

Principles of Biochemistry

A multimedia lecture series
in The Biomedical &
Life Sciences Collection

Editor's Summary

Life is fascinating at many different levels, from interconnected groups of organisms, to individual life forms, to individual living cells, to individual but interconnected molecules within and outside of cells. Here we examine Life at the smallest of these size scales, noticing the properties of each type of biomolecule and how the molecules interact with each other.

We will see proteins as a remarkable state of matter that evolved to carry out often complex tasks. Proteins are partially understood at the level of interacting atoms and molecules, which is to say, their chemistry. We will see biological membranes to be a special state of matter with daunting complexity. We will look at carbohydrates and see simple and important sugars, some simple polymers of these sugars such as cellulose, and other sugar polymers that are more complex.

With this knowledge in hand, the last part of this series is about metabolism, the actual chemical reactions in living systems. We want to understand how glucose is used and how photosynthesis works, which chemical reactions occur and how they are controlled in everyday life. Then we can start to appreciate what can go wrong.



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Series Overview

The series consists of 22 multimedia lectures, which can be used together as a complete introductory course, or separately to learn a single topic. Below you can see the topics covered in the series, accompanied by examples of slides and hyperlinks to the lectures.

Note: this series discusses very little of how DNA and RNA fit into biochemistry. This area is often termed “molecular biology” and is covered by other talks in the collection such as [The biochemistry of DNA and RNA](#).

Lecture 1: Introduction to biochemistry

- Matter in the universe
- Origin of chemistry
- Properties of living systems
- Main categories of biomolecules
- Metabolism and the importance of enzymes

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Only partial knowledge of metabolism

We do not know all the ways that different types of metabolisms are connected to each other

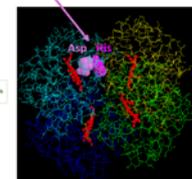


Why these particular molecules and reactions?

- These molecules do not react fast enough on their own
- Catalysts control these reactions
- Catalysts coordinate these reactions

Ion pairs hold haemoglobin together

Haemoglobin is held together by **ion pairs** (purple spacefilling)



Histidine (His) can have positive charge or no charge
Aspartic acid (Asp) can have negative charge or no charge

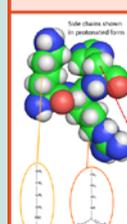
Ion pairs are only formed if each group is charged

Lecture 2: Amino acids and peptides

- Ionisable groups
- Properties and classification of the 20 amino acids
- Formation of the peptide bond
- The hydrophobic effect
- Introduction to myoglobin

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Basic amino acids



Side chains shown in protonated form

Lysine	Lys	pKa = 10
Arginine	Arg	pKa = 12
Histidine	His	pKa = 7

Some chemical modifications:

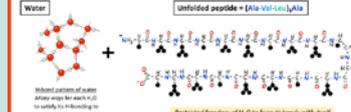
- e.g. On histones, Addition of -CH₃ or acetyl: **lysine**
- e.g. Addition of a protein (Substrate: 25 amino acids, label for destruction) **ubiquitin**

Often find His at enzyme active site, accepting/donating H⁺. Has an aromatic ring

The hydrophobic interaction

Water

Unfolded peptide = [Leu-Val-Leu-Leu-Ala]



Hydroxyl groups of water form H-bonds for each O-H to satisfy its hydrogen bonding to its nearest neighbors

Restricted freedom of H₂O to form H-bonds with itself

Folding

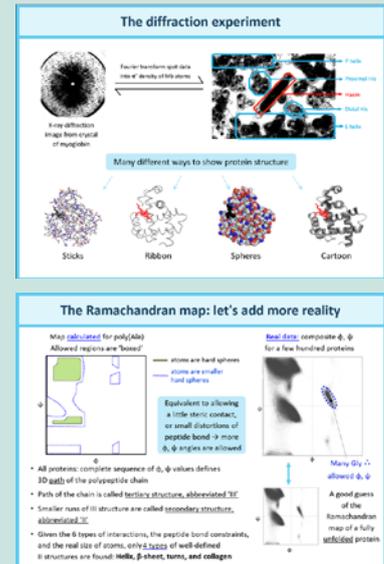
Folded peptide in water

Greater freedom of H₂O to form H-bonds with itself

Lecture 3: Protein structure principles

- Primary protein structure
- X-ray diffraction and protein 3D structure
- Interactions within proteins
- Peptide bond constraints
- Ramachandran maps

