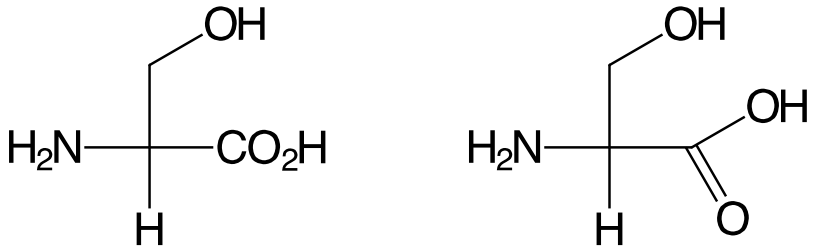




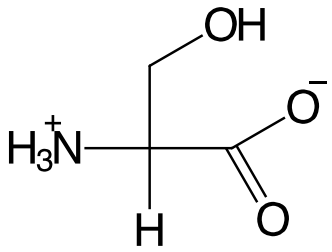


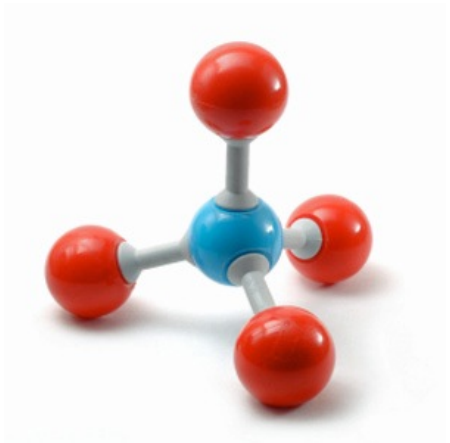
Try it.

- Serine is the primary amino acid whose residue (R) is a methoxy group (—CH_2OH). Draw the unionized structure of this amino acid.



- Draw the zwitterion structure of SER (serine).





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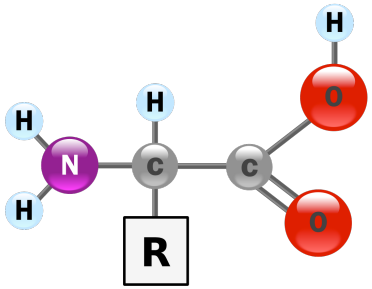

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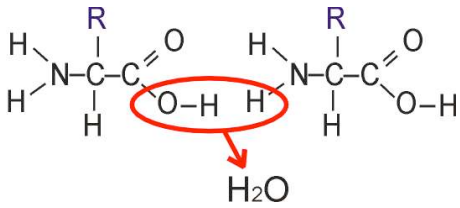
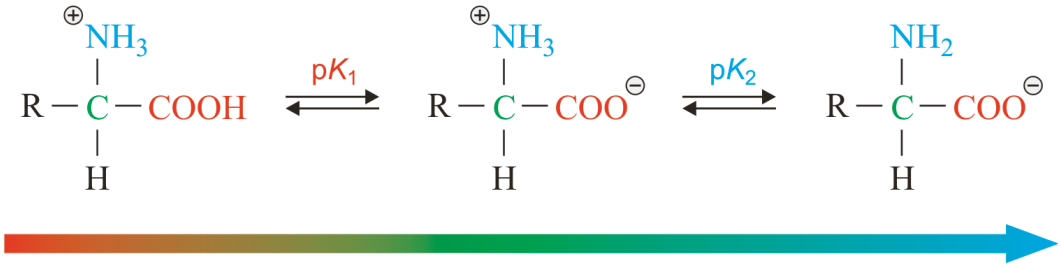
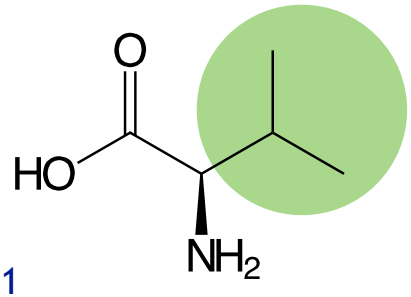
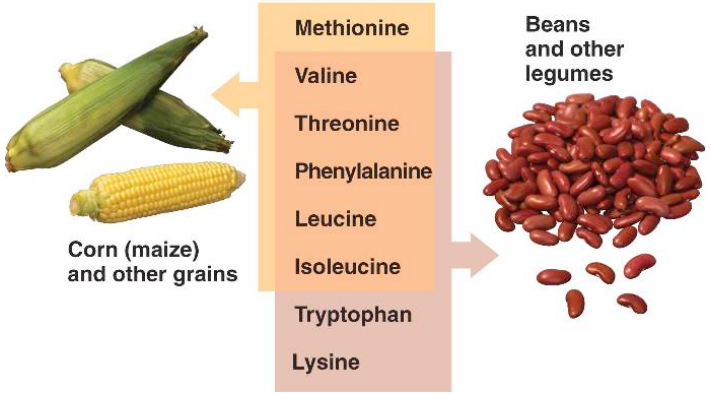
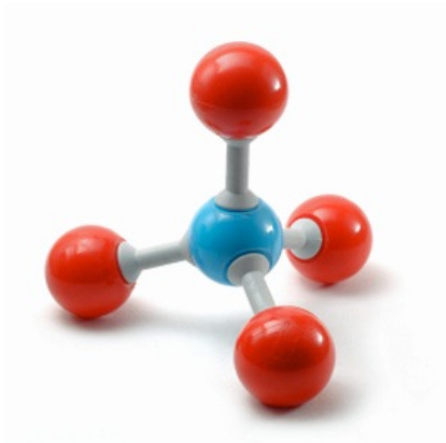




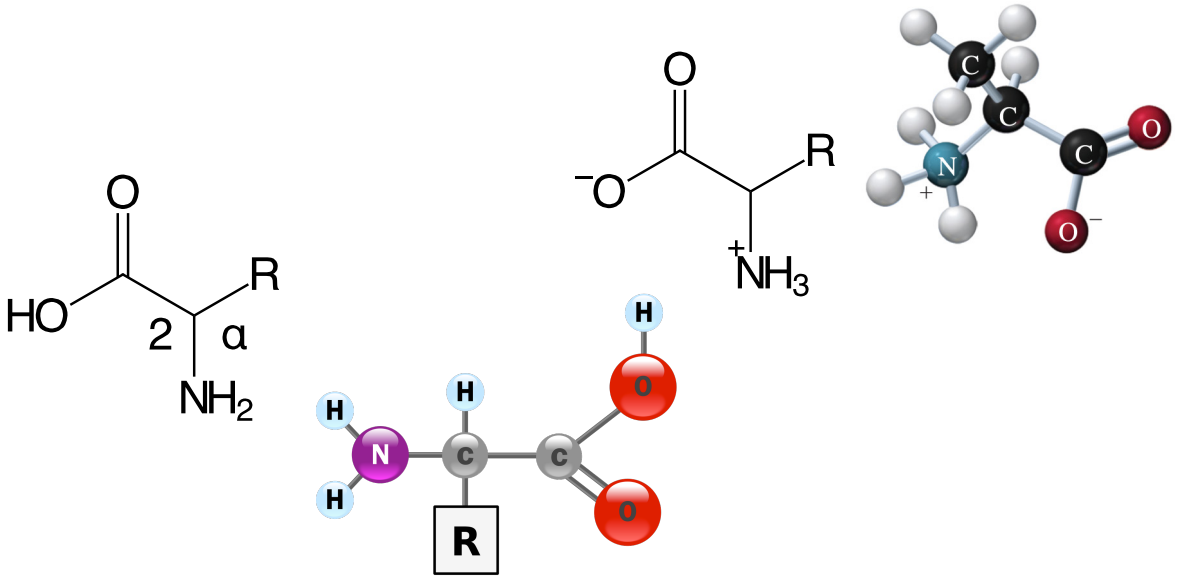






Twenty Primary Amino Acids

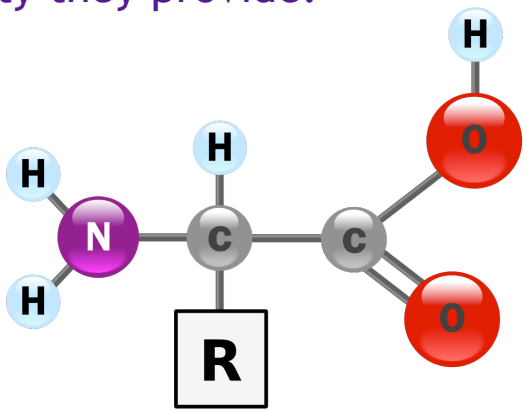
- There are more than 20 α-amino acids that the human body uses (some are consumed to produce energy).
- 20 are used to build proteins.
- These twenty primary amino acids have both a 3 letter and 1 letter designation.
- You need to be able to convert between the names, 3 letter codes and 1 letter codes for these amino acids.



No.	Amino acid	3-Letter code	1-Letter code
1	Alanine	Ala	A
2	Arginine	Arg	R
3	Asparagine	Asn	N
4	Aspartic acid	Asp	D
5	Cysteine	Cys	C
6	Glutamine	Gln	Q
7	Glutamic acid	Glu	E
8	Glycine	Gly	G
9	Histidine	His	H
10	Isoleucine	Ile	I
11	Leucine	Leu	L
12	Lysine	Lys	K
13	Methionine	Met	M
14	Phenylalanine	Phe	F
15	Proline	Pro	P
16	Serine	Ser	S
17	Threonine	Thr	T
18	Tryptophan	Trp	W
19	Tyrosine	Tyr	Y
20	Valine	Val	V

Twenty Primary Amino Acids

- The structural differences in the “R” group of primary amino acids will determine the properties of proteins formed from them.
- Amino acids are classified into different categories to help recognize common functionality they provide.



