



# NITROGEN METABOLISM



# Nitrogen Metabolism

## Overview

- **It is the polymeric nitrogen containing compounds proteins and nucleic acids that define the major attributes of organism such as function and structure. The metabolism of nitrogen encompasses a number of topics, including nitrogen fixation, the anabolism and catabolism of amino acids, purines, etc. Atmospheric nitrogen is the ultimate source of this element in biomolecules.**

# Nitrogen Metabolism

- **The topic of nitrogen metabolism includes:**
  - **Nitrogen Fixation**
  - **Biosynthesis and Breakdown of amino acids, purines and pyrimidines.**

# Nitrogen Fixation

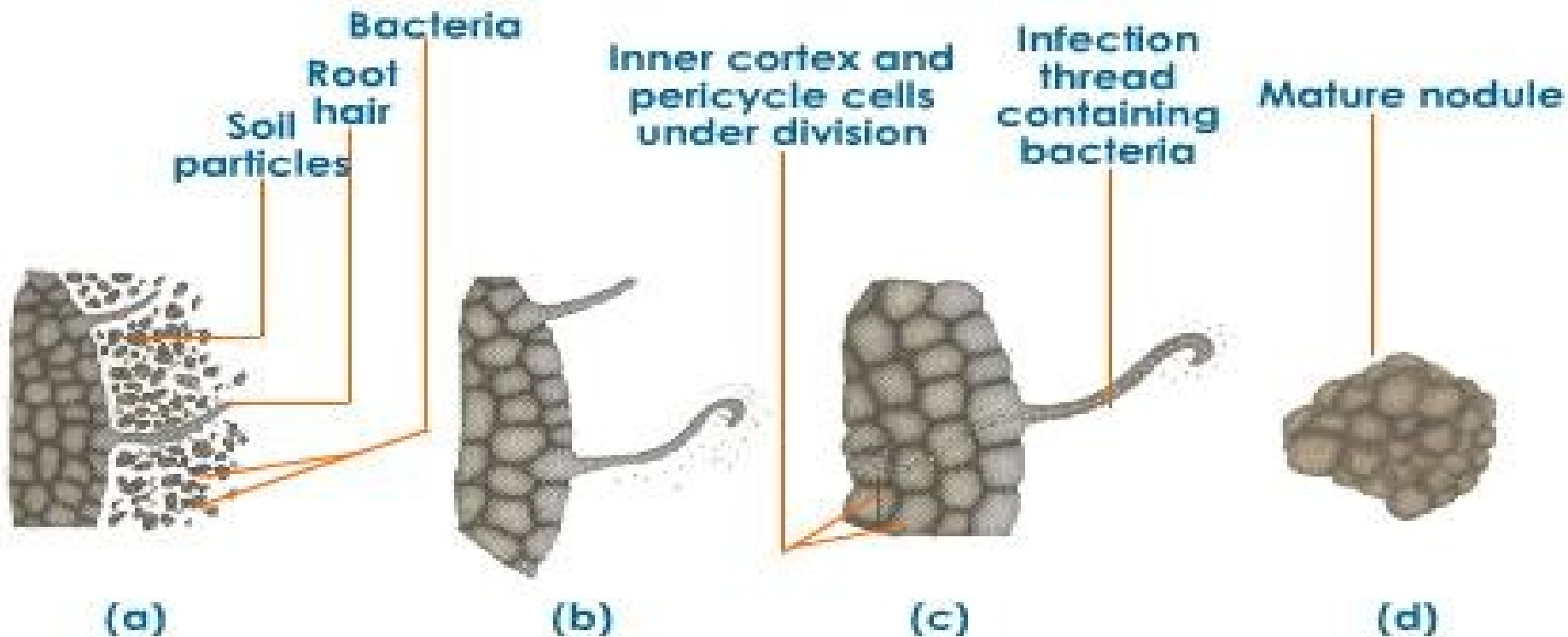
- the process by which inorganic molecular nitrogen ( $N_2$ ) from the atmosphere is incorporated first into ammonia and then into organic compounds that are of use to organism.
- **Nitrification**
  - a process by which ammonia is converted by bacteria into nitrates ( $NO_3^-$ )
- **Denitrification**
  - a process which return nitrogen ( $NO_3^-$  and  $NO_2^-$ ) to the atmosphere

# N<sub>2</sub> Fixation

- Carried out by two types of micro-organisms
  - symbiotic &
  - non-symbiotic (free living micro-organisms)

# Symbiotic N<sub>2</sub> Fixation

- The Fixation of free nitrogen of the soil by microorganisms living symbiotically inside the plant.



