Chemistry Fundamentals

BVIS 560 Molecular Pharmacology

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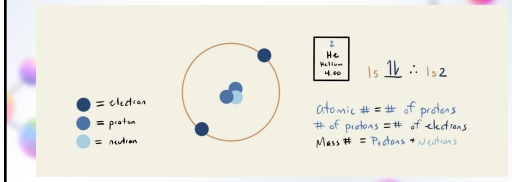
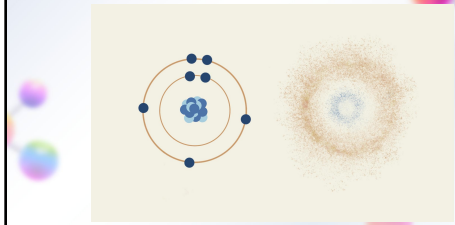
01

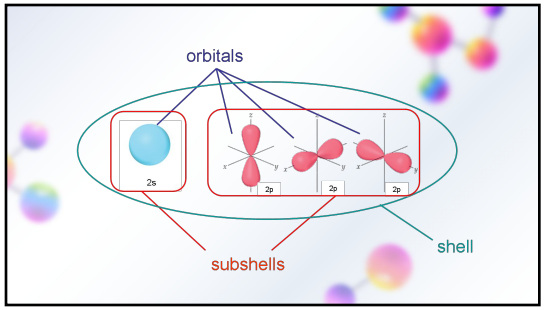
Chemical Energy & Electrons

Learning Objectives

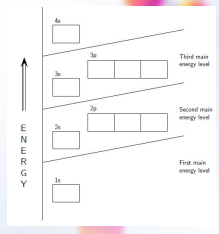
- Describe the structure of the atom
- Explain chemical energy and its relation to electron distribution/charge
- Identify periodic trends



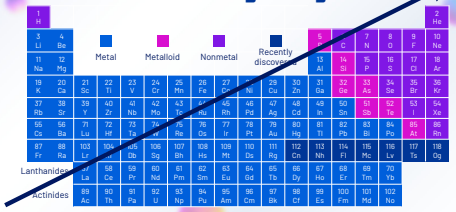




Shell	Subshell	Max electrons in subshell	Max electrons in shell
K	1s	2	2
L	2s	2	2 + 6 = 8
	2p	6	
M	3s	2	2 + 6 + 10 = 18
	3p	6	
	3d	10	
N	4s	2	2 + 6 + 10 + 14 = 32
	4p	6	
	4d	10	
	4f	14	



The periodic table of elements & electronegativity



02

Chemical Bonds

Learning Objectives

- Define a chemical bond
- Identify different types of chemical bonds
- Make biological connections to chemical bonds

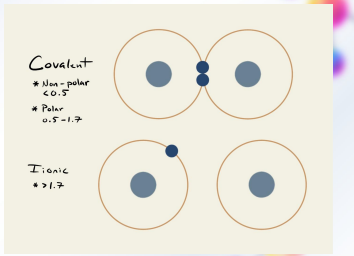


Table 1

Name	Description	Molecular traits	Characteristic
Non-Polar			
London[1] (1930) dispersion	induced dipole – induced dipole	All compounds, non-polar interaction	Transient polarization, scales with molecular size
Polar			
	Hydrogen bonding	Extreme dipole–dipole interaction: H acceptor interacts with H donor	Significant with compounds containing –OH or –NH groups
Keesom[1] (1912)	dipole–dipole	Interaction between strong dipoles	Electronegative groups (e.g., halogens, -OR, $-NO_2$, $-SO_3$)
Debye[2] (1923)	Dipole–induced dipole	Interaction between a strong dipole and a weak dipole	More polarizable = easier induction

03

Organic Chemistry & Functional Groups

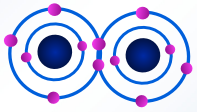
Organic chemistry basics with a focus on functional groups and their expected behavior

Learning Objectives

- List the important qualities of carbon
- Distinguish between visual morphology of aliphatic and aromatic molecules
- Explain the difference between single and double bonds
- Identify key functional groups and their chemical properties