- Four primary categories are:
  - Amino acids with polar “R” groups.
  - Amino acids with non-polar “R” groups.
  - Amino acids with acidic “R” groups.
  - Amino acids with basic “R” groups.

No.	Amino acid	3-Letter code	1-Letter code
1	Alanine	Ala	A
2	Arginine	Arg	R
3	Asparagine	Asn	N
4	Aspartic acid	Asp	D
5	Cysteine	Cys	C
6	Glutamine	Gln	Q
7	Glutamic acid	Glu	E
8	Glycine	Gly	G
9	Histidine	His	H
10	Isoleucine	Ile	I
11	Leucine	Leu	L
12	Lysine	Lys	K
13	Methionine	Met	M
14	Phenylalanine	Phe	F
15	Proline	Pro	P
16	Serine	Ser	S
17	Threonine	Thr	T
18	Tryptophan	Trp	W
19	Tyrosine	Tyr	Y
20	Valine	Val	V

Alanine	
Arginine	
Asparagine	
Aspartic Acid	
Cysteine	

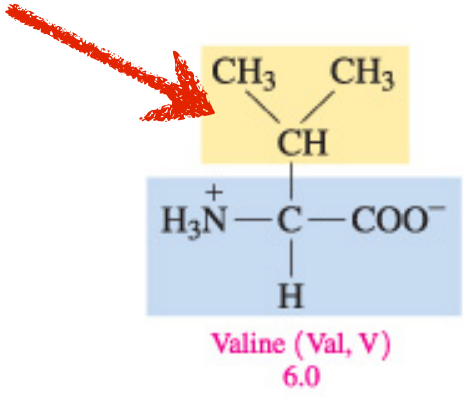
No.	Amino acid	3-Letter code	1-Letter code
1	Alanine	Ala	A
2	Arginine	Arg	R
3	Asparagine	Asn	N
4	Aspartic acid	Asp	D
5	Cysteine	Cys	C
6	Glutamine	Gln	Q
7	Glutamic acid	Glu	E
8	Glycine	Gly	G
9	Histidine	His	H
10	Isoleucine	Ile	I
11	Leucine	Leu	L
12	Lysine	Lys	K
13	Methionine	Met	M
14	Phenylalanine	Phe	F
15	Proline	Pro	P
16	Serine	Ser	S
17	Threonine	Thr	T
18	Tryptophan	Trp	W
19	Tyrosine	Tyr	Y
20	Valine	Val	V

Amino Acids

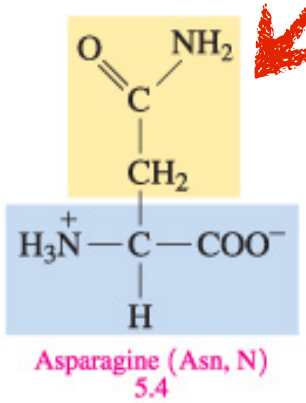
- Amino acids are classified as
  - nonpolar (hydrophobic) with hydrocarbon side chains
  - polar (hydrophilic) with polar or ionic side chains

valine is classified as non-polar because it's side chain is non-polar (an isopropyl group)

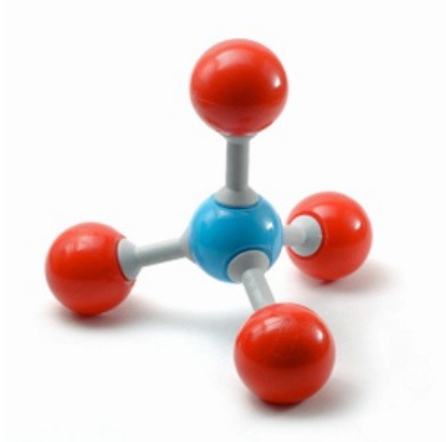
asparagine is classified as polar because it's side chain is polar (an amide)



Nonpolar
Valine

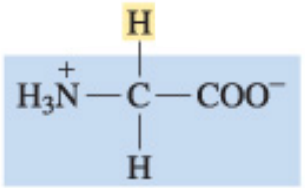


Polar
Asparagine

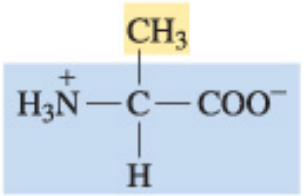


Nonpolar Amino Acids

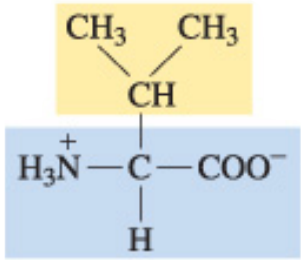
- An amino acid is nonpolar when the R group is H, alkyl, or aromatic.
- Nine of the primary amino acids are considered non-polar.



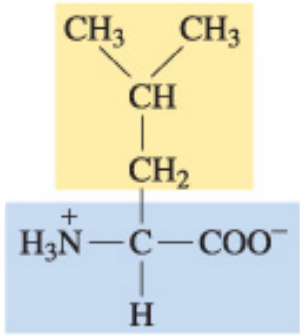
Glycine (Gly, G)
6.0



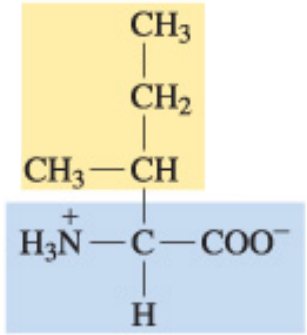
Alanine (Ala, A)
6.0



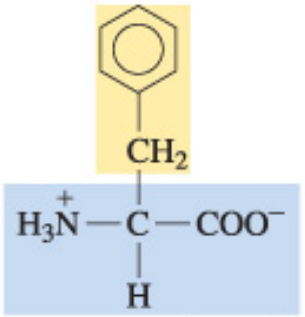
Valine (Val, V)
6.0



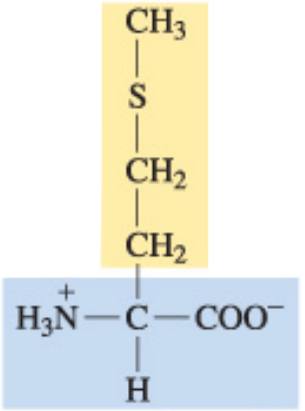
Leucine (Leu, L)
6.0



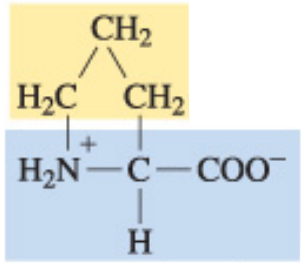
Isoleucine (Ile, I)
6.0



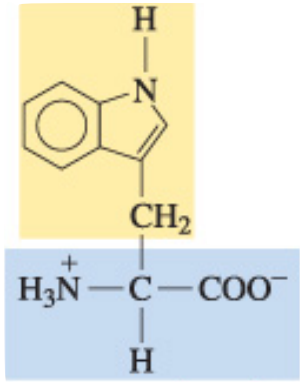
Phenylalanine (Phe, F)
5.5



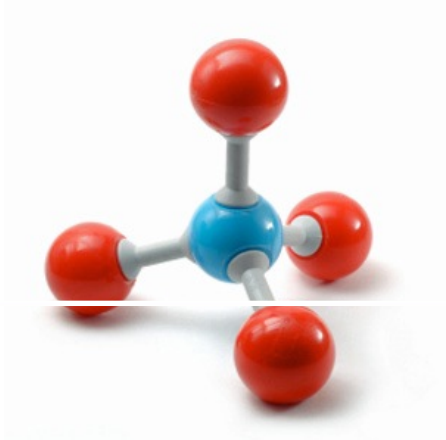
Methionine (Met, M)
5.7



Proline (Pro, P)
6.3

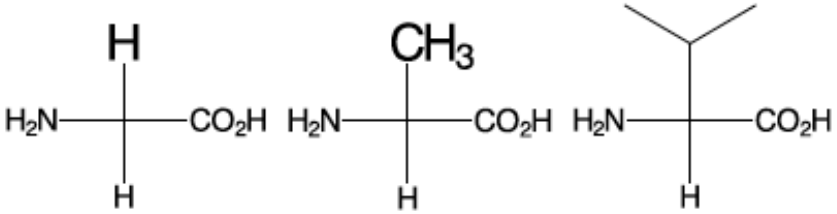


Tryptophan (Trp, W)
5.9



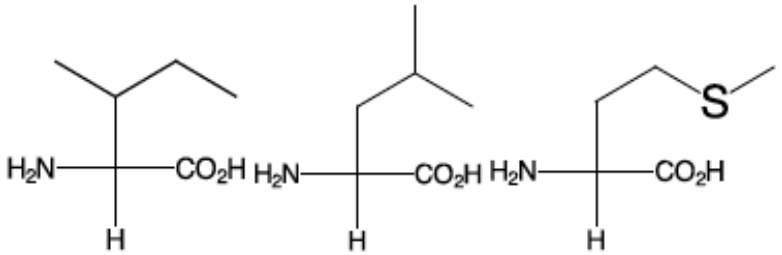
Nonpolar Amino Acids

SIMPLE



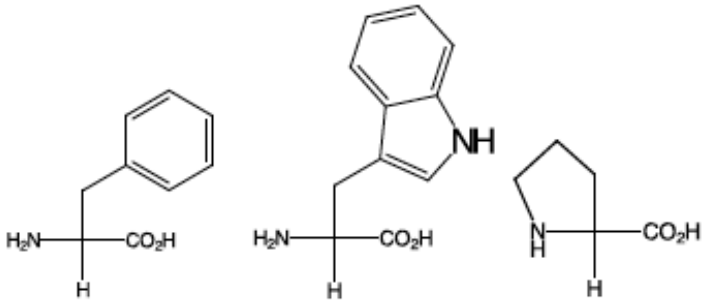
Glycine (GLY) (G) Alanine (ALA) (A) Valine (VAL) (V)

