

**Tishk International University**  
**Faculty of Applied Science**  
**Nutrition and Dietetics Department**



# Nutritional Biochemistry II

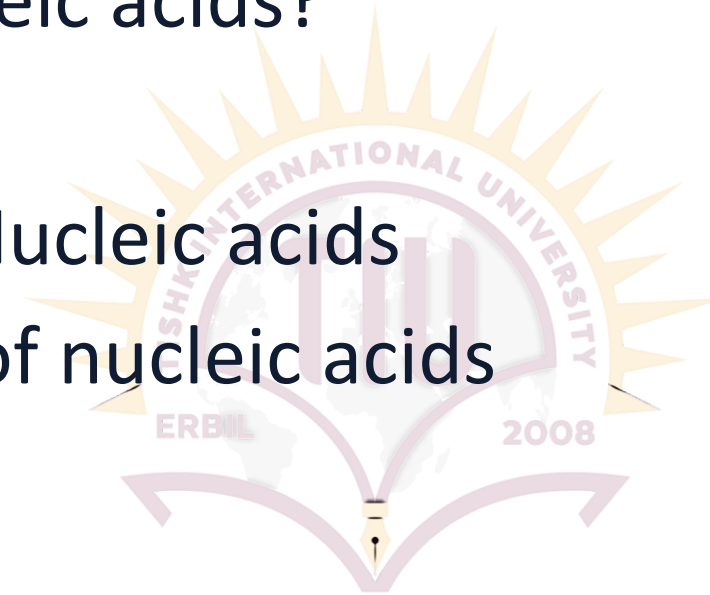
**TOPIC: Nucleic acids and Nucleotides**

**2<sup>nd</sup> Grade- Spring Semester 2025-2026**

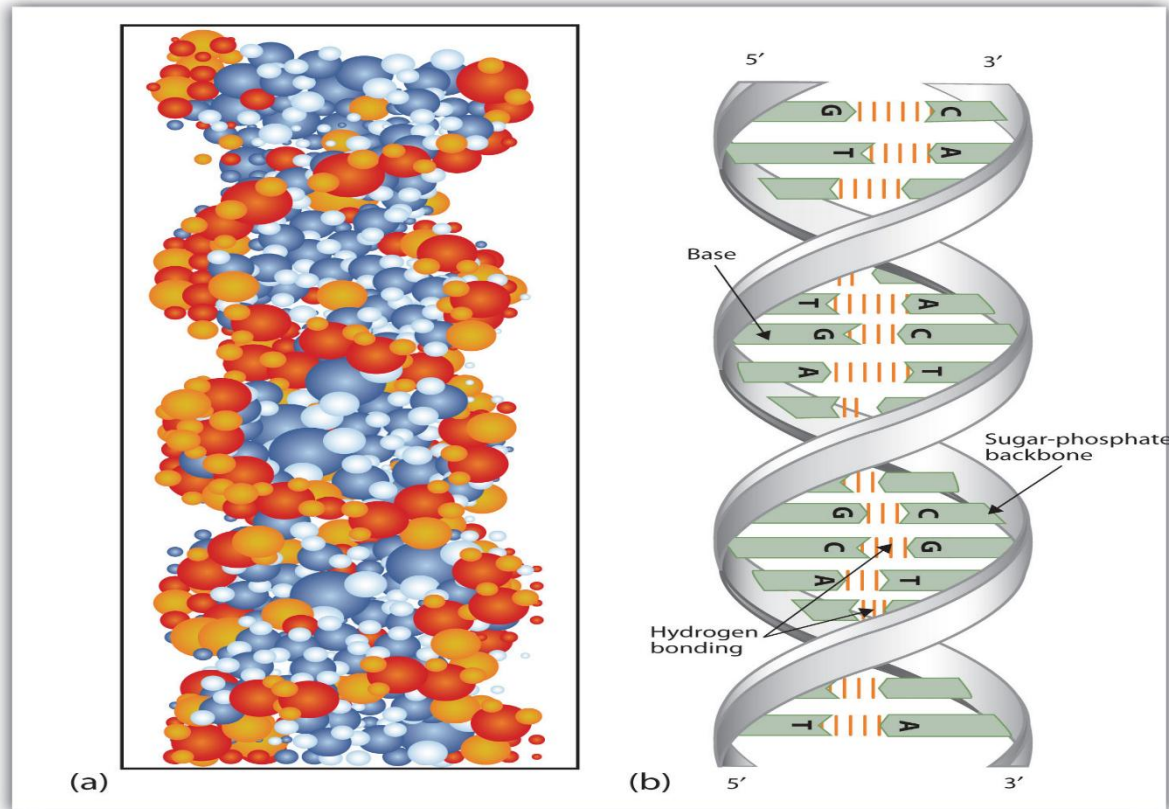
**Instructor: Amani Tahsin**

# Objectives;

- ✓ What are nucleic acids?
- ✓ A brief history
- ✓ Functions of Nucleic acids
- ✓ Components of nucleic acids
- ✓ Nucleotides



# DNA, the bank of genetic information speaks:



*"I am the chemical basis of life and heredity! Organized into genes that control every function;*

*Composed of repeating units of deoxyribonucleotides;*

*Arranged in a double helix, held by hydrogen bonds."*

# Nucleic acids

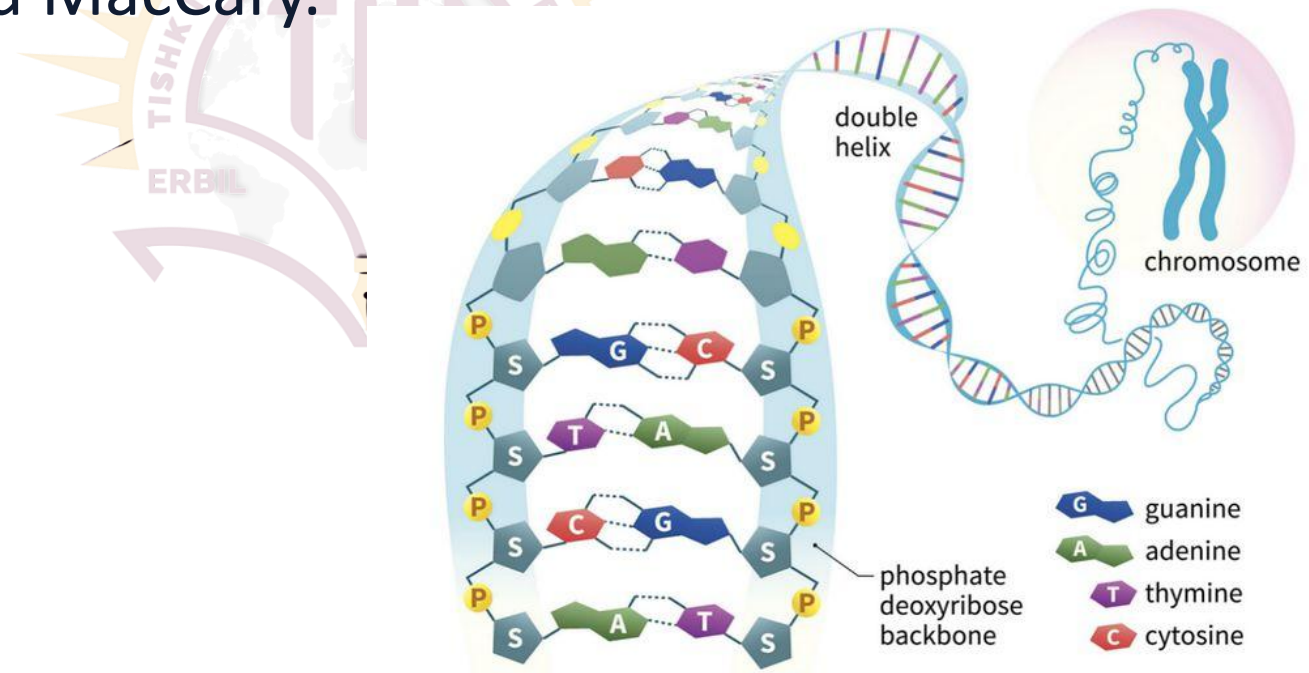
- ✓ Are the largest and the most complex organic molecules.
- ✓ Are macromolecules found in all cells, which participate in the storage, transmission and translation of genetic info.
- ✓ Nucleic acids are macromolecules with molecular masses of over 100 million.