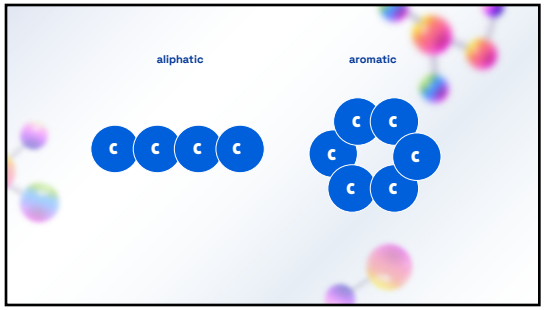
6
C
Carbon
12.0116

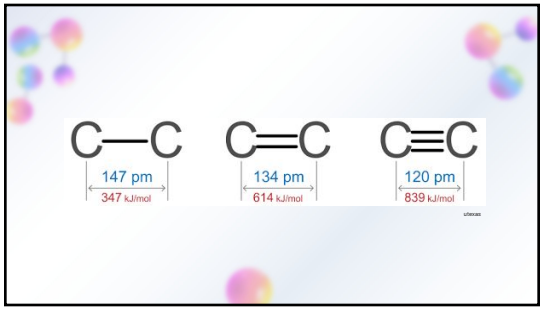
Organic chemistry is the chemistry of carbon

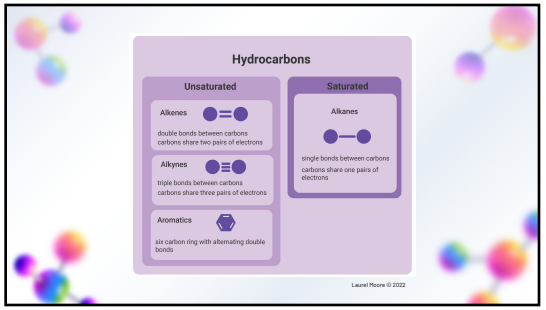


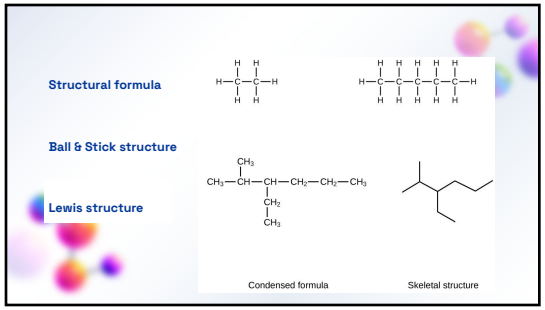
Carbon

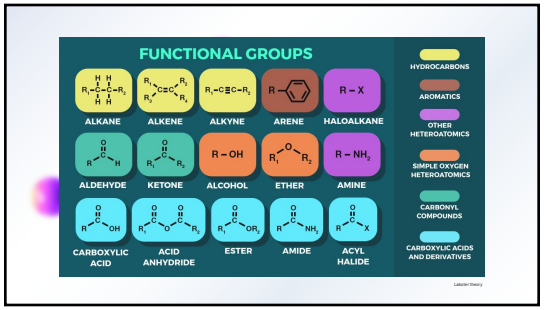
6 electrons
4 valence electrons
4 bonds
Catenate