- (a) Development of root nodules in soybean
- (b) Rhizobium bacteria contact a susceptible root hair
- (c) Infection thread carrying bacteria
- (d) A mature nodule complete with vascular tissues continuous with those of root

# Non-Symbiotic Micro-organism

## Nitrogen fixation by free-living microorganisms

**Cyanobacteria**

***Azotobacter***

***Clostridium***



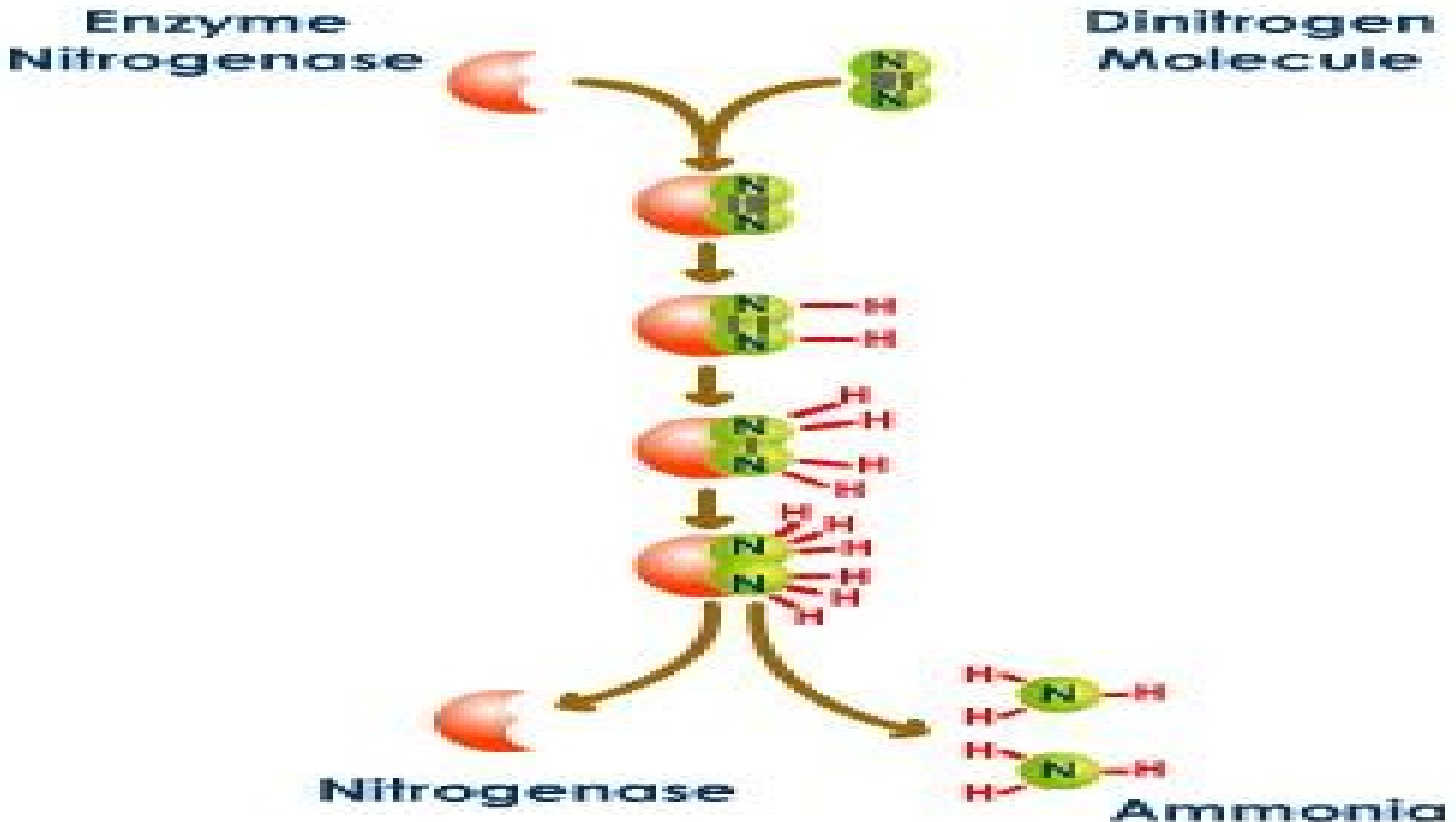
# Steps in Nitrogen Fixation

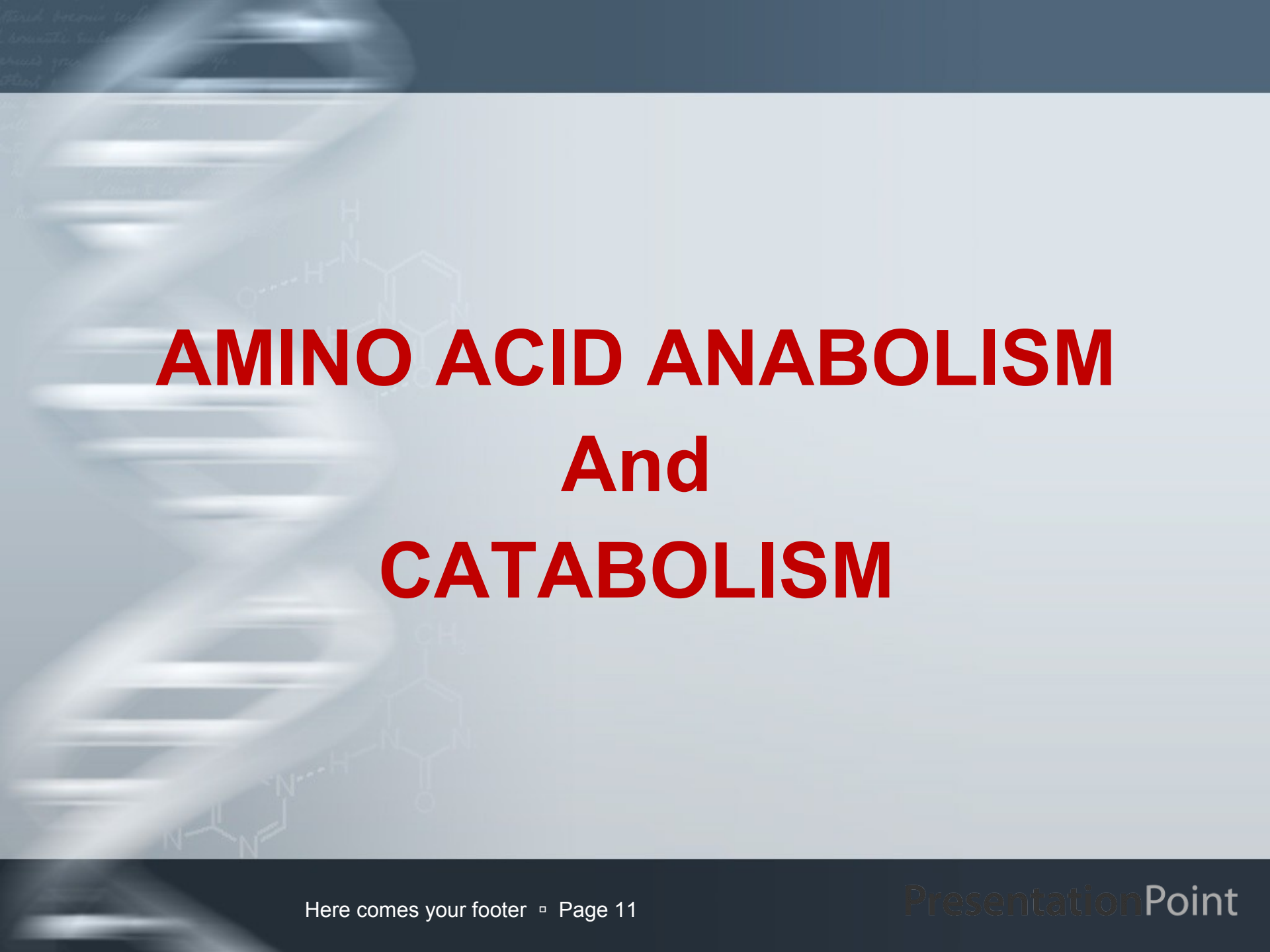
1. Atmospheric nitrogen is reduced by the addition of hydrogen atoms.
2. As a result the bonds between the two nitrogen atoms ( $\text{N}_2 \rightarrow \text{N} \equiv \text{N}$ ) are broken down resulting in the formation of ammonia.
3. Nitrogen fixation thus requires the following three components:
  - 1.) A strong reducing agent
  - 2.) ATP to transfer hydrogen atoms to dinitrogen.
  - 3.) enzyme systems



**4) Ammonia thus formed as a result of nitrogen fixation is used for the synthesis of amino acids. Amino acids are the building blocks for the synthesis of proteins.**