FLOPPY

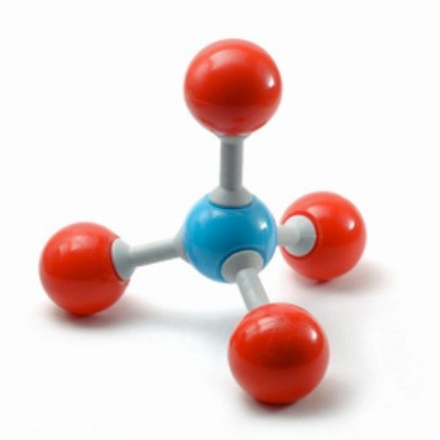


Leucine (LEU) (L) Isoleucine (ILE) (I) Methionine (MET) (M)

CYCLIC

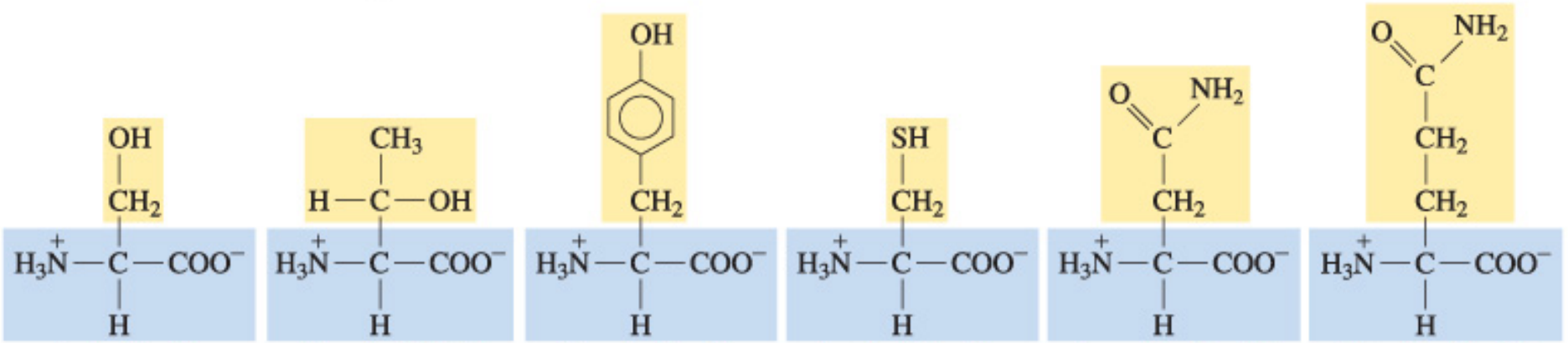


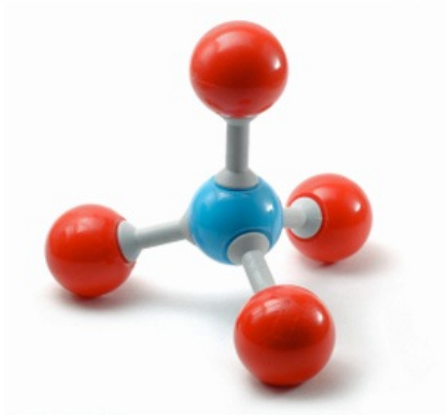
Phenylalanine(PHE) (F) Tryptophan(TRP) (W) Proline(PRO) (P)



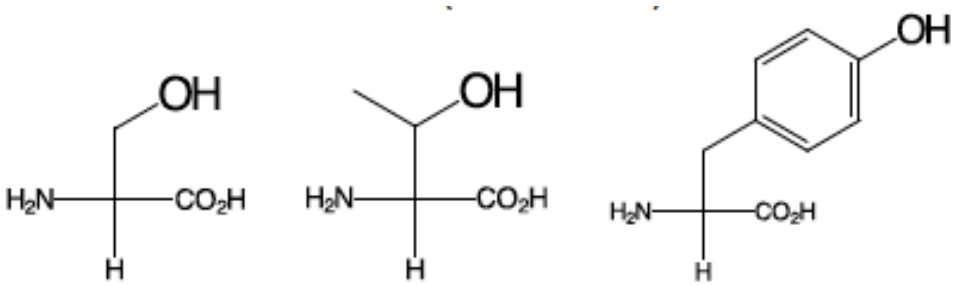
Polar Amino Acids

- An amino acid is polar when the R group is an alcohol, a thiol, or an amide.





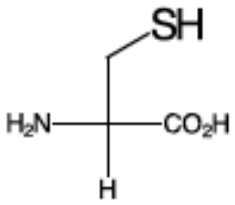
Polar Neutral Amino Acids



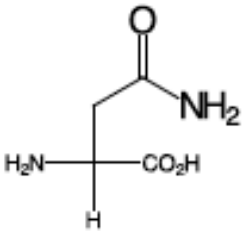
Serine (SER) (S)

Threonine (THR) (T)

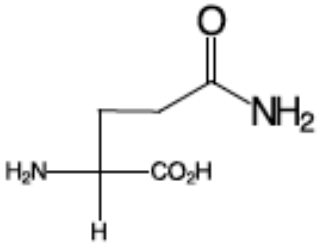
Tyrosine (TYR) (Y)



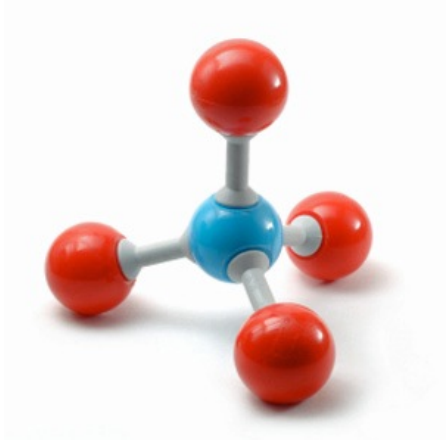
Cysteine (CYS) (C)



Asparagine (ASN) (N)

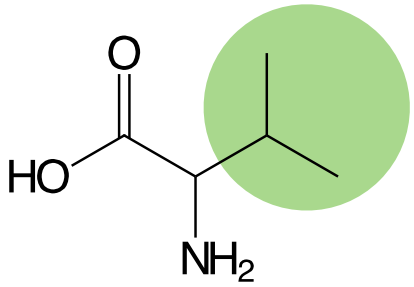


Glutamine (GLN) (Q)

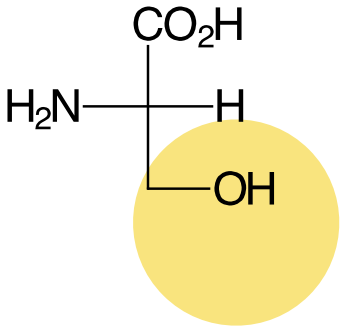


Try it.

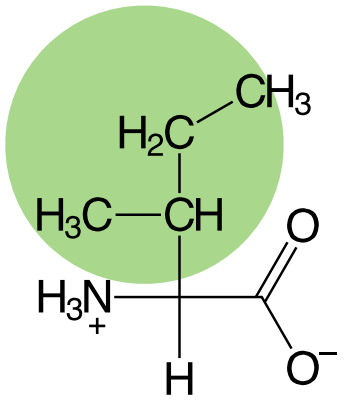
- For each amino acid shown below, determine if it's a polar or non-polar amino acid.



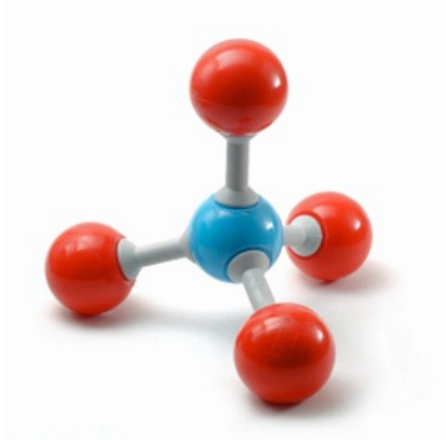
Valine (VAL, V)
Non-polar



Serine (SER, S)
Polar



Isoleucine (ILE, I)
Non-polar

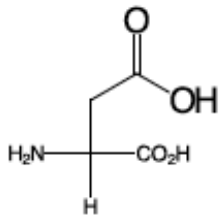


Acidic Amino Acids

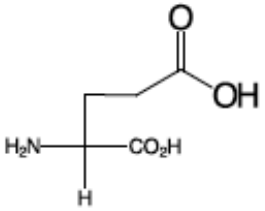
- An amino acid is acidic when the R group is a carboxylic acid.