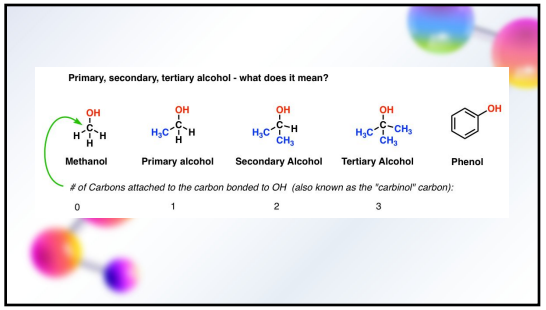

aliphatic
aromatic

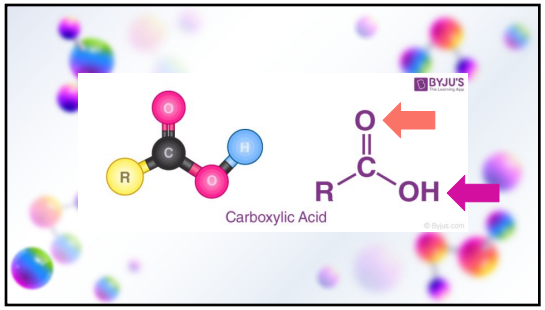

C—C
147 pm
347 kJ/mol
C=C
134 pm
614 kJ/mol
C≡C
120 pm
839 kJ/mol

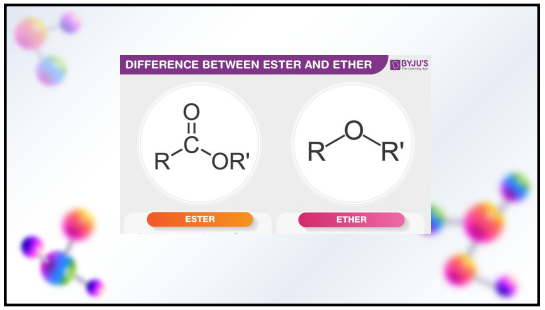

Hydrocarbons
Unsaturated
Alkenes
double bonds between carbons
carbons share two pairs of electrons
Alkynes
triple bonds between carbons
carbons share three pairs of electrons
Aromatics
six carbon ring with alternating double bonds
Saturated
Alkanes
single bonds between carbons
carbons share one pairs of electrons
Laurel Moore © 2022

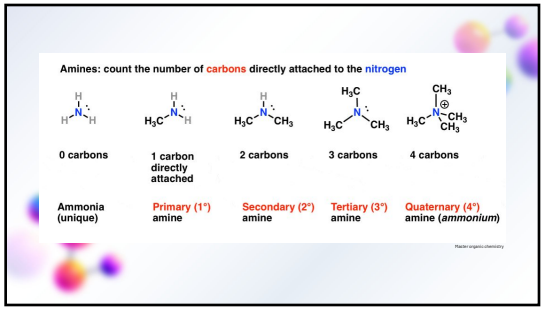

Structural formula
Ball & Stick structure
Lewis structure
Condensed formula
Skeletal structure

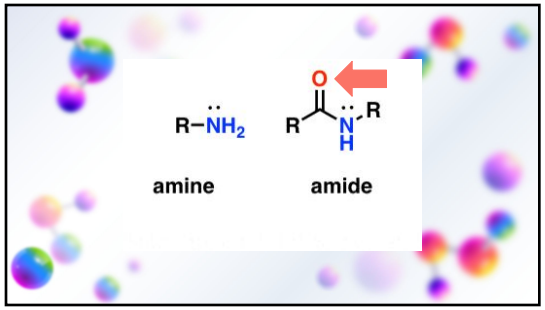

FUNCTIONAL GROUPS
ALKANE
ALKENE
ALKYNE
ARENE
HALOALKANE
ALDEHYDE
KETONE
ALCOHOL
ETHER
AMINE
CARBOXYLIC ACID
ACID ANHYDRIDE
ESTER
AMIDE
ACYL HALIDE
HYDROCARBONS
AROMATICS
OTHER HETEROATOMICS
SIMPLE OXYGEN HETEROATOMICS
CARBONYL COMPOUNDS
CARBOXYLIC ACIDS AND DERIVATIVES

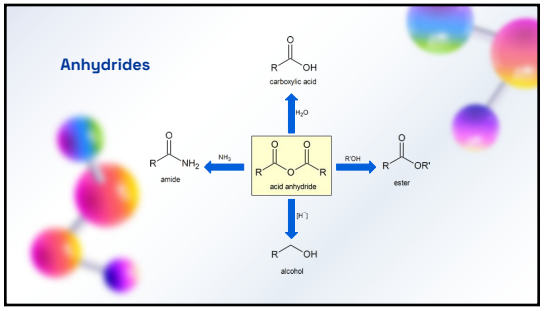

Primary, secondary, tertiary alcohol - what does it mean?
Methanol
Primary alcohol
Secondary Alcohol
Tertiary Alcohol
Phenol
# of Carbons attached to the carbon bonded to OH (also known as the "carbinol" carbon):
0
1
2
3