# Nitrogen Fixation Process

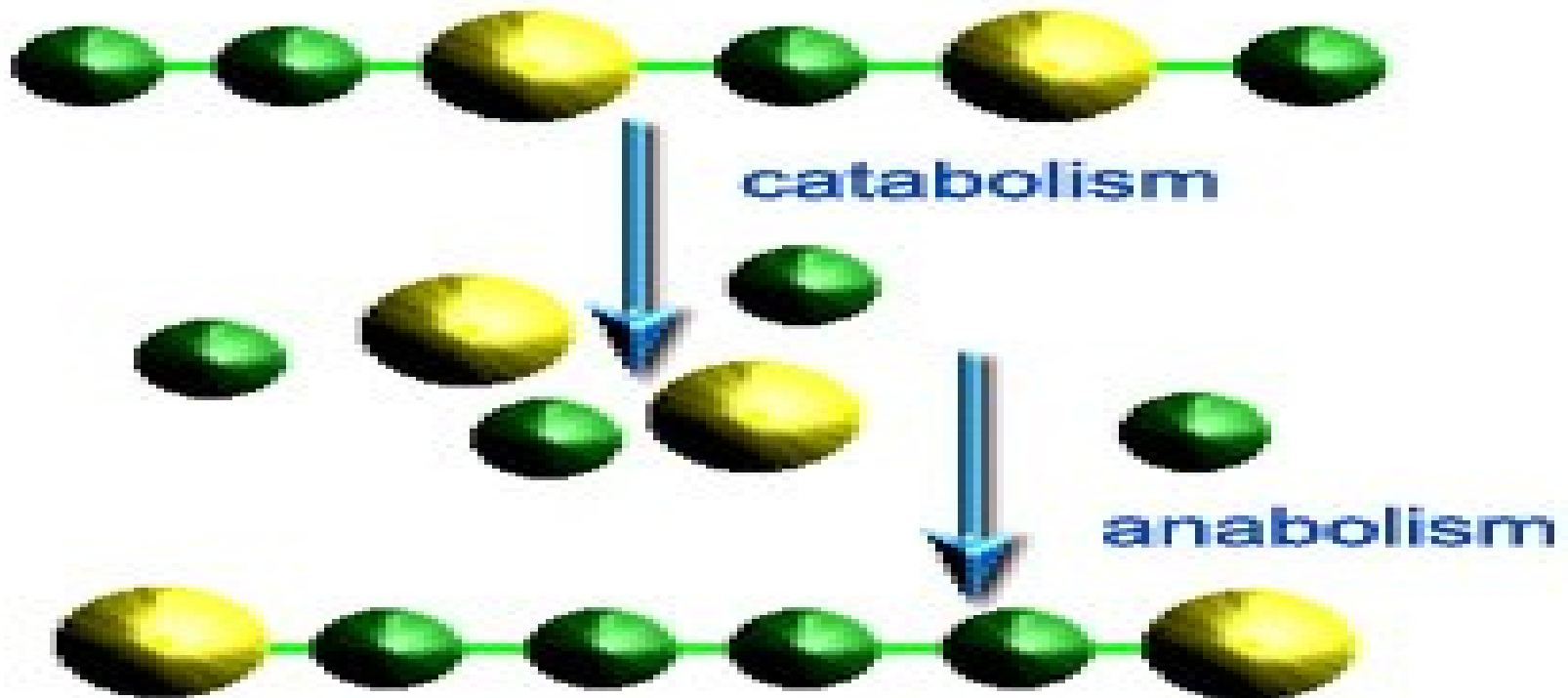




# **AMINO ACID ANABOLISM And CATABOLISM**

**Anabolism-** also known as biosynthesis, build things and consumes energy.