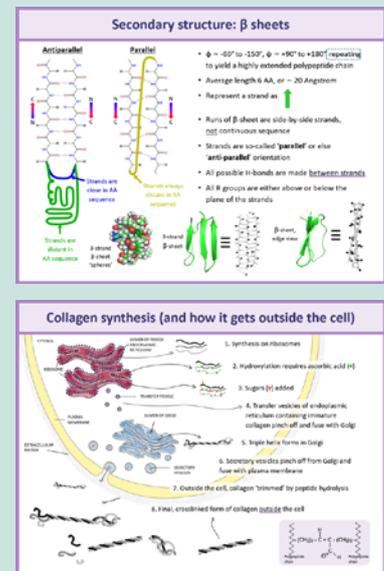
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Lecture 4: Observed protein structures

- Protein secondary structures (α helix, β -sheet, turns, and collagen)
- Collagen properties
- The 'protein fold'
- Protein arrangement according to type of fold, superfamily and family

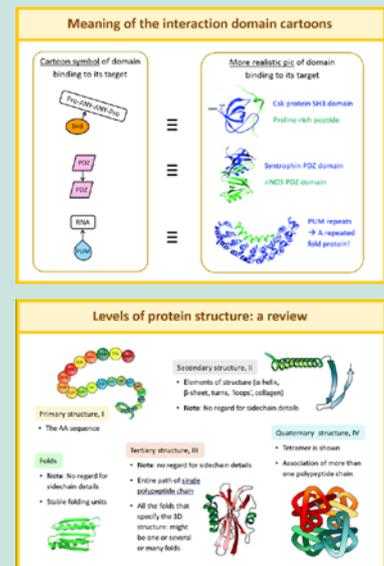
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Lecture 5: Protein folds and IV structure

- Multiple-folds
- Stable quaternary structure
- Transient quaternary structure
- Binding/Interaction domains
- Levels of protein structure

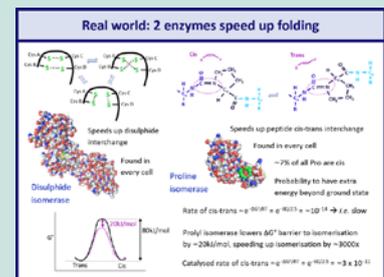
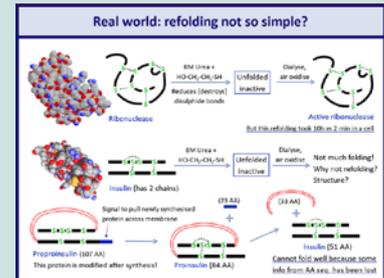
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Lecture 6: Protein stability and folding

- Protein stability
- Folding and refolding
- Molecular chaperones
- Motions within proteins
- Protein classification by function and complexity

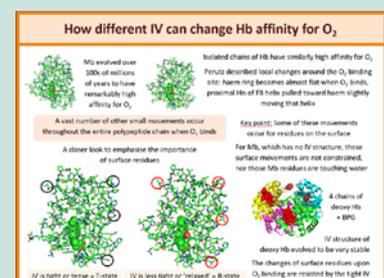
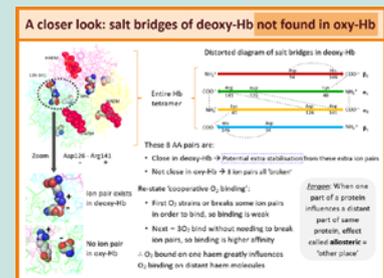
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Lecture 7: Haemoglobin structure and stability