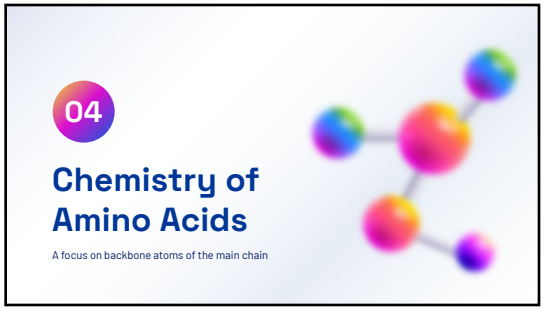

BYJU'S
Carboxylic Acid


DIFFERENCE BETWEEN ESTER AND ETHER
BYJU'S
ESTER
ETHER


Amines: count the number of carbons directly attached to the nitrogen
0 carbons
1 carbon directly attached
2 carbons
3 carbons
4 carbons
Ammonia (unique)
Primary (1°) amine
Secondary (2°) amine
Tertiary (3°) amine
Quaternary (4°) amine (ammonium)


amine
amide


Anhydrides
carboxylic acid
amide
acid anhydride
ester
alcohol

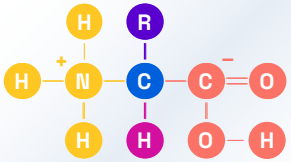

04
Chemistry of Amino Acids
A focus on backbone atoms of the main chain

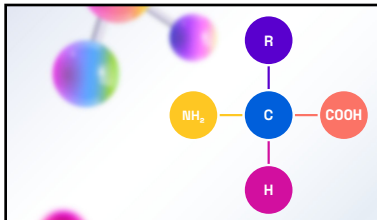
Learning Objectives

- Identify the different groups that make up the basic backbone of an amino acid
- Understand chirality and what makes amino acids chiral molecules
- Recognize how covalent peptide bonds are formed between amino acids

The "Amino Acid Backbone"

- Alpha Carbon
- Amino Group (NH2)
- Carboxylic Acid Group (COOH)
- Unique R Group