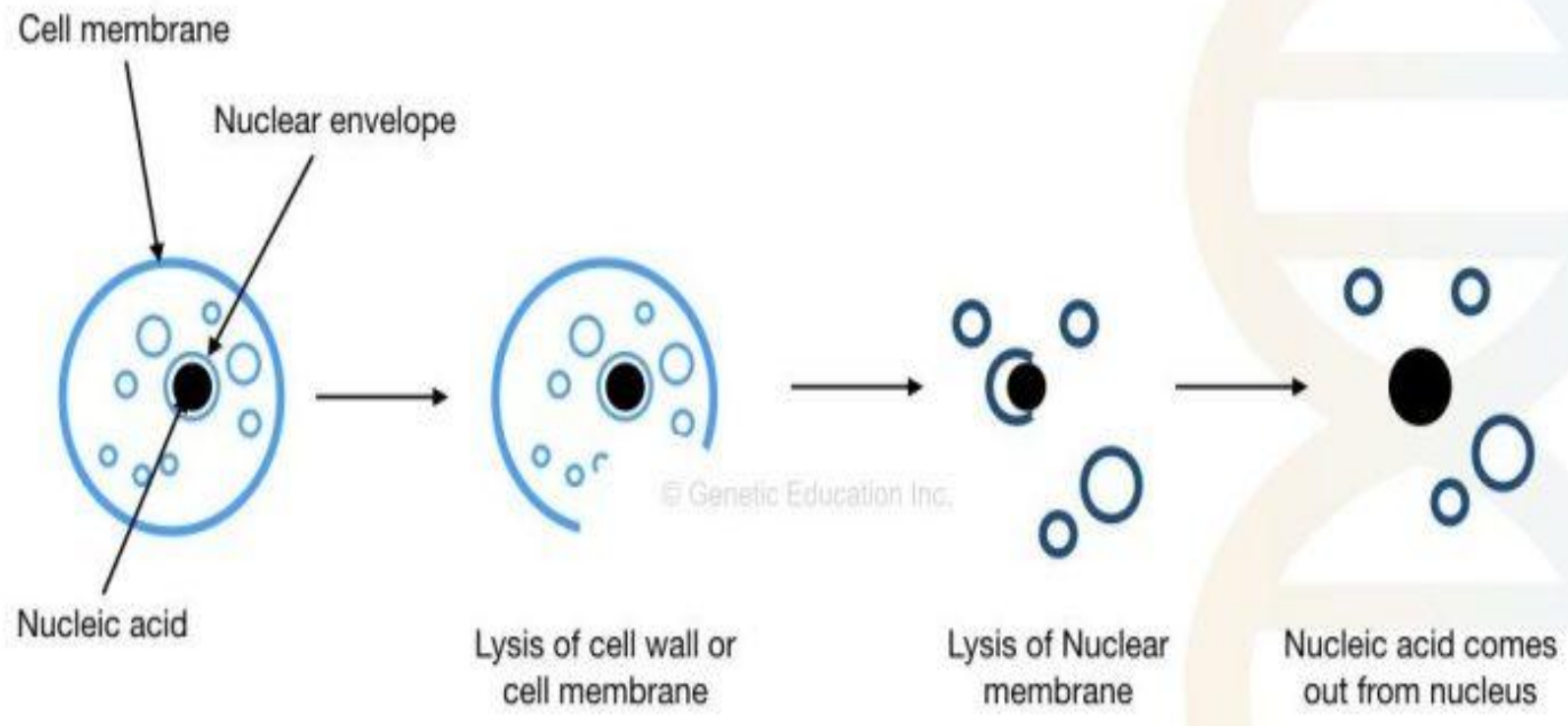
## Types of Nucleic acids

- ✓ There are 2 types of nucleic acids, **deoxyribonucleic acid (DNA)** and **ribonucleic acid (RNA)**.
- ✓ Primarily, nucleic acids serve as repositories and transmitters of genetic information.
- ✓ Which on hydrolysis of DNA and RNA the sugar deoxyribose and ribose will yield respectively.

# Brief History

DNA was discovered in 1869 by Johann Friedrich Miescher, a Swiss researcher. The demonstration that DNA contained genetic information was first made in 1944, by Avery, Macleod and MacCarty.





# Functions of Nucleic acids

## ❖ Functions of DNA

- ✓ DNA is a permanent storage place for genetic information.
- ✓ DNA controls the synthesis of RNA.
- ✓ The sequence of nitrogenous bases in DNA determines the protein development in new cells.
- ✓ Further, every aspect of cellular function is under the control of DNA.

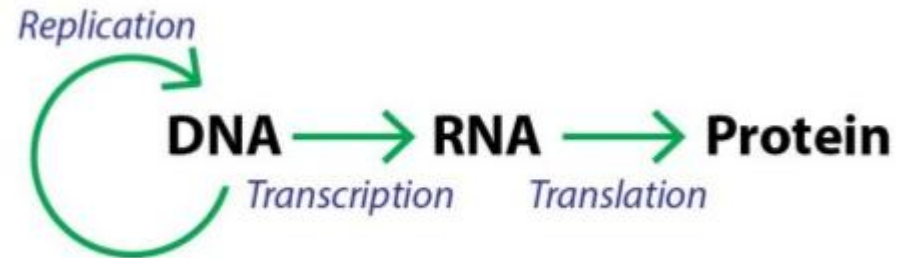
# Functions of Nucleic acids

## ❖ Functions of RNA

- ✓ RNA is synthesized by DNA for the transportation of genetic information to the protein building apparatus in the cell.
- ✓ RNA also directs the synthesis of new proteins using the genetic information it has transported.
- ✓ mRNA, is used to transfer genetic info. through plasma membranes.

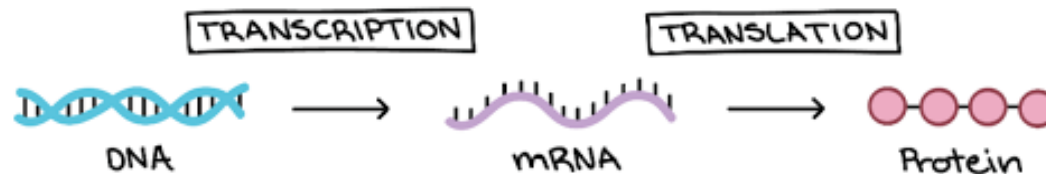
## Functions of Nucleic acids

- **DNA** is organized into *genes*, the fundamental units of genetic information.
- The genes control the protein synthesis through the mediation of RNA, as shown below