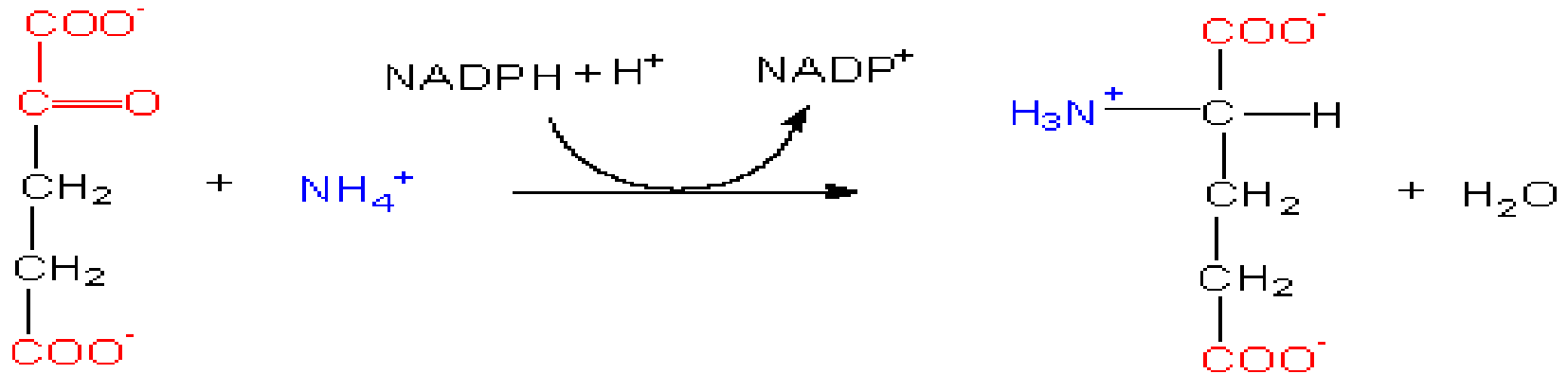
**Catabolism-** destructive metabolism, breakdown of amino acid to form energy.



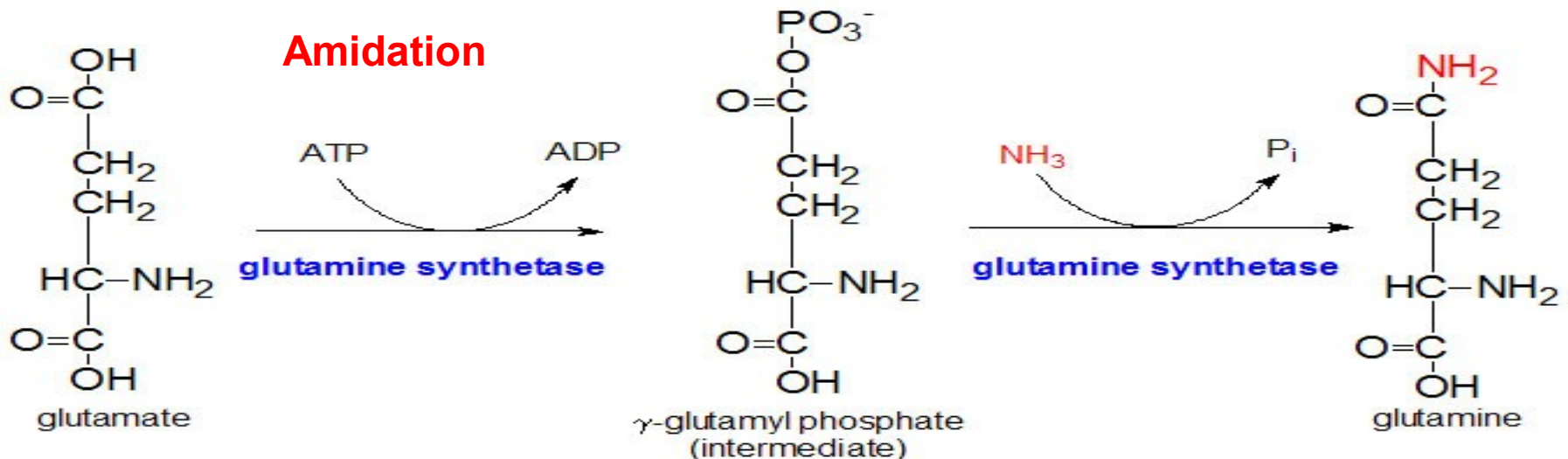
# Amino Acid Biosynthesis (Anabolism)