- Myoglobin vs. haemoglobin
- T-state and R-state of haemoglobin
- Haemoglobin affinity for O₂
- The Bohr effect
- Two models for O₂ binding affinity

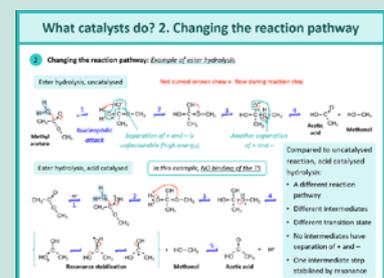
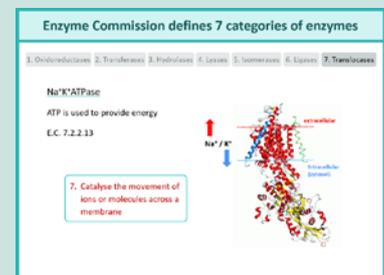
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Lecture 8: Enzyme specificity and catalysis

- Categories of enzymes
- Enzyme specificity
- Reaction rate
- Gibbs function
- The Boltzmann distribution
- Catalysts roles and mechanisms

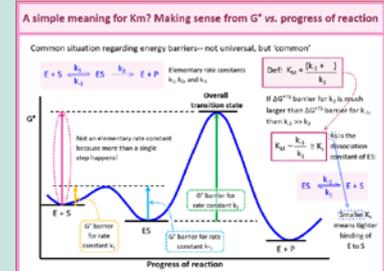
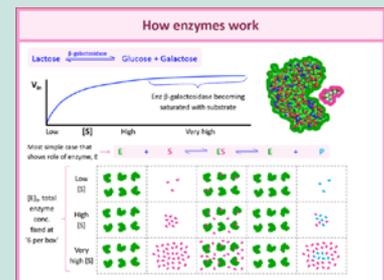
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Lecture 9: Enzyme kinetics (Michaelis-Menten)

- Initial reaction velocity
- Catalysed vs. uncatalysed reaction pathways
- Enzyme saturation/Maximum reaction velocity
- Michaelis-Menten equation
- Energy barriers and rate constants
- Measuring K_m and V_{max}
- The Lineweaver-Burk plot

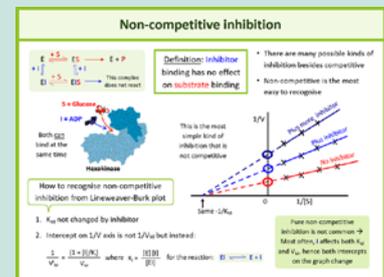
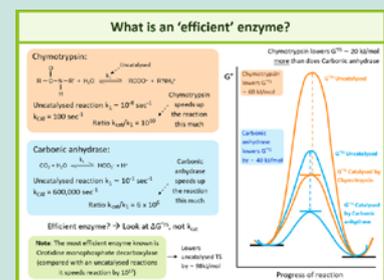
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Lecture 10: Enzyme inhibition; chymotrypsin

- Efficient enzymes
- Competitive inhibition
- Non-competitive inhibition
- Irreversible inhibition
- Diagrams of enzyme mechanisms
- Chymotrypsin mechanism

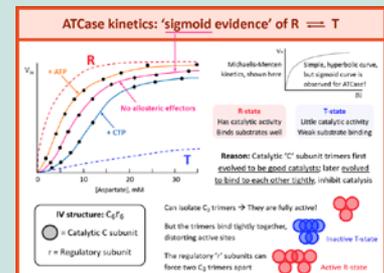
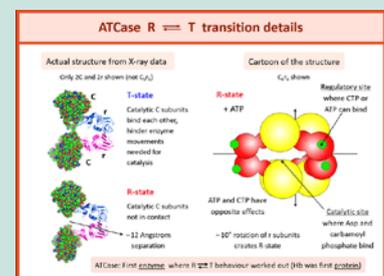
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Lecture 11: Enzyme regulation and coenzymes