# Functions of Nucleic acids

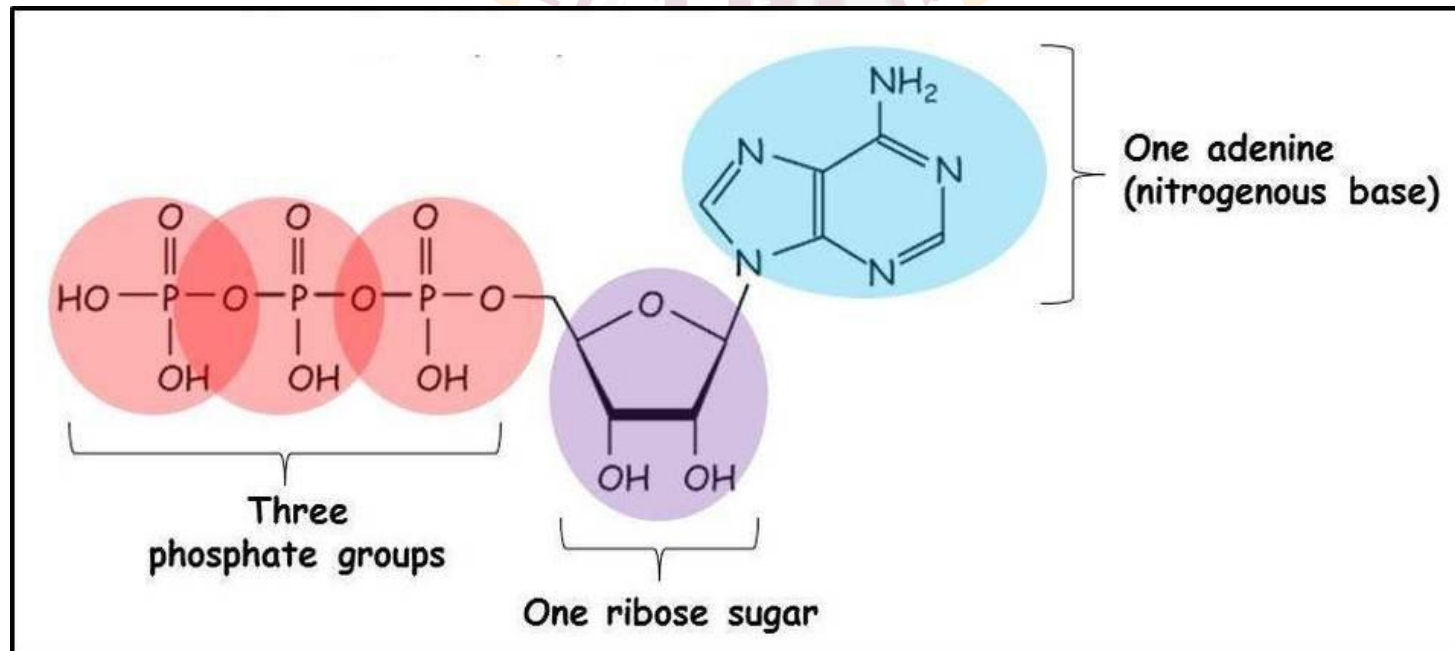
The interrelationship of these three classes of biomolecules (DNA, RNA and proteins) constitutes the *central dogma of molecular biology* or more commonly the *central dogma of life*.



## Providing Energy

Nucleic acids can be used to create energy in the form of ATP (adenosine triphosphate).

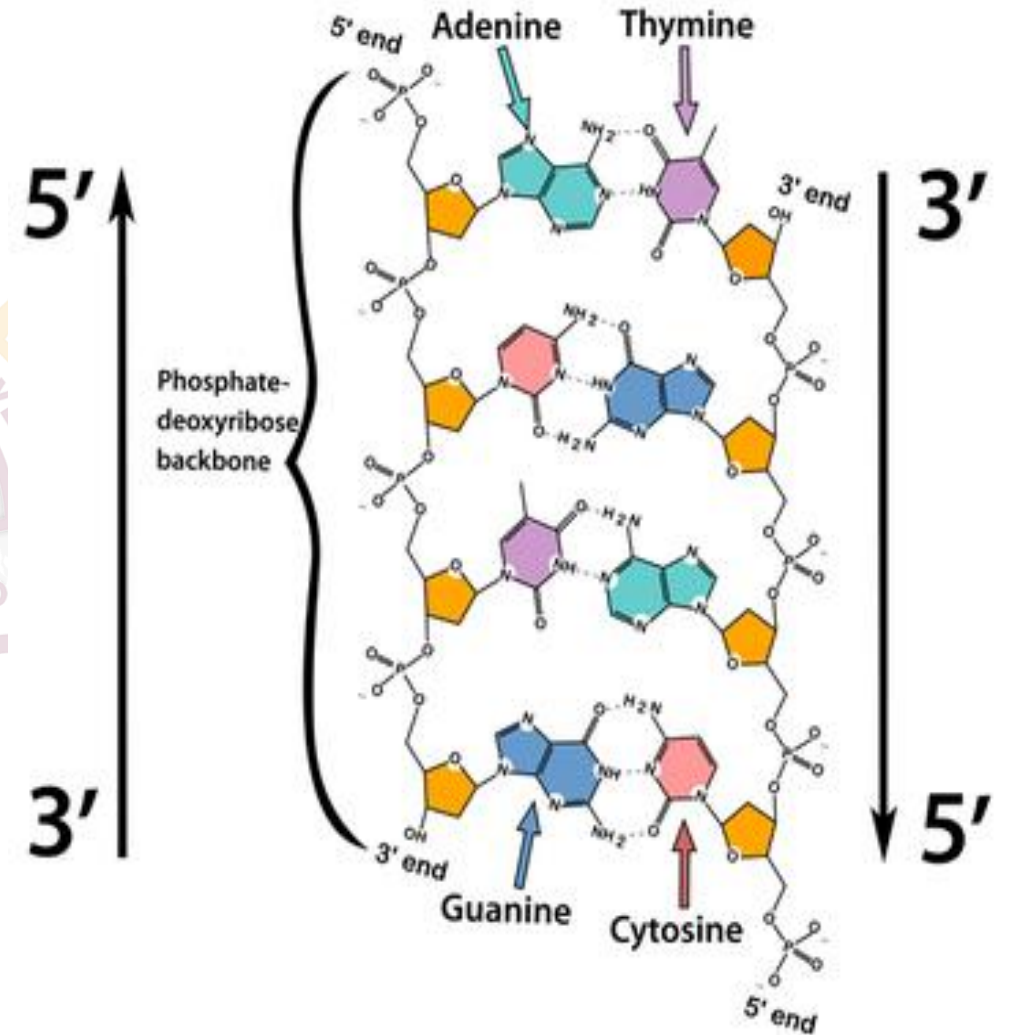
ATP is formed with the nitrogenous bases adenosine and ribose.



## Components of Nucleic acids:

Nucleic acids are the polymers of nucleotides held by 3' and 5' phosphate bridges.

On hydrolysis with either an enzyme or by heating with dilute acids or alkalis, nucleic acids yield a group of compounds known as nucleotides.



## Kinds of Nucleic acids

❖ DNA, found only inside the nucleus of the cell.

Contains the organism's genetic information including instructions for how to make proteins.

❖ RNA, found in both inside and outside of the nucleus.

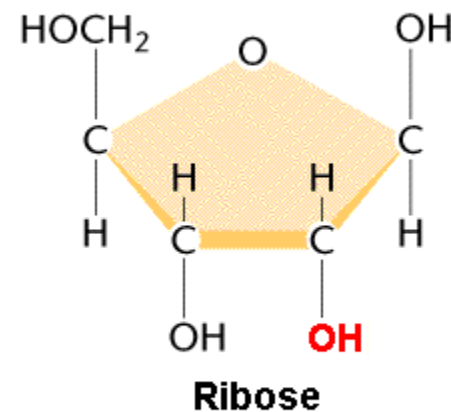
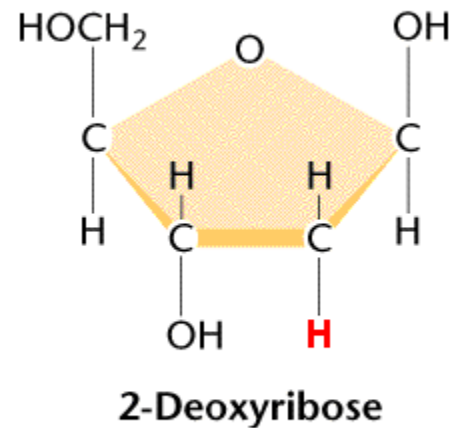
Directs the building of proteins.