## ■ Biosynthesis of Glutamate from $\alpha$ -ketoglutarate

### Reductive amination



## ■ The production of glutamine from glutamate

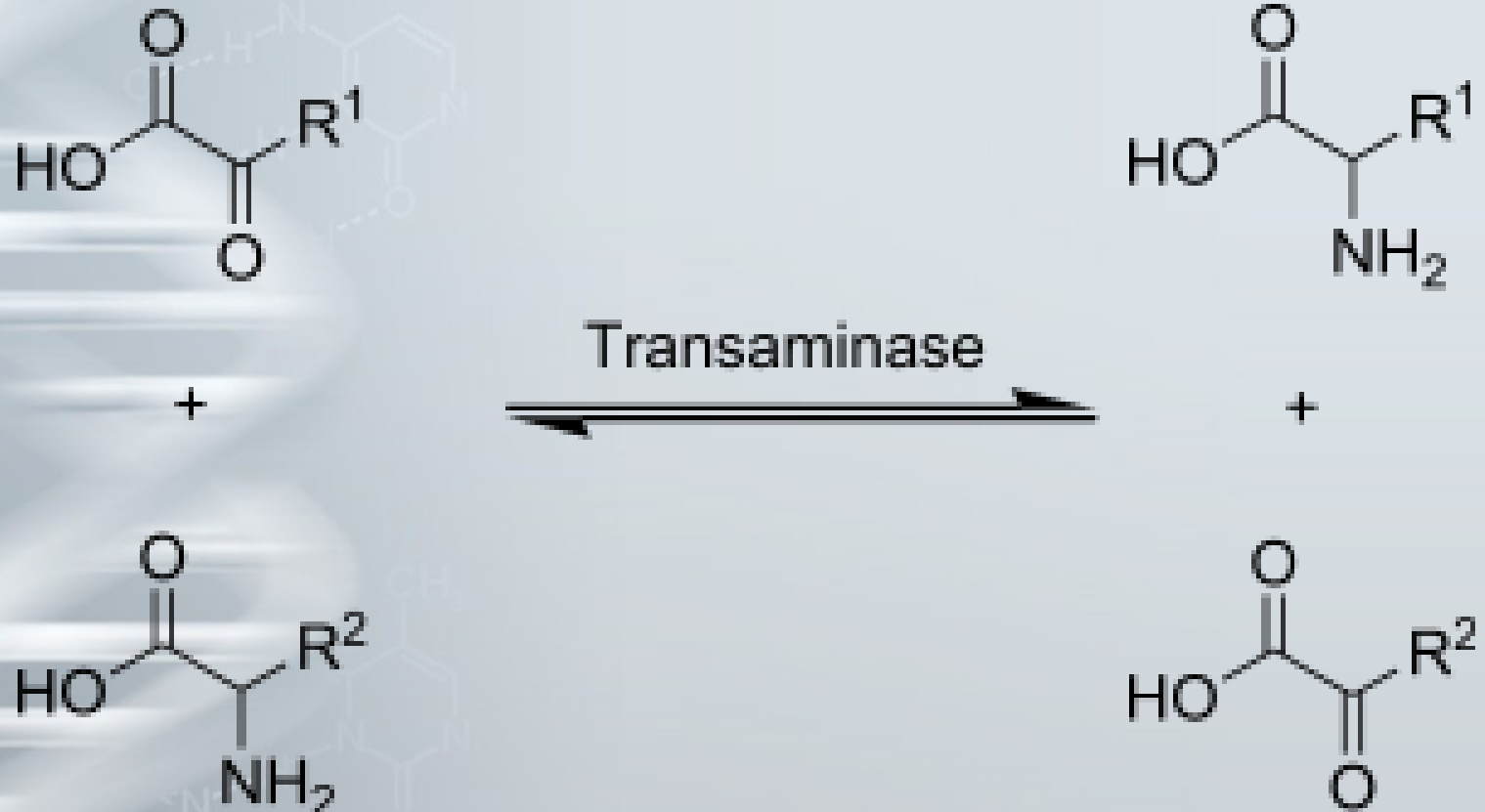


## **What are some common features in amino acid biosynthesis?**

- transamination**
- one-carbon transfer**

**Transamination- the transfer of amino groups from one molecule to another; an important process in the anabolism and catabolism of amino acid.**

## ▪ Example of transamination reactions



# Essential Amino Acids

- Some amino acids may be synthesized in human cells, some however cannot. The latter are referred to as essential amino acids meaning that they are required dietary components.

Nonessential	Essential
Alanine	Arginine*
Asparagine	Histidine
Aspartate	Isoleucine
Cysteine	Leucine
Glutamate	Lysine
Glutamine	Methionine*
Glycine	Phenylalanine*
Proline	Threonine
Serine	Tyrptophan
Tyrosine	Valine