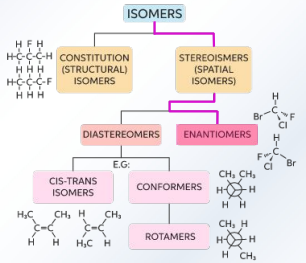


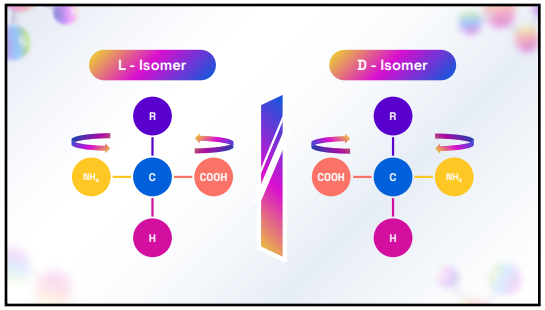
Chirality

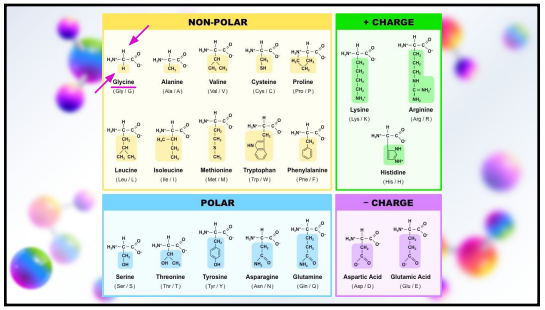
in Amino Acids

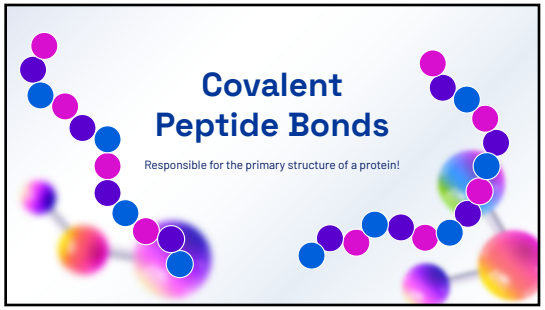
Chirality

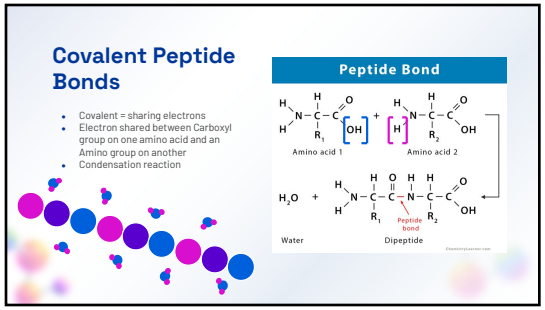
- Mirrored Isomers
- Cannot be superimposed onto each other

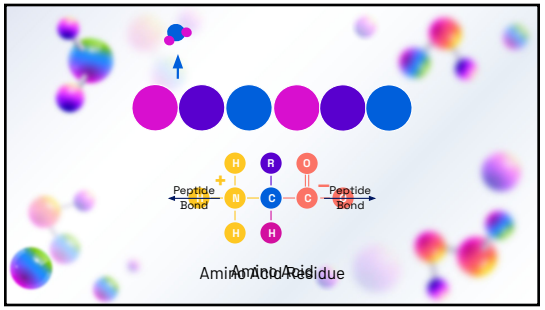


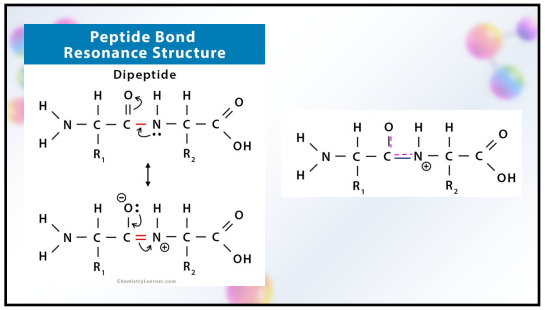

L - Isomer
D - Isomer
R
NH2
C
COOH
H


NON-POLAR
+ CHARGE
POLAR
- CHARGE
Glycine
Alanine
Valine
Cysteine
Proline
Leucine
Isoleucine
Methionine
Tryptophan
Phenylalanine
Lysine
Arginine
Histidine
Serine
Threonine
Tyrosine
Asparagine
Glutamine
Aspartic Acid
Glutamic Acid


Covalent
Peptide Bonds
Responsible for the primary structure of a protein!


Covalent Peptide Bonds
Covalent = sharing electrons
Electron shared between Carboxyl group on one amino acid and an Amino group on another
Condensation reaction
Peptide Bond
Amino acid 1
Amino acid 2
Water
Dipeptide
Peptide bond


Peptide Bond
Peptide Bond
Amino Acid Residue


Peptide Bond Resonance Structure
Dipeptide

05

Chemistry of Amino Acids

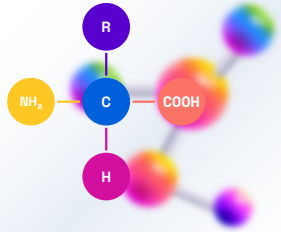
A focus on R-groups and side chains

Learning Objectives

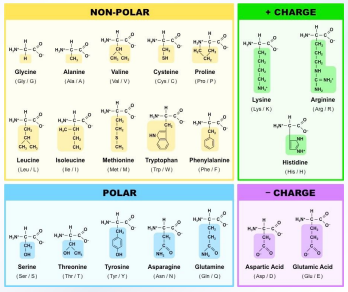
- Understand structure and chemical components of different R-groups that characterize each amino acid.
- Understand special features of the R groups and how they can be modified in different chemical reactions.