# Sugars of Nucleic acids

The five carbon monosaccharides (pentoses) are found in the nucleic acid structure.

*RNA* contains *D-ribose* while *DNA* contains *D-deoxyribose*.



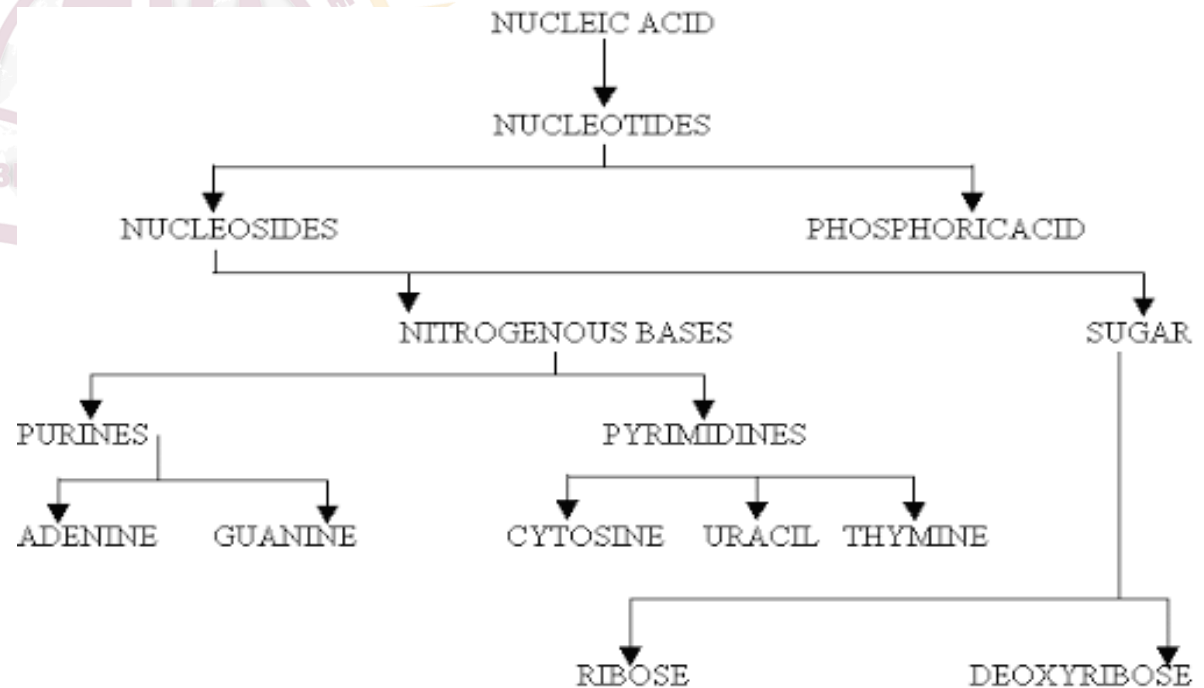
# Hydrolysis of nucleic acids

➔ NUCLEOTIDE.

Which can be considered the units that make up the polymer.

A *nucleotide* consists of 3 parts:

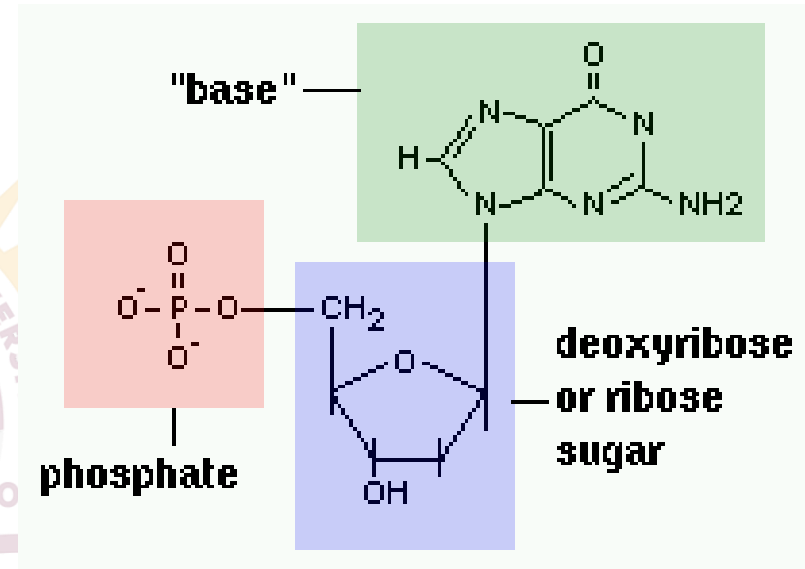
1. Heterocyclic base
2. Sugar
3. Phosphoric acids



# Nucleotides

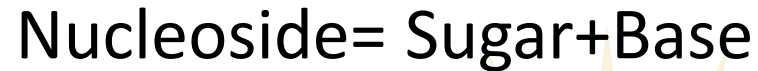
Nucleotides are composed of a nitrogenous base, a pentose sugar and a phosphate.

- Perform a wide variety of functions in the living cells.
- Being monomeric units in the nucleic acid (DNA and RNA structure).
- Including as structural components of some coenzymes of B-complex vitamins (e.g FAD, NAD<sup>+</sup>), in the energy reactions of cells (ATP is the energy currency).
- Have role in the control of metabolic reactions.

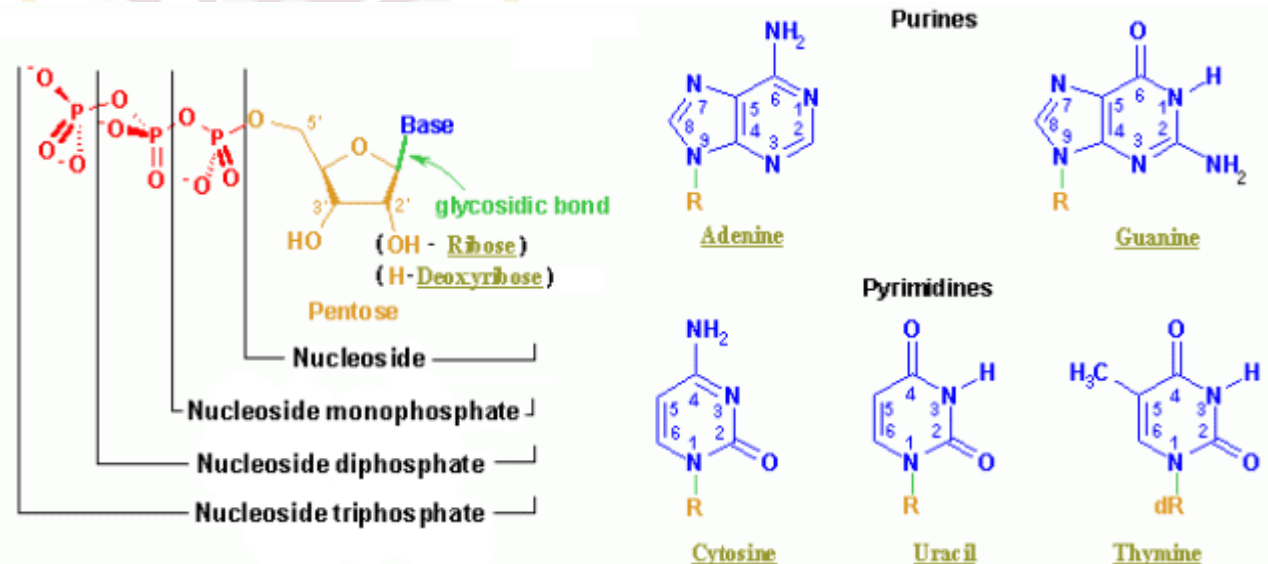


# Nomenclature of Nucleotides

- The addition of a pentose sugar to base produces a *nucleoside*.