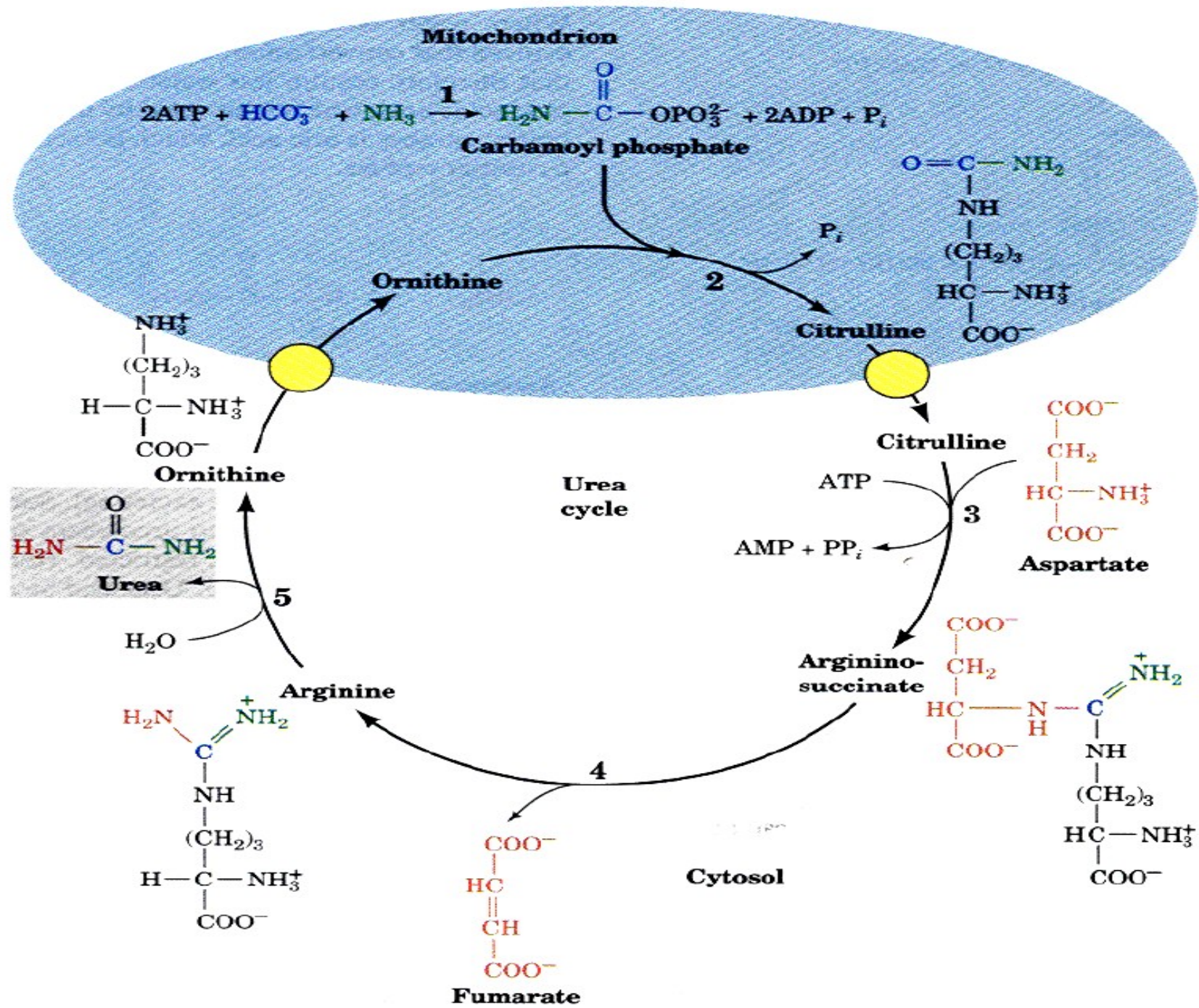


# Amino Acid Catabolism

**- What is the role of the urea cycle in amino acid Breakdown?**

**It is the central pathway in nitrogen metabolism. The urea cycle is a liver resident process removing nitrogen in form of ammonia to be excreted from the body..**

- **The urea cycle consists of five reactions: two mitochondrial and three cytosolic. The mitochondrial matrix performs the biosynthetic part of the precursors citrulline and aspartate, and the cytoplasm (cytosol), which after formation of arginino-succinate cleaves this intermediate into three different products, one of which is the net product (urea), the other two (ornithine and fumarate) are recycled into the matrix compartment and their respective cycle to start a new round of urea formation.**