- Metal ions
- Coenzymes
- Control of enzyme concentration (synthesis, degradation)
- Control of enzyme activity
- Aspartate carbamoyl transferase allostery
- Chymotrypsin activation

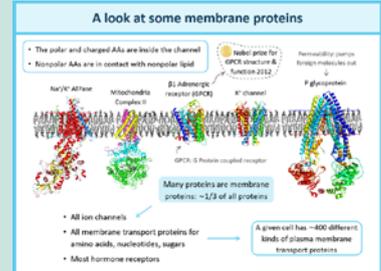
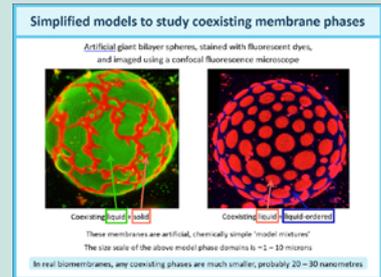
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Lecture 12: Lipids, biomembranes and membrane proteins

- Properties of biomembranes
- Types of lipid bilayer phases
- Types of fatty acyl chains
- Phospholipases
- Types of membrane association
- Membrane fusion

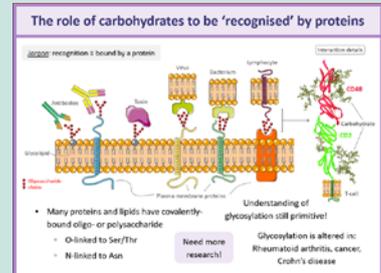
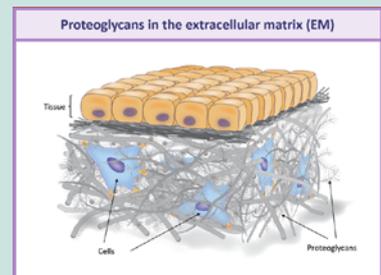
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Lecture 13: Structure and function of carbohydrates

- Properties of carbohydrates and their complexity
- Carbohydrate energy role
- Carbohydrate structural role
- Glycosaminoglycans & proteoglycans
- Carbohydrate recognition role

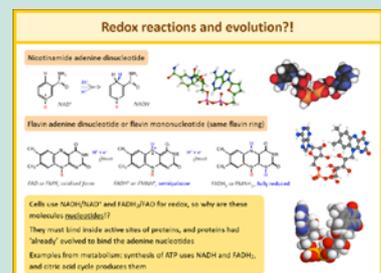
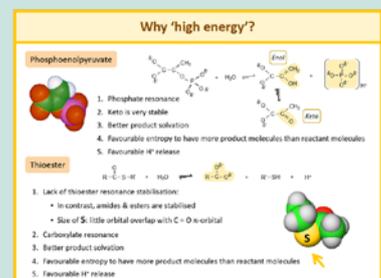
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Lecture 14: Metabolism principles

- High-energy molecules
- Information in the Gibbs function
- Types of transport across biomembranes
- Oxidation-reduction reactions

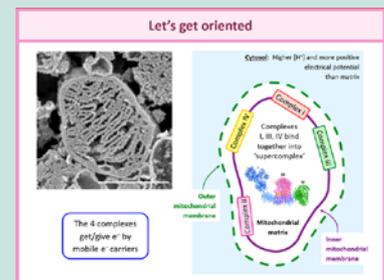
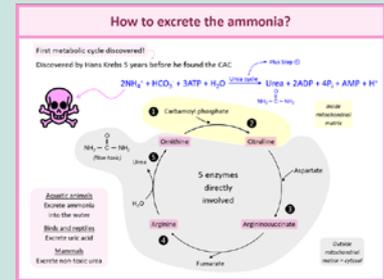
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Lecture 18: Urea cycle; oxidative phosphorylation

- Amino acids catabolisms
- Urea Cycle and connections to other metabolism
- Overview of 'energetics metabolism'
- Electronic transport in Mitochondria (Complexes I to IV)
- ATP synthase Motions within proteins
- H⁺ gradient in mitochondria and Chemiosmotic mechanism