- The term mononucleotide is used when a single phosphate moiety is added to a nucleoside, e.g. adenosine monophosphate (AMP).
- The prefix 'd' is used to indicate if the sugar is deoxyribose (e.g. dAMP).

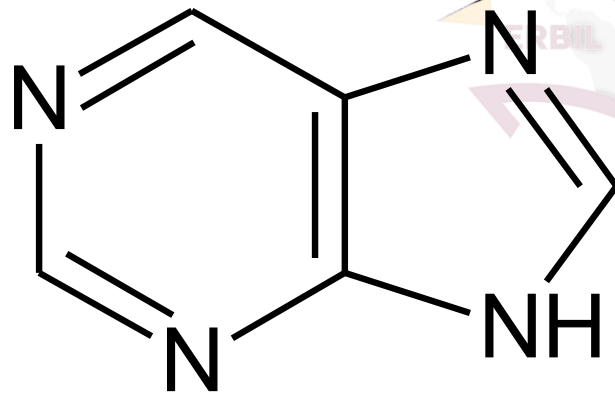


# HETEROCYCLIC BASES

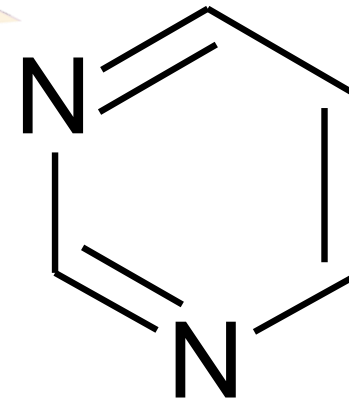
- Present in nucleic acids are divided into two types:

## PURINES & PYRIMIDINES.

- The two purines present both in DNA & RNA are Adenine & Guanine.
- For pyrimidines Cytosine is present in both DNA and RNA, whereas Thymine is found in DNA only and Uracil is present in RNA only.



Purine



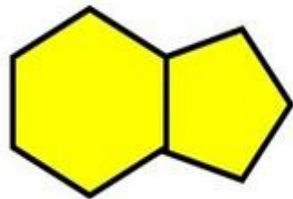
Pyrimidine

## There are five nitrogenous bases in total:

Found in:

DNA

RNA

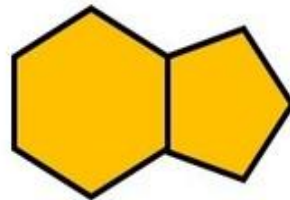


Guanine

Found in:

DNA

RNA

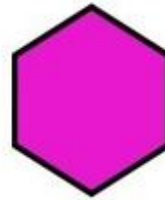


Adenine

Found in:

DNA

RNA



Cytosine

Found in:

DNA



Thymine

Found in:

RNA



Uracil

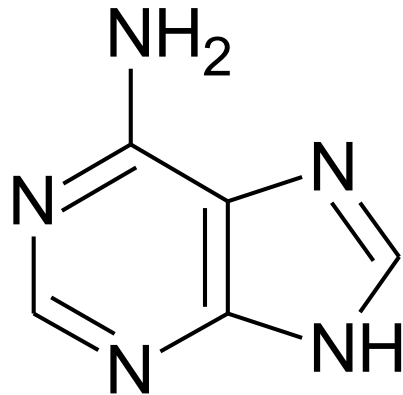
**Purines** = double ring structures

**Pyrimidines** = single ring structures

# Purines

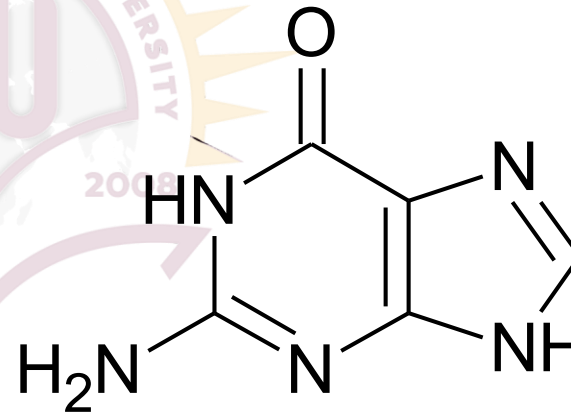
- Found in nucleic acids are derivatives of a substance, purine, that does not occur naturally.
- As indicated by their structures;

The purine bases are mainly two.



Adenine

6-amino purine



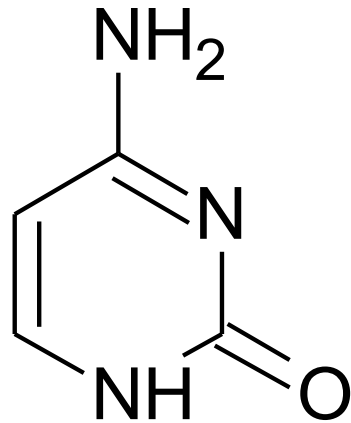
Guanine

2-amino -6-oxy purine

# Pyrimidines

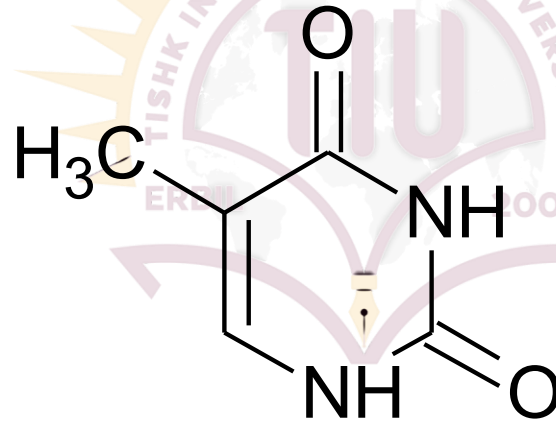
- Is a six-membered heterocyclic ring containing two nitrogen atoms.
- Three important derivatives of pyrimidine found in nucleic acids are thymine, cytosine and uracil.

The Pyrimidine bases are mainly three



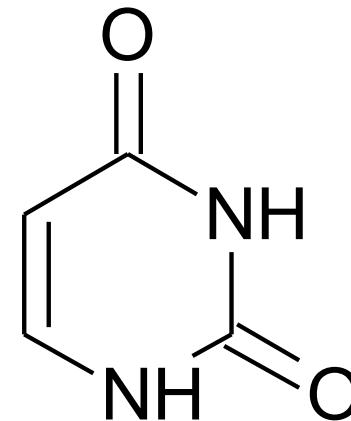
**Cytosine**

2-oxy-4-amino pyrimidine



**Thymine**

2,4-dioxy-5-methyl  
pyrimidine



**Uracil**

2,4-dioxy pyrimidine

# Purine, Pyrimidine and Nucleotide Analogs

The pharmacological applications of certain analogs are listed below:

1. **Allopurinol** is used in the treatment of hyperuricemia and gout.
2. **5-Fluorouracil**, 6-mercaptopurine, 8-azaguanine, 3-deoxyuridine, 5- or 6-azauridine, 5- or 6-azacytidine and 5-idouracil are employed in the treatment of cancers. These compounds get incorporated into DNA and block cell proliferation.
3. **Azathioprine** is used to suppress immunological rejection during transplantation.
4. **Arabinosyladenine** is used for the treatment of neurological disease, viral encephalitis.
5. **Arabinosylcytosine** is being used in cancer therapy as it interferes with DNA replication.
6. The drugs employed in the treatment of AIDS namely zidovudine or AZT and didanosine are sugar modified synthetic nucleotide analogs.

# Metabolic Functions

## 1. Role in energy metabolism.

ATP is a nucleotide, chemically it is adenosine triphosphate. It is store house of energy.

## 2. Nucleotides are monomeric units of nucleic acids

DNA-Deoxy ribonucleic acid RNA-Ribonucleic acid.