Amino Acids with Charged R Groups

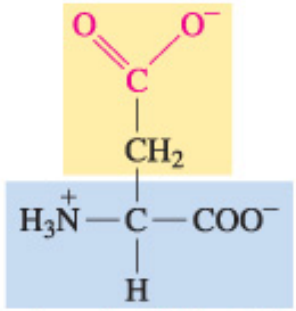
Acidic (negative charge)



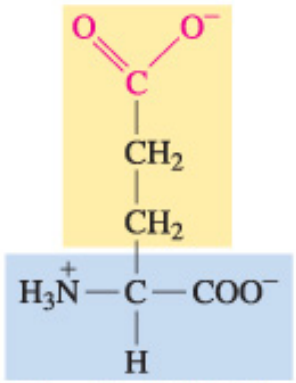
Aspartic Acid (ASP) (D)



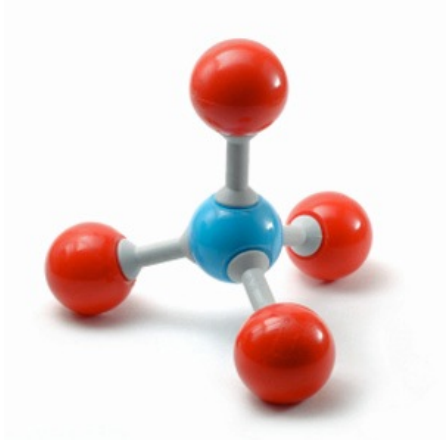
Glutamic Acid (THR) (T)



Aspartic acid (Asp, D)
2.8

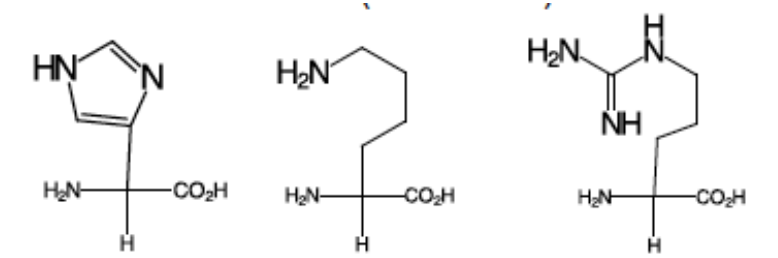


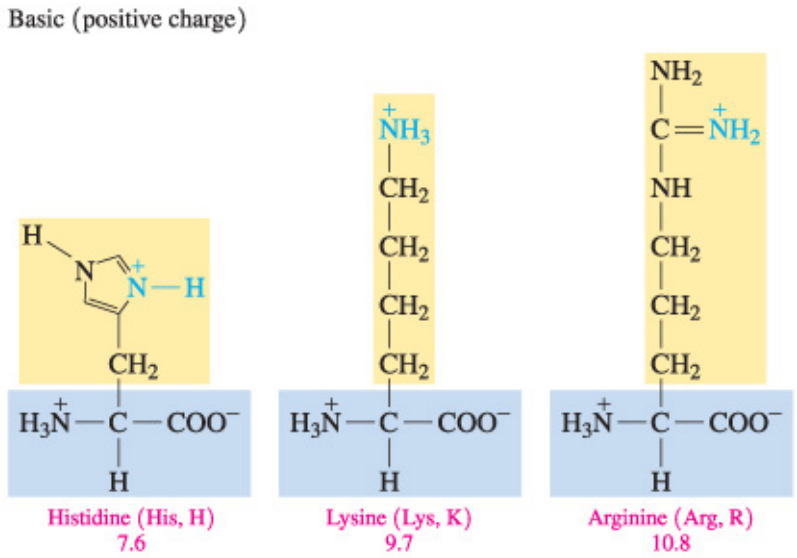
Glutamic acid (Glu, E)
3.2

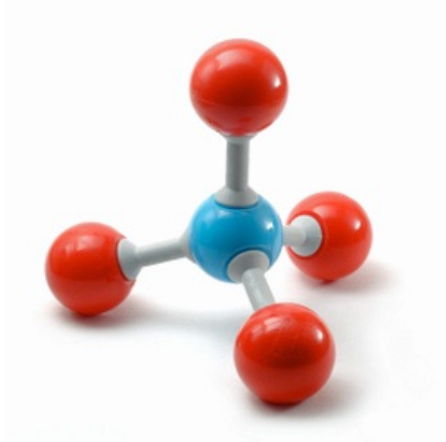


Basic Amino Acids

- An amino acid is basic when the R group is an amine.



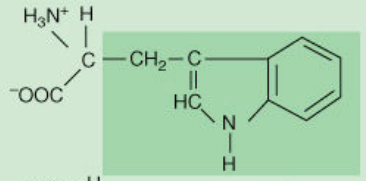




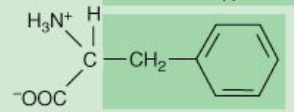
Twenty Primary Amino Acids

you do not need to memorize the structure of each amino acid.

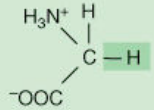
Neutral, nonpolar



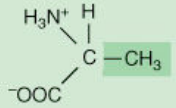
Tryptophan (Trp) (W)



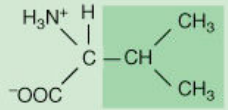
Phenylalanine (Phe) (F)



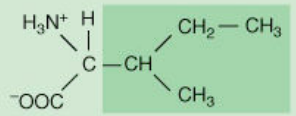
Glycine (Gly) (G)



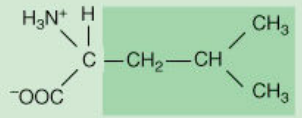
Alanine (Ala) (A)



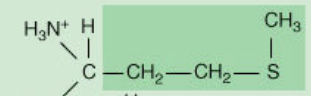
Valine (Val) (V)



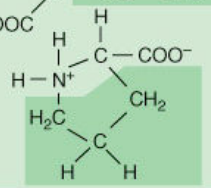
Isoleucine (Ile) (I)



Leucine (Leu) (L)

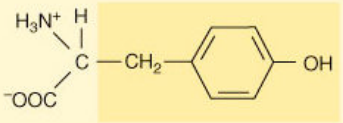


Methionine (Met) (M)

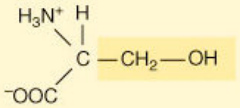


Proline (Pro) (P)

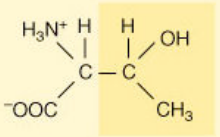
Neutral, polar



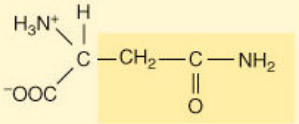
Tyrosine (Tyr) (Y)



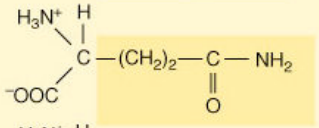
Serine (Ser) (S)



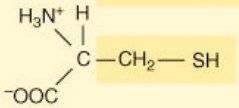
Threonine (Thr) (T)



Asparagine (Asn) (N)

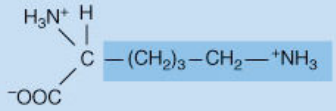


Glutamine (Gln) (Q)

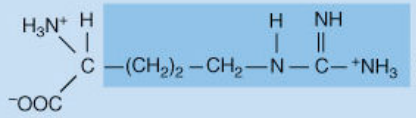


Cysteine (Cys) (C)

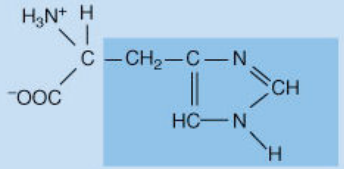
Basic



Lysine (Lys) (K)

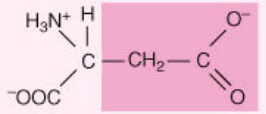


Arginine (Arg) (R)

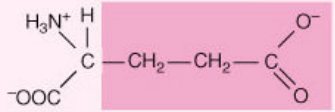


Histidine (His) (H)

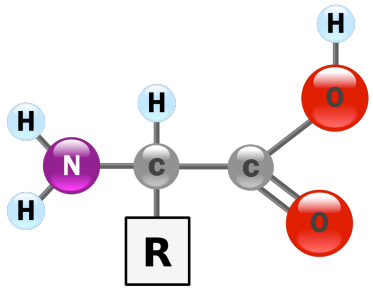
Acidic



Aspartic acid (Asp) (D)



Glutamic acid (Glu) (E)



Amino Acids

- Talking about Proteins
  - A whole new scale
  - Protein Function
- Amino Acids
  - Structure
    - α Carbon
    - Zwitterion
  - 20 Primary Amino Acids
    - Polar and Nonpolar
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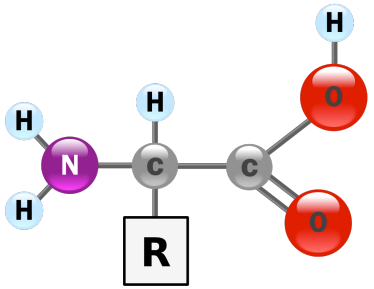
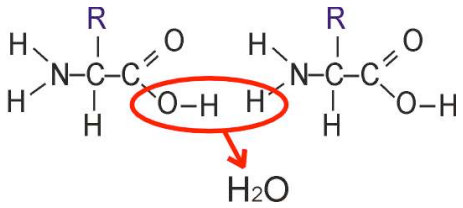
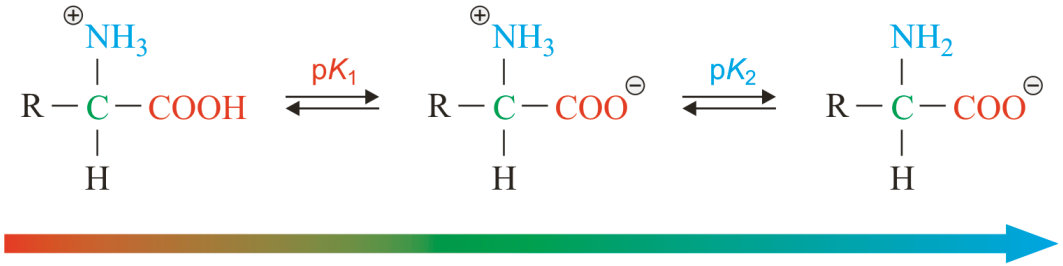
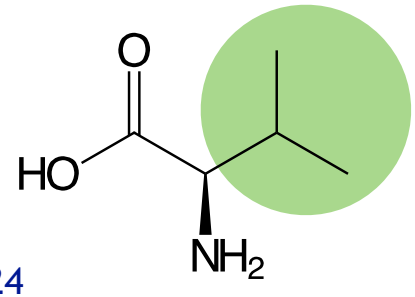
  - Drawing Amino Acids
  - D/L Stereoisomers
  - Sources
    - Essential Amino Acids