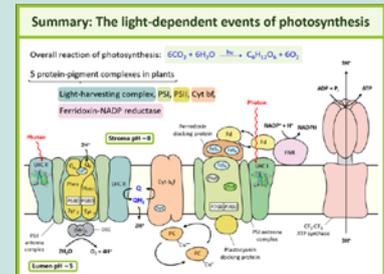
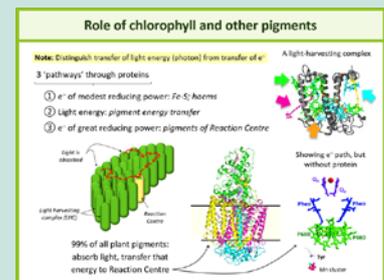
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Lecture 19: Light-driven reactions in photosynthesis

- Introduction to photosynthesis
- Fates of absorbed light
- Role of chlorophyll and other pigments
- Events in photosystems II and I
- Photosynthesis vs. electronic mitochondrial transport
- Z-scheme

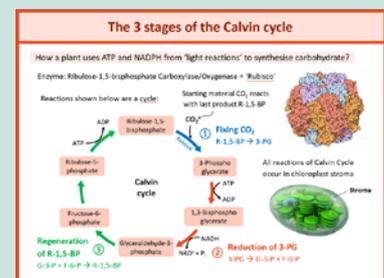
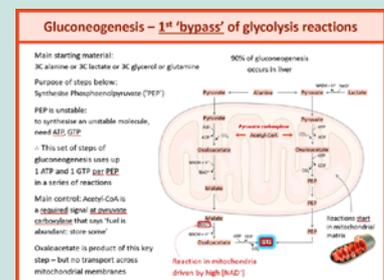
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Lecture 20: Gluconeogenesis and the Calvin cycle

- Anabolism
- Gluconeogenesis vs. glycolysis
- Substrate cycling
- Calvin Cycle step by step

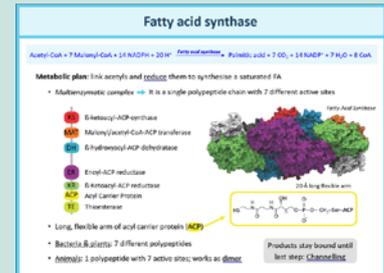
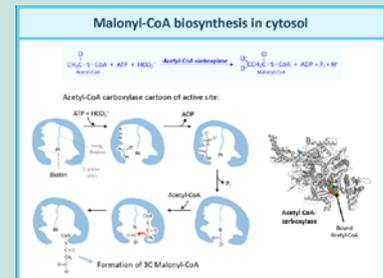
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Lecture 21: Synthesis of lipids and N-containing molecules

- Fatty acid synthase complex in detail
- Biosynthesis of complex lipids
- Synthesis of fats and phospholipids
- Cholesterol biosynthesis
- Lipoproteins and their roles
- Synthesis of N-containing molecules

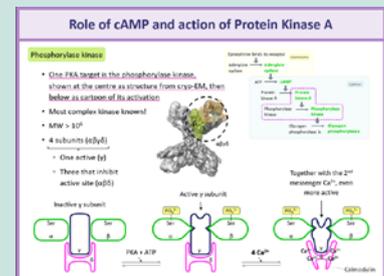
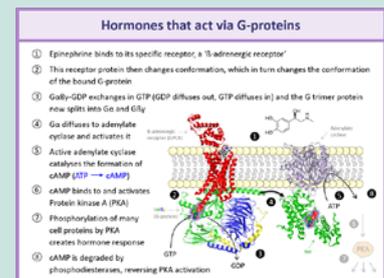
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Lecture 22: Hormone mechanisms