## 3. Physiological mediates:

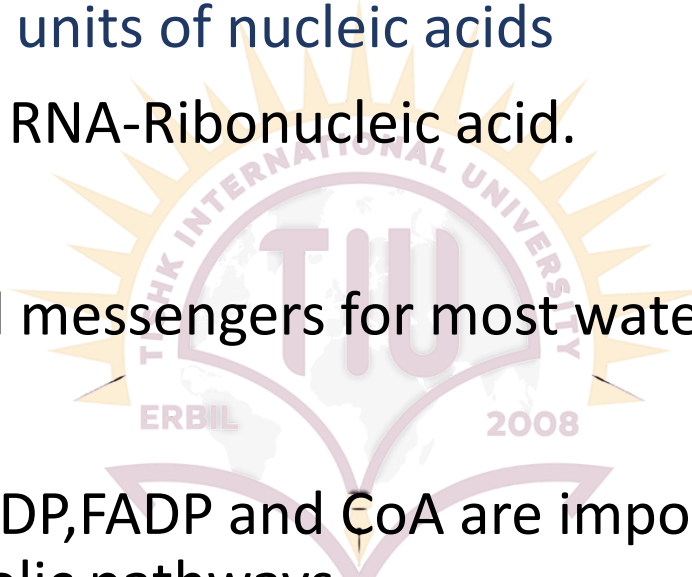
cAMP and cGMP are second messengers for most water soluble hormones.

## 4. Components of co enzymes

Coenzymes such as NAD,NADP,FADP and CoA are important constituents of cells and are involved in many metabolic pathways.

## 5. Activated intermediates

The nucleotides serve as carriers of activated intermediates required for different reactions; such as UDP-glucose is a key intermediate in the synthesis of glycogen.



## Metabolism:

The total of all anabolic and catabolic reactions is termed metabolism.

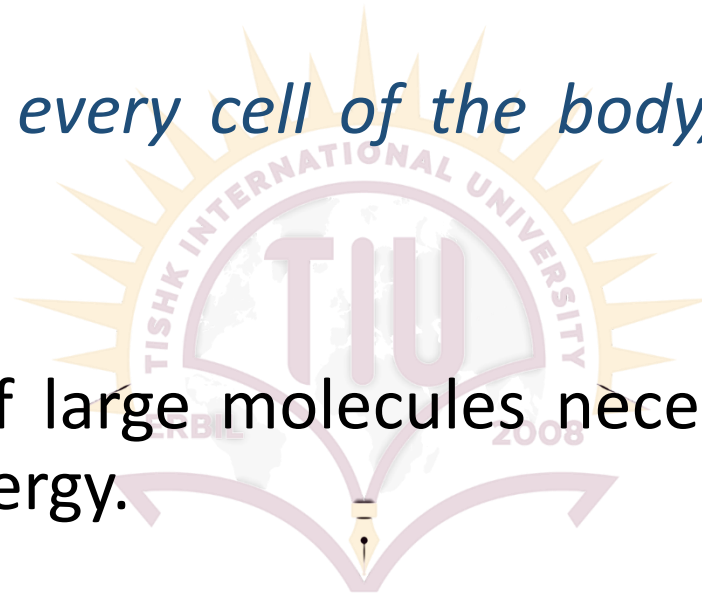
*Metabolism occurs in every cell of the body, every minute of the day.*

## Anabolism:

Is the build up of large molecules necessary for life and is a process requiring energy.

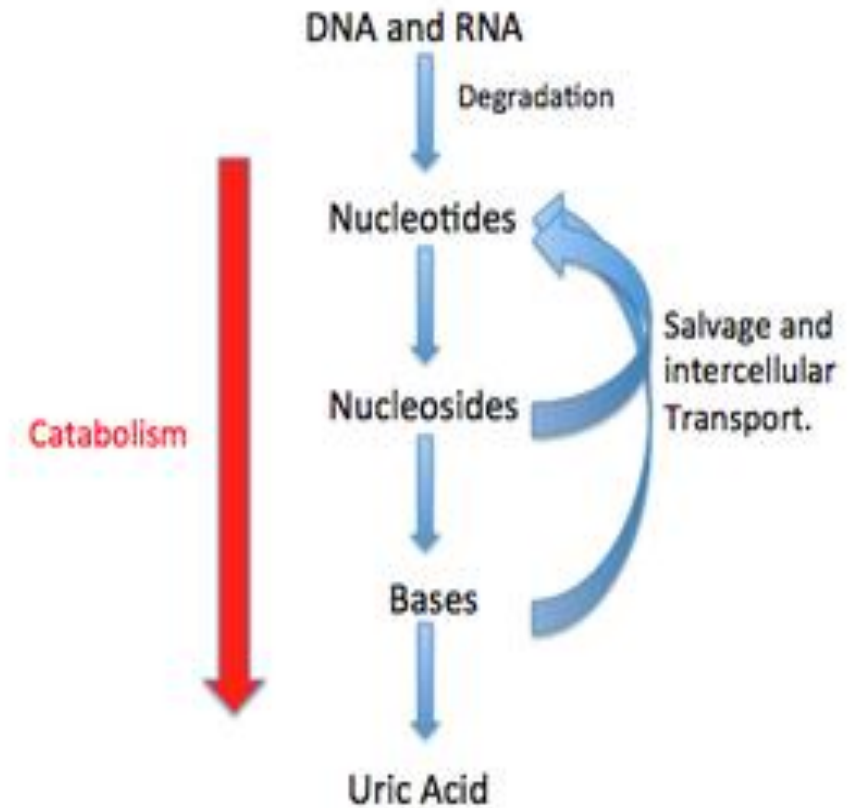
## Catabolism:

Is the break down or oxidation of large molecules into smaller molecules with the release of energy.



# Hydrolysis of Polynucleotides

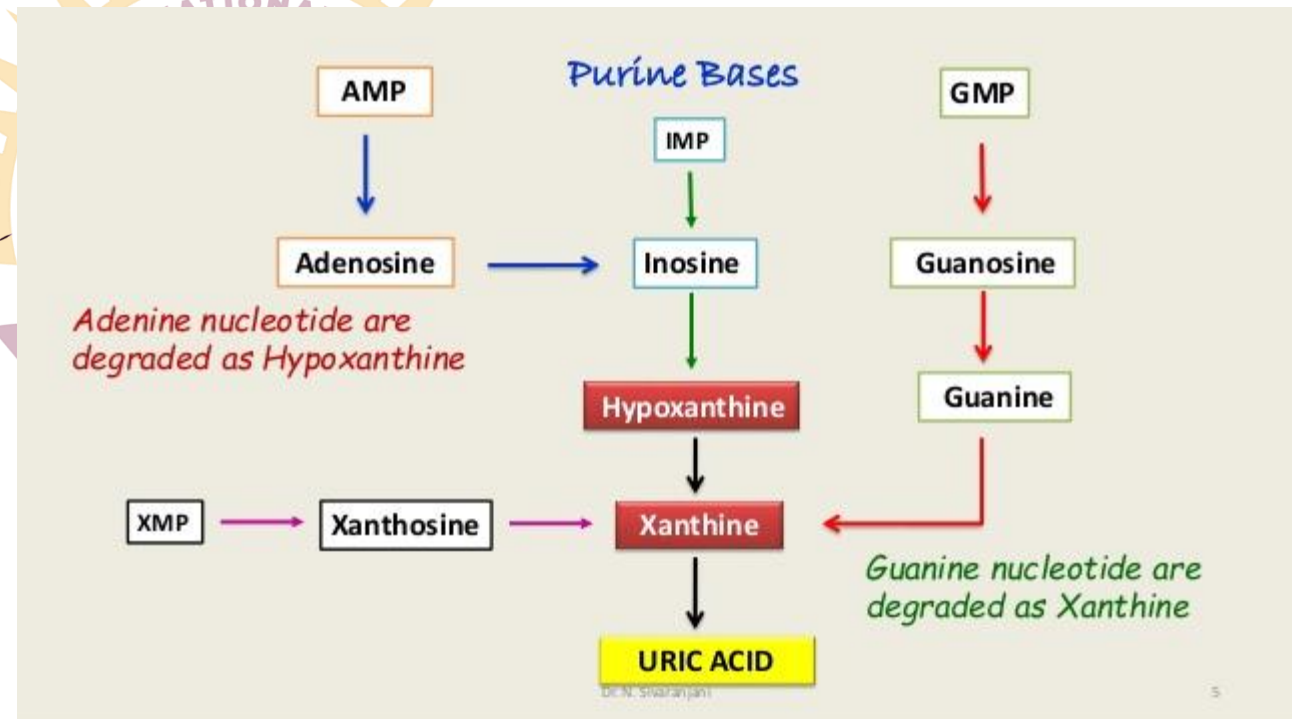
- Dietary nucleoprotein is degraded by *pancreatic enzymes* and tissue nucleoprotein by *lysosomal enzymes*.
- After dissociation of the protein and nucleic acid, the protein is metabolized like any other protein.
- The nucleotides are hydrolyzed by *nucleotidases* to give the nucleosides and Pi.