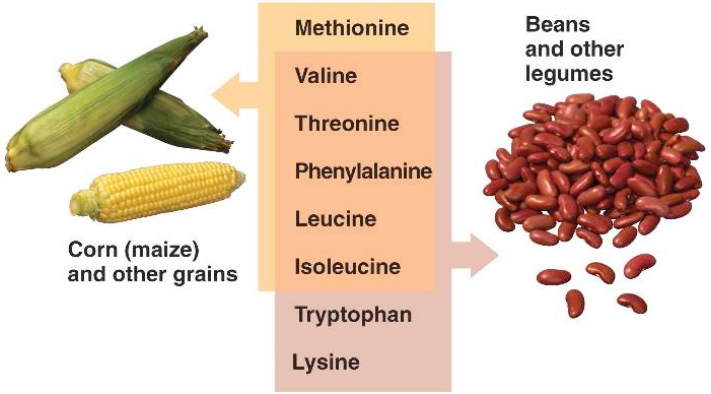


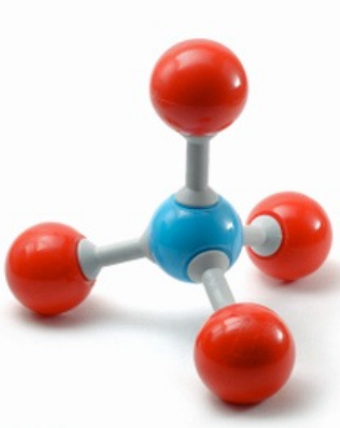
- Acid-Base Reactions
  - pI of Amino Acids
    - Below the pI
    - Above the pI





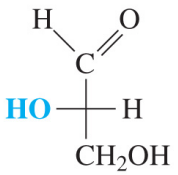




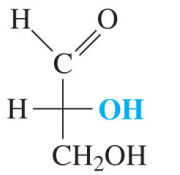


Stereoisomers

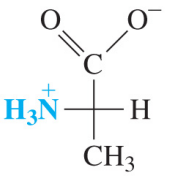
- All the α-amino acids except for glycine are chiral.
- The α-carbon is attached to four different atoms.
- If we draw the amino acid as a fisher projection:
  - The $-NH_3^+$ group appears on the right in D enantiomer.
  - The $-NH_3^+$ group appears on the left in L enantiomer.



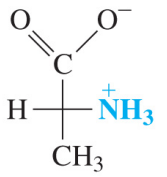
L-Glyceraldehyde



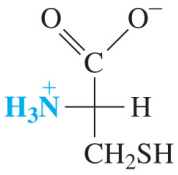
D-Glyceraldehyde



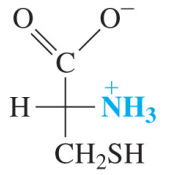
L-Alanine



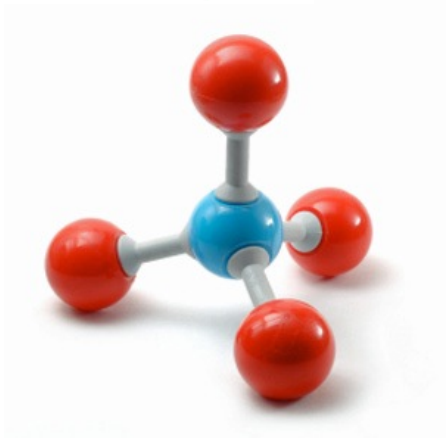
D-Alanine



L-Cysteine

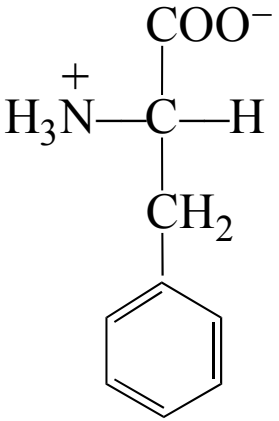


D-Cysteine

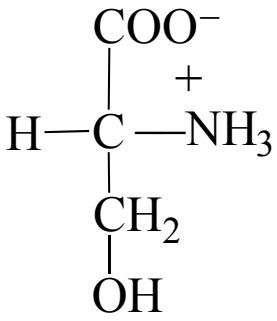


Try it.

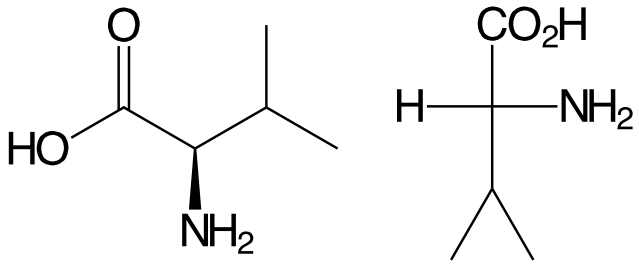
- Identify the following amino acids as D or L enantiomers:



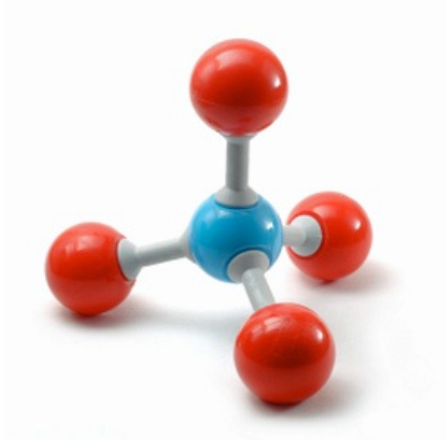
L-Phenylalanine



D-Serine



D-Valine



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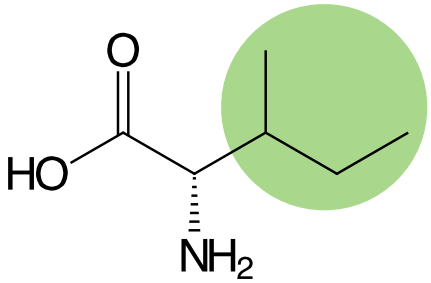
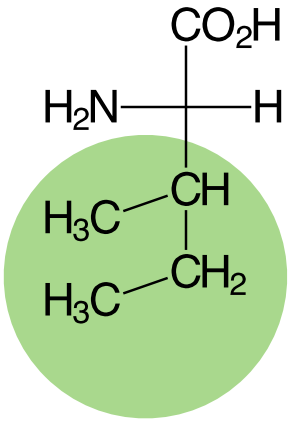
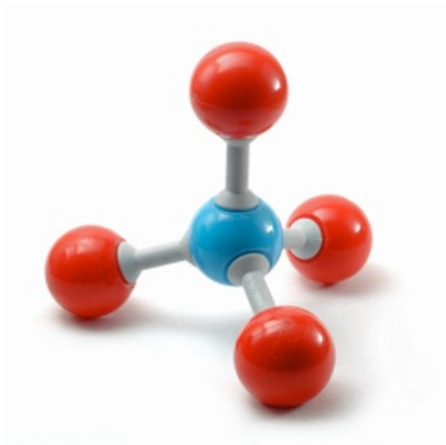




L-Isoleucine



Ch16

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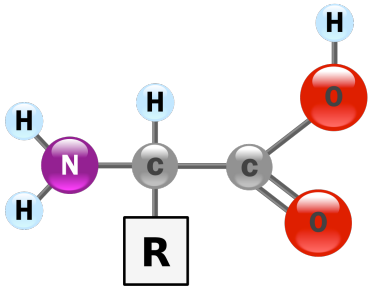