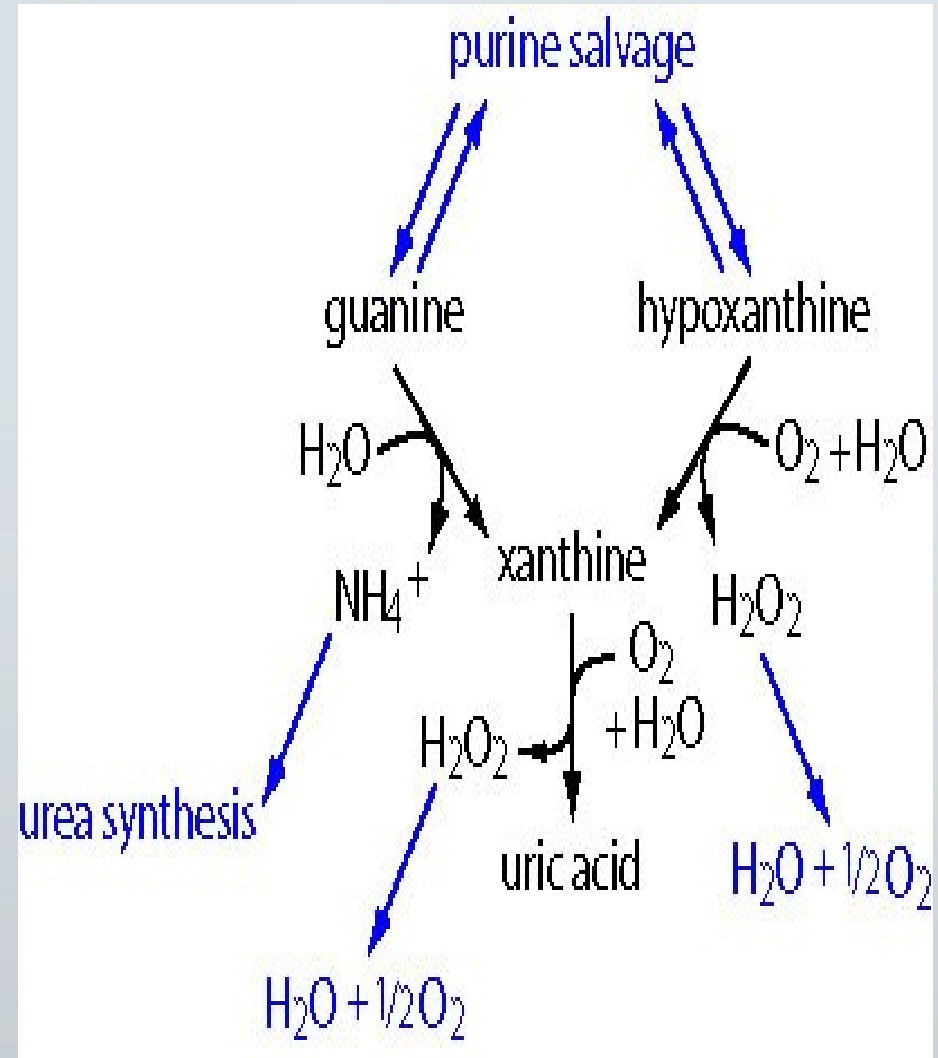


# Urea Cycle

1. **Carbamoyl Phosphate + Ornithine = Citrulline**
2. **Citrulline + Aspartate = Argininosuccinate**
3. **Cleavage of Argininosuccinate = Arginine & Fumarate**
4. **Cleavage of Arginine Releases Urea & re-forms Ornithine**
5. **Control of the Urea cycle Involves Carbamoyl Phosphate Synthetase**

# Purine Catabolism

- The end product of purine catabolism in man is uric acid. It is formed primarily in the liver and excreted by the kidney in the urine.



- **In birds, some reptiles, insects, dogs, and primates uric acid is also the end product. In all other terrestrial animals, including all other mammals, allantoin is the product excreted, whereas allantoate is the product in fish.**

▪ **Gout is a disease in humans that is caused by the overproduction of uric acid. Deposits of uric acid (which is barely soluble in water) accumulate in the joints of hands and feet. Allopurinol is a compound used to treat gout; it inhibits the degradation of hypoxanthine to xanthine and of xanthine to uric acid, preventing the buildup of uric acid deposits.**

# Biochemical Connections

## ▪ Lesch-Nyhan Syndrome

- A deficiency of the enzyme hypoxanthine-guanine phosphoribosyltransferase (HGPRT), is a genetic disease. The biochemical consequences include an elevated concentration of PRPP (Phosphoribosilpyrophosphate) and increased production of purines and uric acid. The accumulation of uric acid leads to kidney stones and gout, but the most striking clinical manifestations are neurological in nature. There is a compulsive tendency toward self-mutilation among patients with this syndrome; they tend to bite their fingertips and parts of their lips.



The development of kidney stones and gouty symptoms can be prevented by administering allopurinol, but there is no real treatment for the self-destructive behavior and the mental retardation and spasticity that accompany it. The diverse manifestations of this disease show clearly that metabolism is extremely complex and that the failure of one enzyme to function can have consequences that rich far beyond the reaction that it catalyzes.