# Purine Catabolism

## Humans catabolize purines to uric acid:

Humans convert the major purine nucleosides adenosine and guanosine to the excreted end product uric acid via the intermediates and reactions.



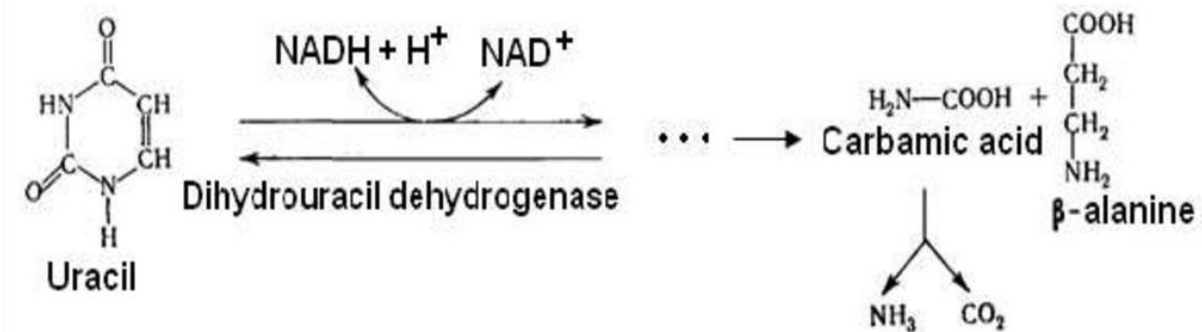
## Uric acid:

Uric acid is the end product of the metabolism of the purines (adenine and guanine), are present in RNA and DNA.

In humans, uric acid is excreted in the urine, but in other mammals uric acid is further oxidized to allantoin before excretion (most mammals have the enzyme uricase which oxidizes urate to the much soluble allantoin).

# Pyrimidine Catabolism

- In contrast to purines, pyrimidines undergo ring cleavage and the usual end products of catabolism are beta-amino acids plus ammonia and carbon dioxide.
- Pyrimidines from nucleic acids or the energy pool are acted upon by nucleotidases and pyrimidine nucleoside phosphorylase to yield the free bases. The 4-amino group of both cytosine and 5-methyl cytosine is released as ammonia.



## **Factors affect the plasma uric acid level in normal individual:**

In the normal individual the plasma urate level is influenced by a wide range of factors:

### **1. Sex:**

0.05-0.1 mmol/L higher in males; probably related to increased renal clearance in females, increased body mass in males.

### **2. Age:**

Uric acid levels are usually higher in older age group.

### 3. Exercise:

Lactic acidemia increases plasma urate.

### 4. Diet:

A/ elevated levels with high meat intake.

B/ alcohol increases plasma urate by lactate inhibition of urate secretion and increased turnover of adenine.

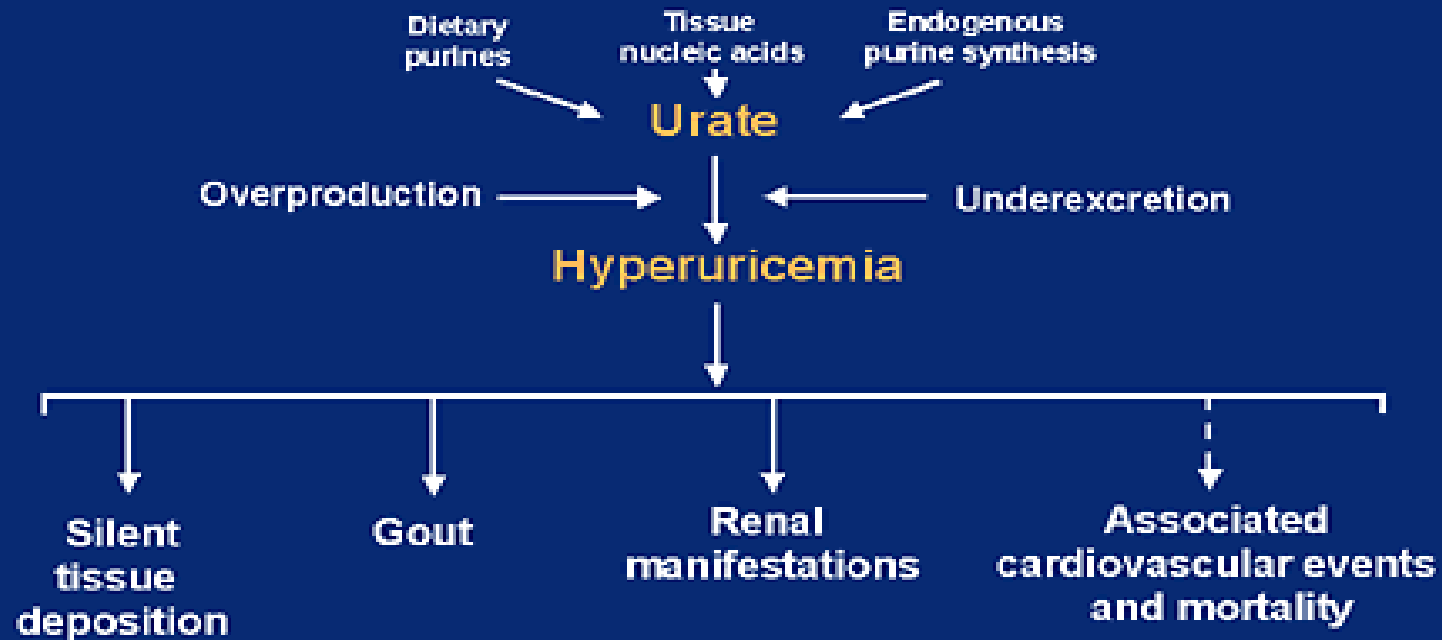
C/ fasting increases ketones, the  $\beta$ -hydroxy butyrate competitively inhibiting urate

Secretion by renal tubules.