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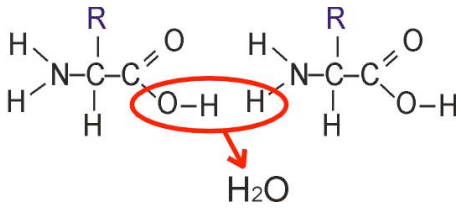
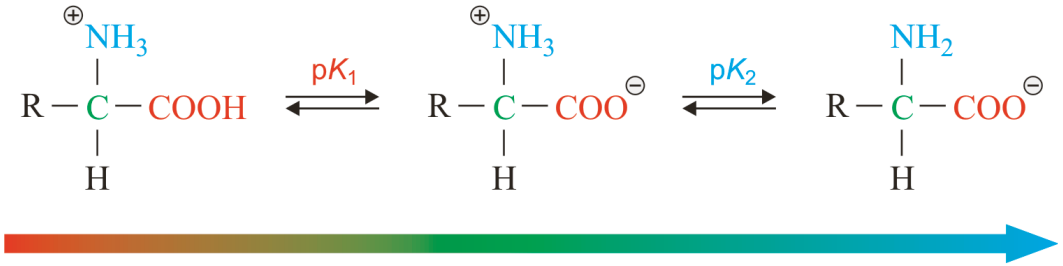
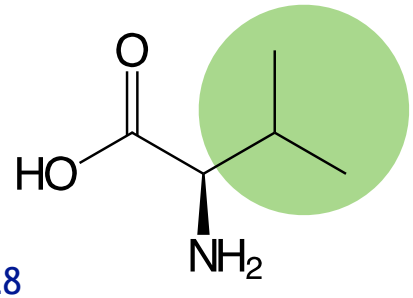
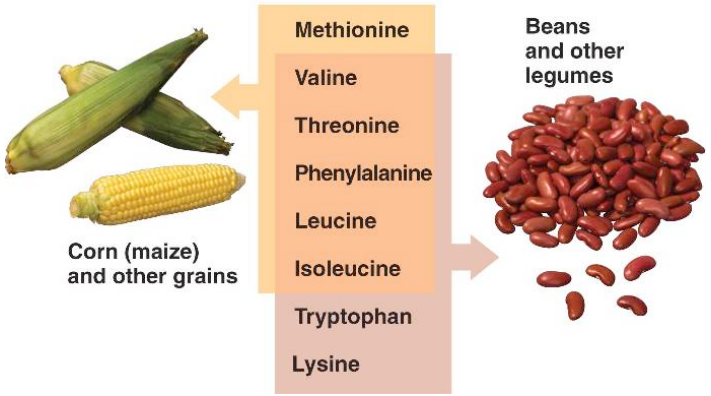
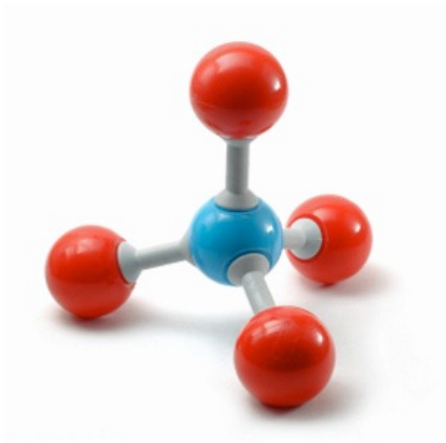




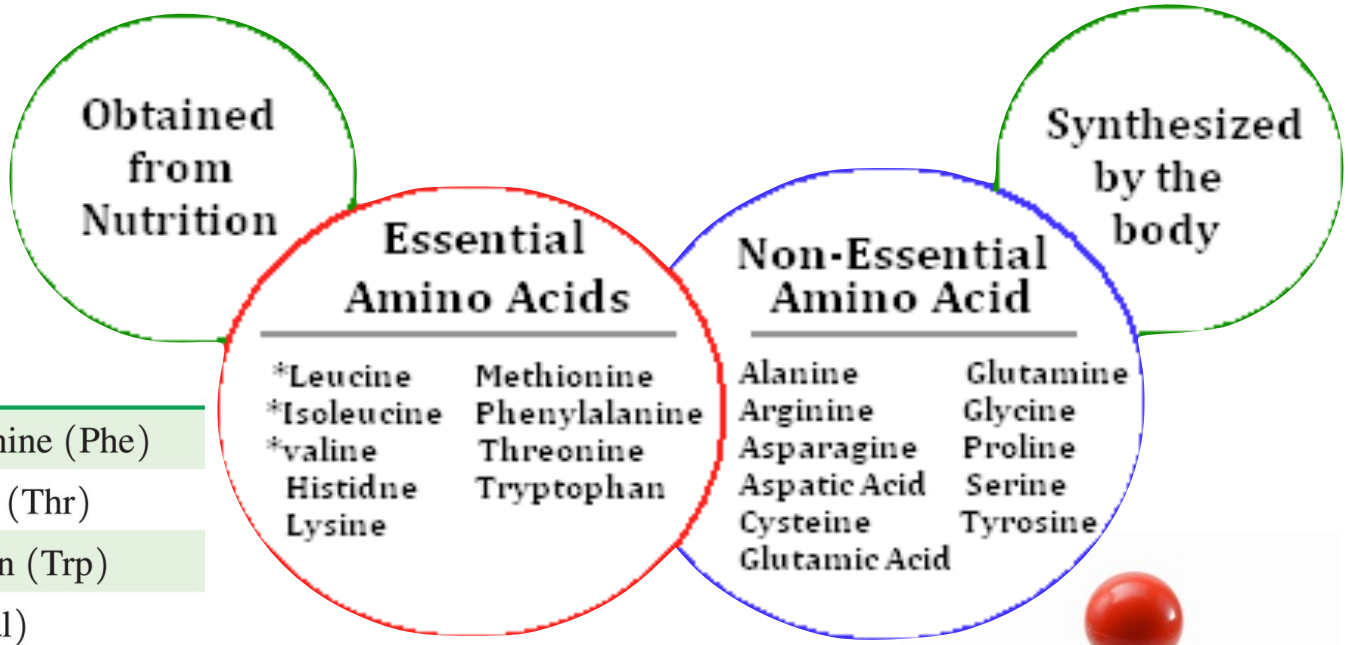




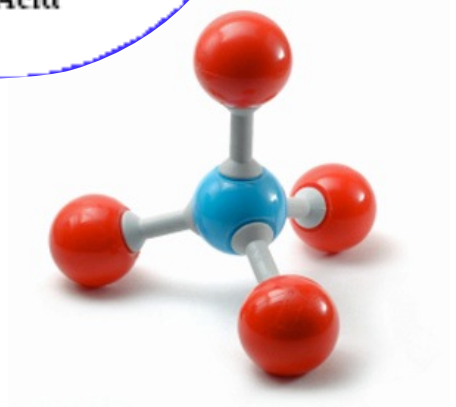


Sources of Amino Acids

- Of the 20 amino acids used to build the proteins in the body,
  - only 11 can be synthesized in the body
  - the other 9 amino acids are essential amino acids that must be obtained from the proteins in the diet



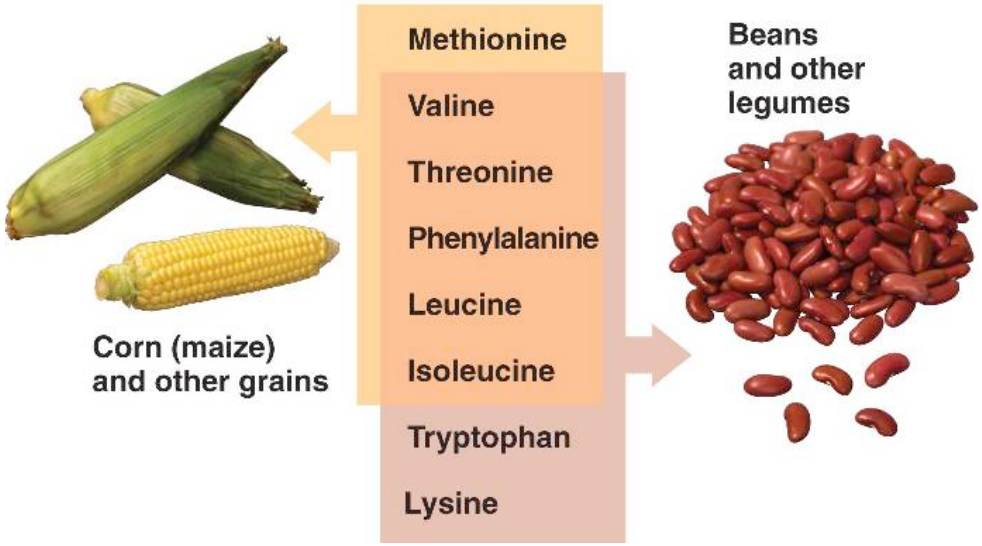
Histidine (His)	Phenylalanine (Phe)
Isoleucine (Ile)	Threonine (Thr)
Leucine (Leu)	Tryptophan (Trp)
Lysine (Lys)	Valine (Val)
Methionine (Met)	

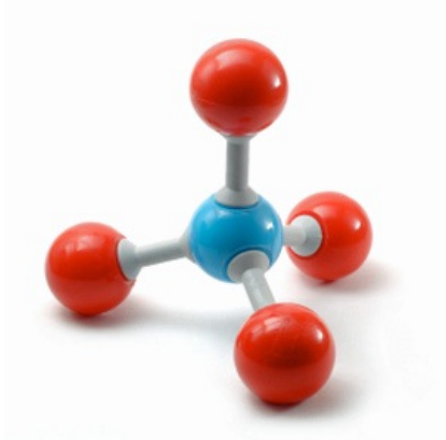


Sources of Amino Acids

- Complete proteins such as eggs, milk, meat, and fish contain all of the essential amino acids.

- Incomplete proteins from plants such as grains, beans, and nuts are deficient in one or more essential amino acids.