5A

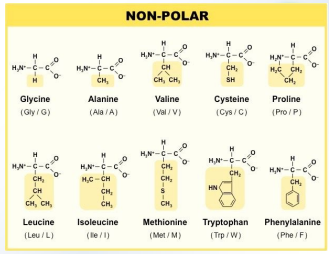
R-Groups



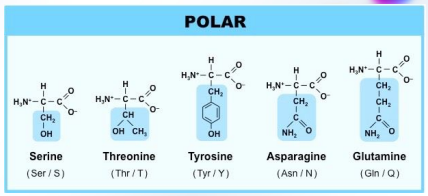
R-Groups



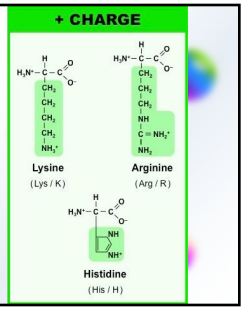
Nonpolar (hydrophobic) groups



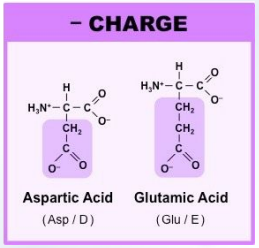
Polar (hydrophilic) groups

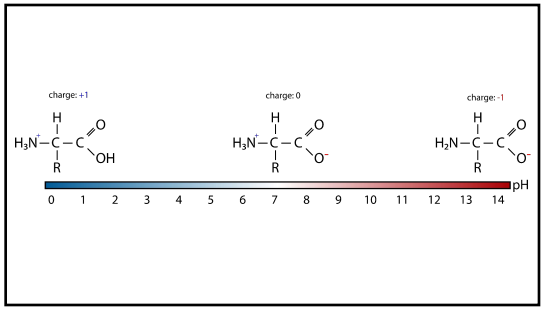


Positively charged (basic) groups



Negatively charged (acidic) groups

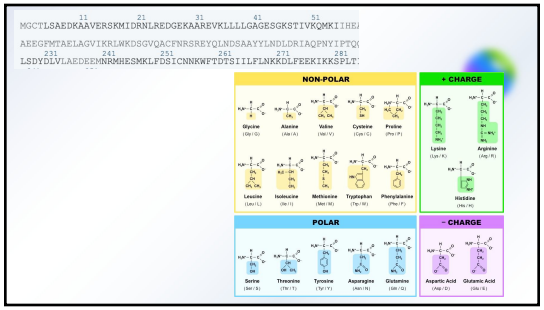




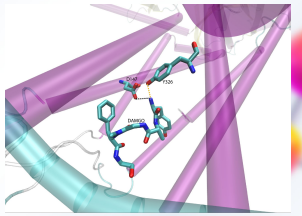
5B

Protein Visualization

- Understand how a single amino acid is denoted and visualized in 3D protein visualization



Using PDB File for Visualization



5C

Amino Acids with Special Features

Learning Objectives

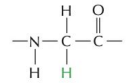
- Identify amino acids with special features
- Understand the these features exert an effect on the structure and biological activity of proteins
- Understand how specific modifications of R-groups can change local chemistry

Glycine is the simplest amino acid

Glycine has a single hydrogen atom where other amino acids have a side chain

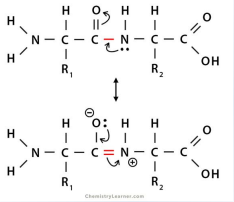
glycine

(Gly, or G)

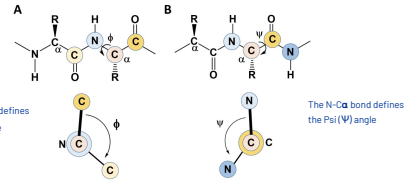


Peptide Bond Resonance Structure

Dipeptide



Torsion Angles

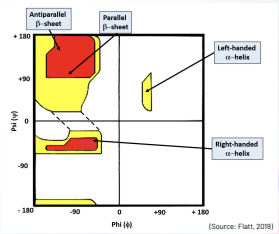


(Source: Flatt, 2019)