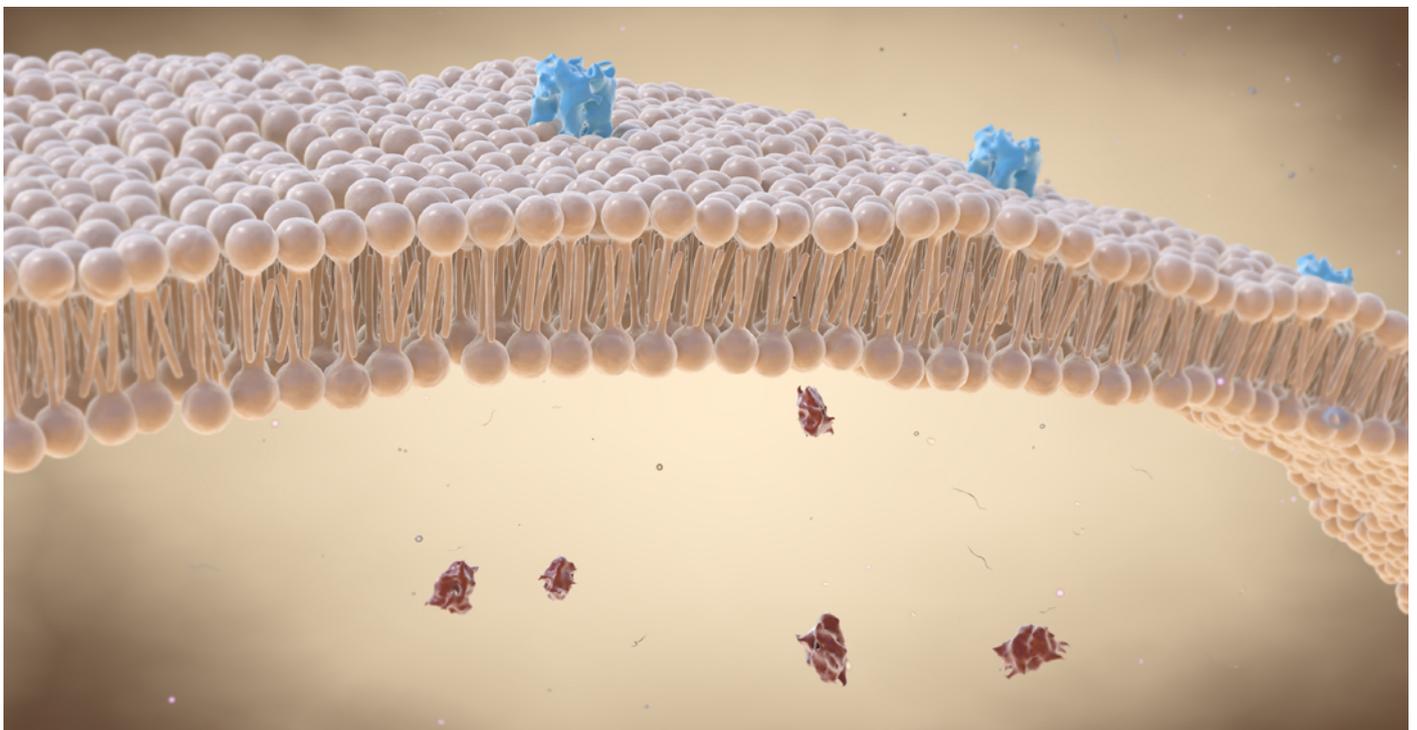
- Hormone action via G-protein
- Steroid hormone action in nucleus
- Insulin action in cytosol and nucleus
- Metabolic control to cancer
- Course summary

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About the Editor

Prof. Gerald W. Feigenson has been a faculty member at Cornell University since 1974. He has established several fundamental properties of cell membranes, including the nature of the membrane protein lipid boundary layer, phase behavior of lipid mixture models of the plasma membrane, and the nature of line tension at the boundary of membrane rafts. He is the co-founder of the Cornell Field of Biophysics, and has taught undergraduate biochemistry for many years. Prof. Feigenson is the recipient of multiple awards for his educational work.



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