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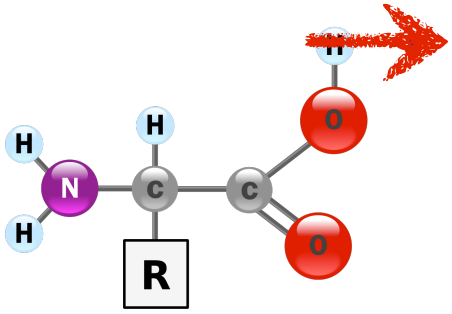

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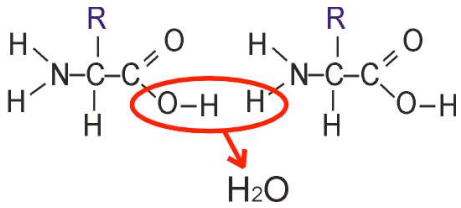
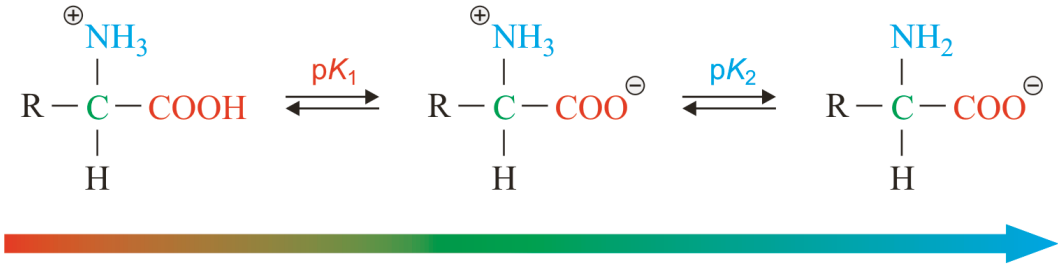
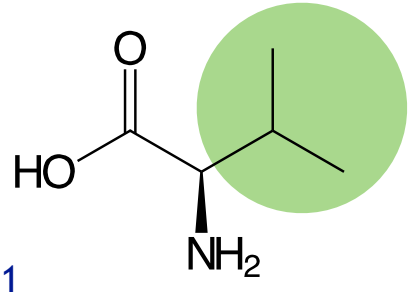
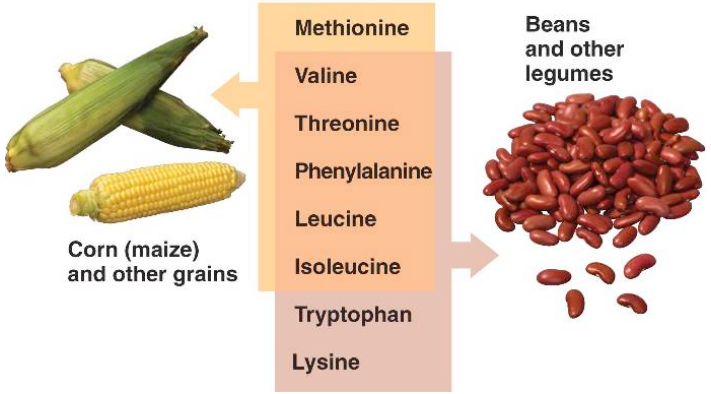
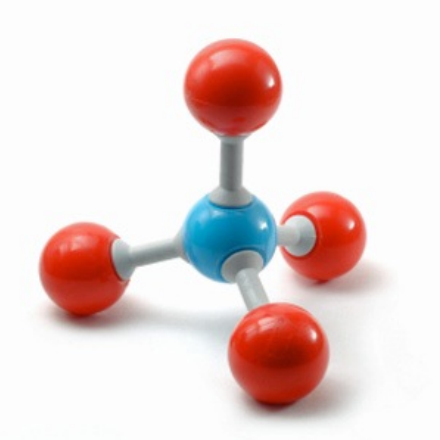






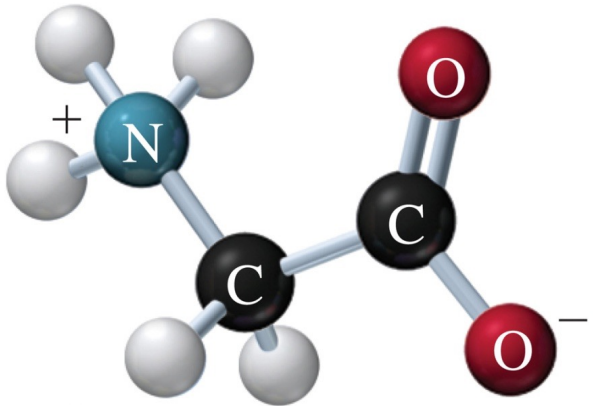


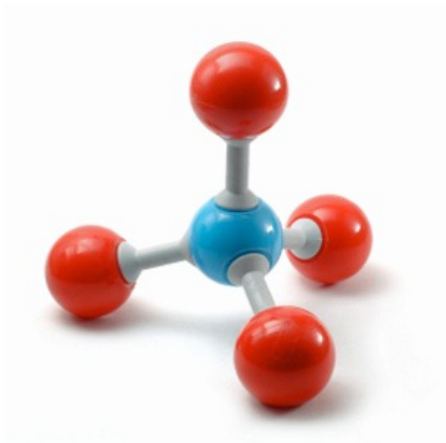


Isoelectric Point

- When an amino acid with positive and negative charges is overall neutral in charge, it is said to be at its isoelectric point (pI).

- Ball-and-stick model of glycine at its pI of 6.0.

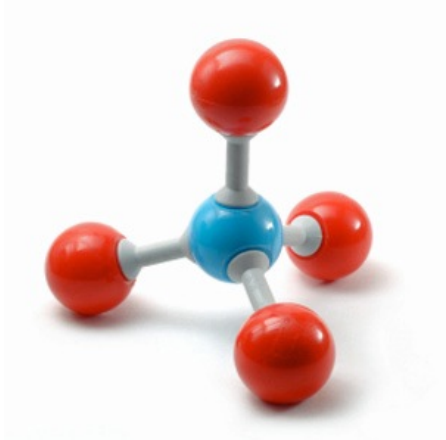




Isoelectric Point

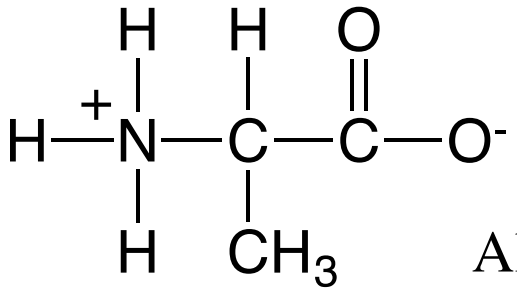
- The isoelectric point of an amino acid is the pH at which
  - the charged groups on an amino acid are balanced
  - the amino acid is neutral

- An amino acid can exist as
  - a positive ion if a solution is more acidic (lower pH) than its pI
  - as a negative ion if a solution is more basic (higher pH) than its pI



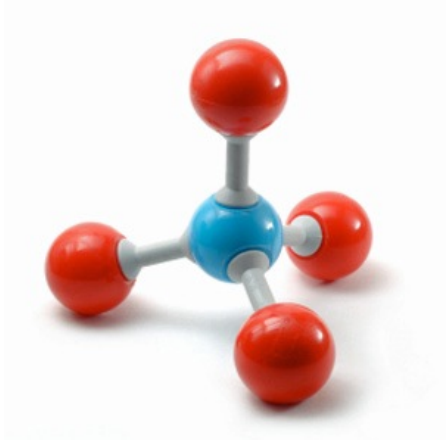
Ionized Forms of Amino Acids

- The pI values for nonpolar and
  - and polar neutral amino acids
  - are from pH 5.1 to 6.3.



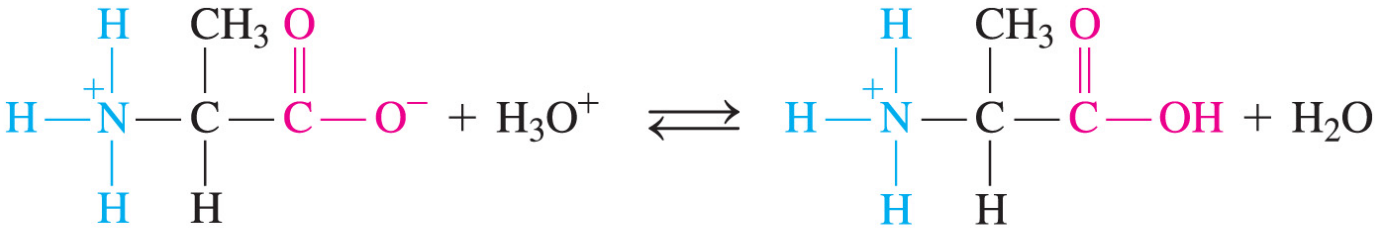
Alanine, pH = 6.0

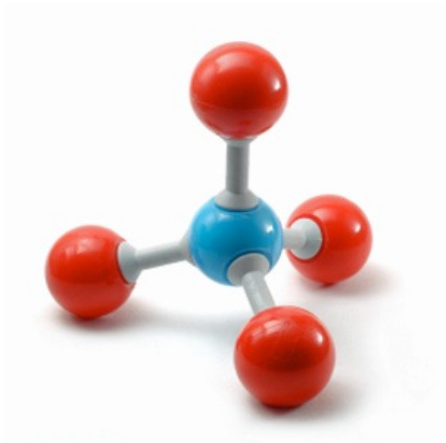
- Alanine has a zero overall charge at its pI of 6.0 with a carboxylate anion ($-COO^{1-}$) and an ammonium cation ($-NH_3^+$).



Ionized Forms of Amino Acids

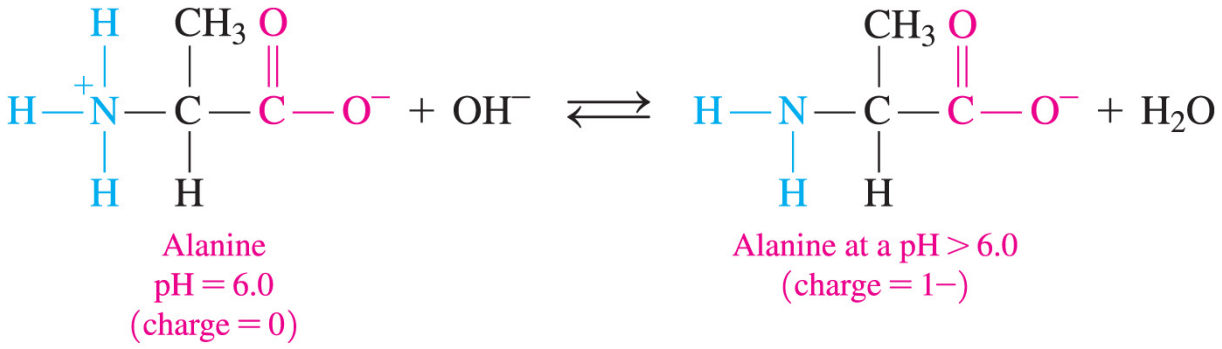
- Alanine adds an H+ to the carboxyl group (— COO–) when the solution is more acidic than its pI (pH < 6).