Ramachandran Plots display the most stable Phi and Psi torsion angles for a given peptide

Favorable Phi (Φ) torsion angles

Favorable Psi (Ψ) torsion angles

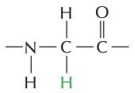


(Source: Flatt, 2019)

Glycine has a broader range of Phi and Psi angles because of its smaller R group

glycine

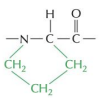
(Gly, or G)



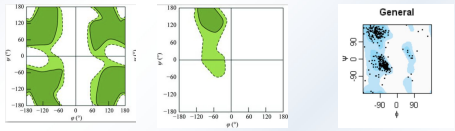
Proline has a bulky, cyclic R-group that restricts psi and phi bond rotations

proline

(Pro, or P)



Glycine and proline have unique Ramachandran plots



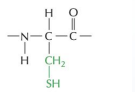
Glycine | Proline | Other amino acids

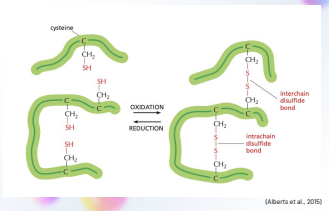
(Biological Crystallography, 2013)

Cysteine has the only side chain that forms disulfide bonds

cysteine

(Cys, or C)

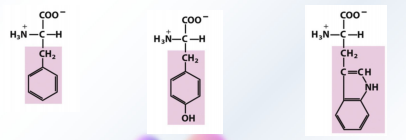




(Alberts et al., 2015)

Aromatic R-groups

Phenylalanine | Tyrosine | Tryptophan



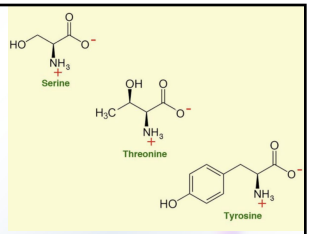
5D

Modifications of R-Groups can change local chemistry

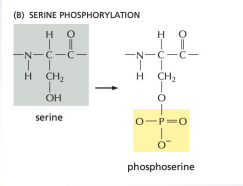
Serine is a polar amino acid. It's non-essential for humans but is a precursor for many important cellular compounds.

Threonine is a polar amino acid. It is essential for humans.

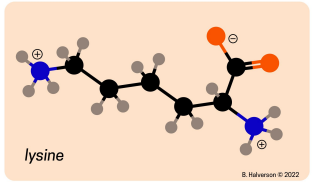
Tyrosine is a polar amino acid. It is non-essential for humans.



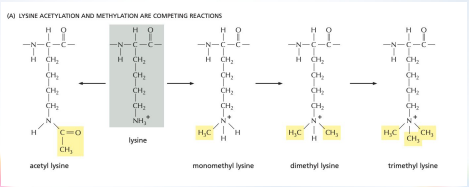
Serine, threonine, and tyrosine all contain hydroxyl groups, making them frequent sites for phosphorylation.



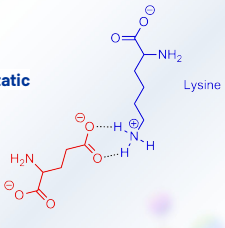
Protein phosphorylation is a reversible post-translational modification where kinase adds a covalently bound phosphate group to an amino acid residue.



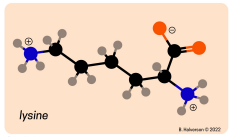
Lysine modifications

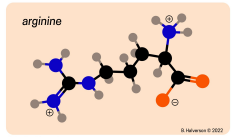


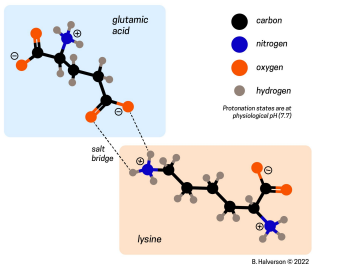
Salt bridges are a type of electrostatic interaction between oppositely charged atoms or groups of atoms



Lysine and arginine commonly form salt bridges







Salt bridge between lysine and glutamic acid

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Thank you!