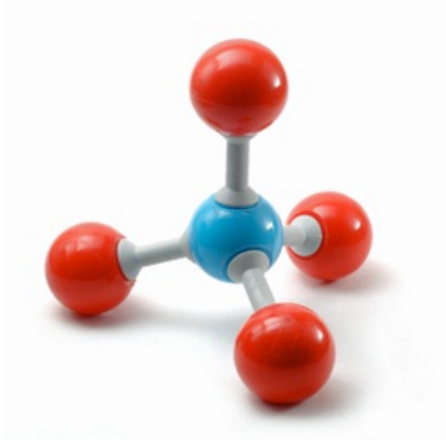


Ionized Forms of Amino Acids

- At a pH higher than 6.0, the — NH3+ group loses H+ and forms an amino group (— NH2) that has no charge.



- Because the — COO− group has a charge of 1−, alanine has an overall negative charge (1−) at a pH higher than 6.0.



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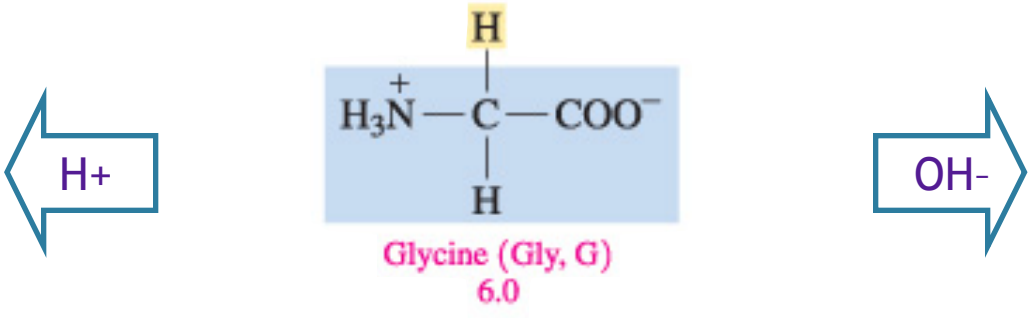
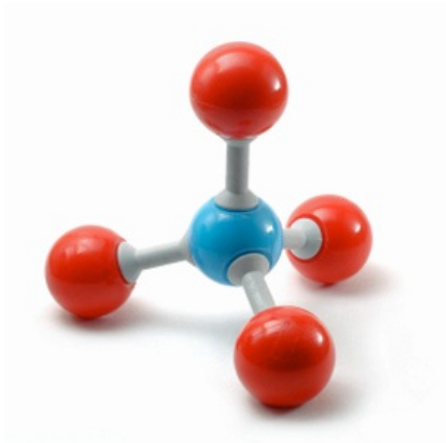
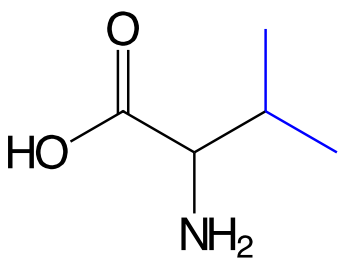


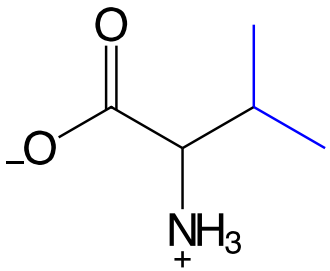
H_3N^+-CH_2-COOH	H_3N^+-CH_2-COO^{1-}	H_2N-CH_2-COO^{1-}
Positive ion	Neutral	Negative ion
low pH	pI	high pH



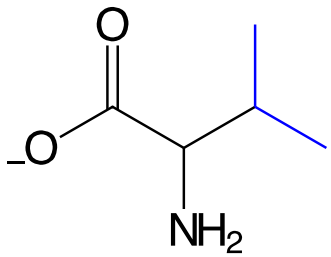
Try it.

- The un-ionized form of valine is drawn below. Write the zwitterion of valine at it's pI point.

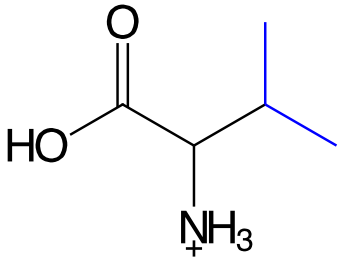


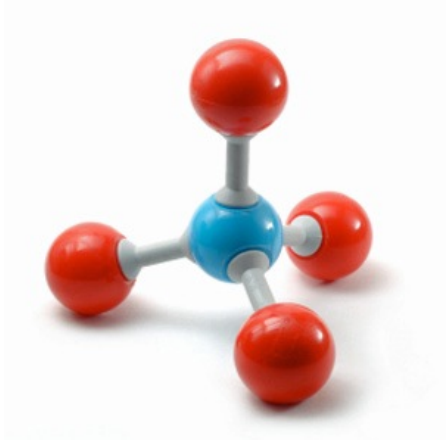


- Write the zwitterion of valine when the pH is above the pI of valine.



- Write the zwitterion of valine when the pH is below the pI of valine.





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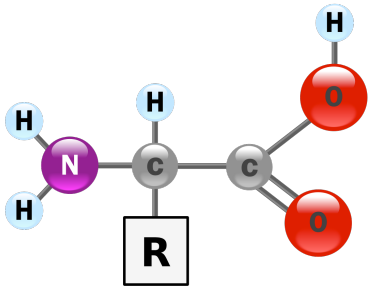
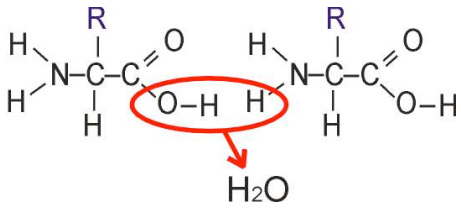
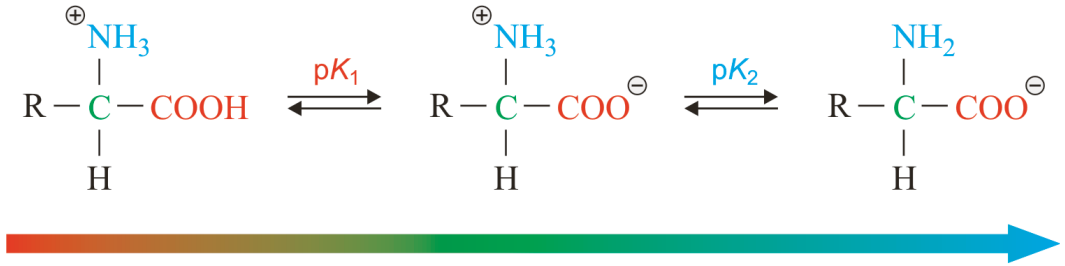
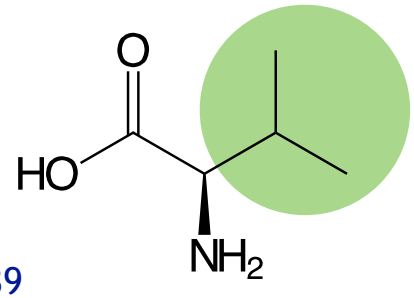
  - Sources
    - Essential Amino Acids

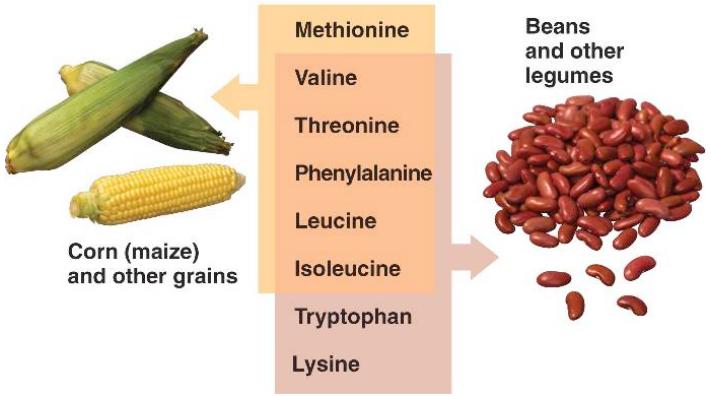


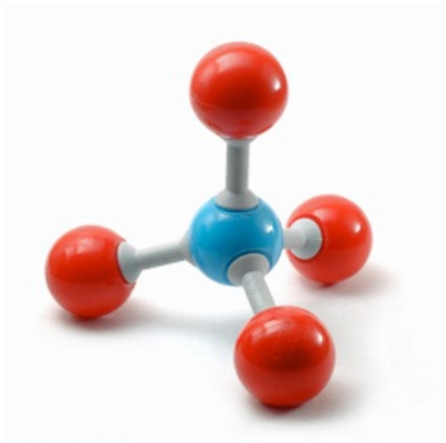
- Acid-Base Reactions
  - pI of Amino Acids
    - Below the pI
    - Above the pI











Questions?