# Gouts and Hyperuricemia



## The Hyperuricemia Cascade



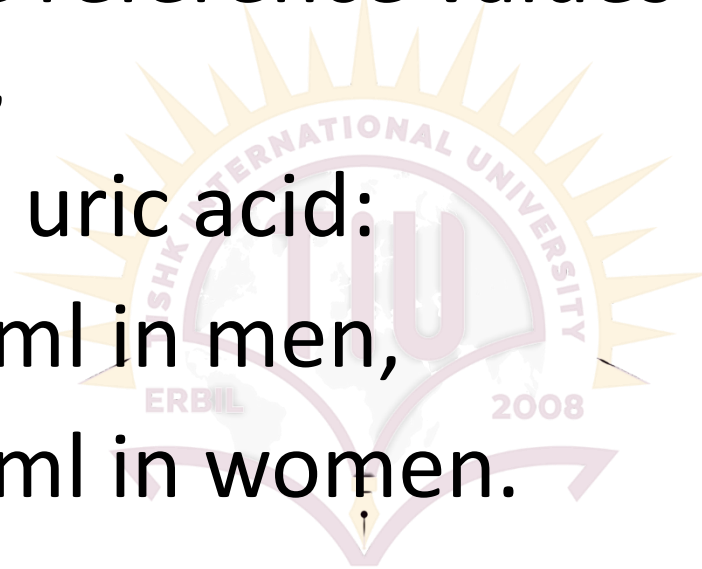
## Hyperuricaemia:

Hyperuricaemia can be defined, on the basis of the reference values for healthy individuals,

As a plasma uric acid:

> 9 mg/100ml in men,

> 7 mg/100ml in women.



## Causes of hyperuricaemia:

Increased plasma uric acid may be attributable to a number of mechanisms:

1. Increased rate of urate formation, (over production of urate):

A/ increased synthesis of purines (endogenous pathway).

B/ increased intake of purines (exogenous pathway).

C/ increased turnover of nucleic acids (malignancy, lymphoma, leukemia, tissue damage, starvation).

## 2. Reduced rate of excretion:

A/ renal disease.

B/ drugs- diuretics, aspirin.

C/ lactic acidaemia- alcohol, exercise.

D/ ketosis- diabetes mellitus, starvation.

E/ hypercalcaemia.

F/ pregnancy- induced hypertention.

# Gout

## Elevated Purine Source

- **Catabolism of Purines**
- Tumor lysis syndrome
- **Diet**
  - meat (beef, pork, lamb)
  - seafood (scallops, shrimp, tuna)
  - beer, distilled spirits
  - drinks with fructose

## Gout Risk Factors

- **Male gender**
- **Age**
- Obesity
- Ethnicity (Pacific Islanders)
- Polymorphisms (genetics)
- Kidney disease

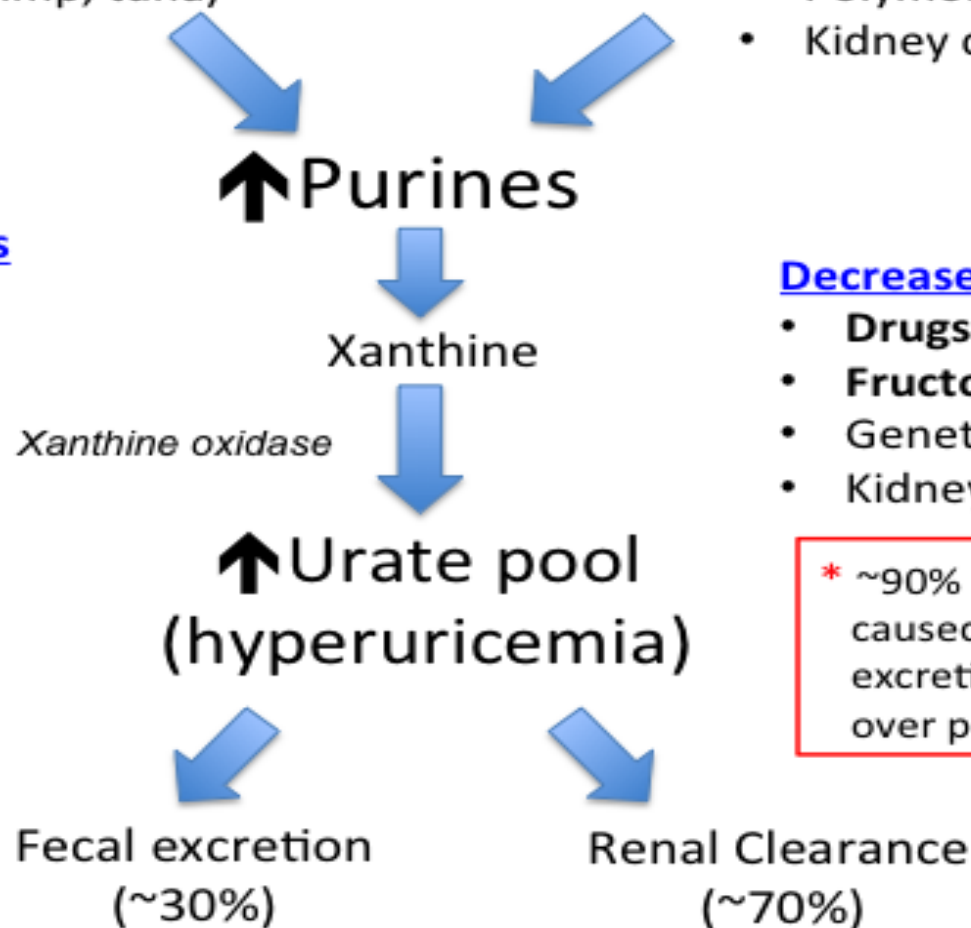
## Hyperuricemia Related Risks

- **Joint inflammation**
- Kidney or bladder stones
- Nephropathy
- CV disease
- Metabolic syndrome

## Decreased Renal Clearance \*

- **Drugs (HTZ, aspirin...)**
- **Fructose**
- Genetic factors
- Kidney disease

\* ~90% of cases of gout are caused by inefficient renal excretion of urate vs. over production.



## Gout:

Gout is a metabolic disease characterized by recurrent attacks of arthritis; uric acid deposits in the joints, kidneys, and other tissues; and elevated blood uric acid levels.

**There are two forms of gout:**

## 1. Primary gout:

- ✓ Primary gout is characterized by elevated uric acid levels in blood due to variety of metabolic abnormalities (enzyme abnormalities) that lead to the over production of purine nucleotides via the de novo pathway,
- ✓ With the over production of uric acid the levels of uric acid in the serum and urine are elevated, and there are deposits of sodium urate crystals in the joints of extremities.
- ✓ Formation of sodium urate crystals leads not only to the joint problems but also to renal disease.

e.g/ deficiency in glucose-6-phosphatase (glycogen storage disease type 1 : von gierks disease) leads to increased purine nucleotide synthesis de novo.

The lack of conversion of glucose-6-phosphate to glucose leads to increased hexose monophosphate shunt activity. The increased utilization of glucose-6-phosphate via the shunt results in increased ribose-5-phosphate levels.

## 2. Secondary gout:

Hyperuricaemia may occur as a complication of a number of disorders, all of which affect either uric acid production or excretion, or both, secondary to some other disease (decreased excretion or increased production).

e.g/ excretion is decreased in patients treated with thiazide and frusemide (diuretic therapy) (most effective diuretics cause hyperuricaemia), probably by reducing distal tubular secretion of uric acid (increased reabsorption).

e.g/ production is increased in leukemia and pneumonia (increased break down W.B.C. rich in uric acid). (Increased break down of nucleic acids).

In leukemia and pneumonia the number of W.B.C increased and W.B.C. contain purine.



## Principles of treatment of hyperuricaemia:

1. Reducing a diet rich in purines especially red meat, and reducing alcohol consumption.
2. Increasing renal excretion of urate by uricosuric drugs, such as probenecid a general inhibitor of the tubular secretion of organic acid.

3. colchicine, which has anti-inflammatory effect in acute gouty arthritis but does not affect urate metabolism. Colchicines cause blocks cell division, inhibits the synthesis and release of the leukotrienes approximately are mediators of inflammation.
4. Reducing urate production by using drugs those inhibit xanthine oxidase activity, such as allopurinol which is structurally similar to hypoxanthine so acting as competitive inhibitor.

- ✓ The overall effect of allopurinol treatment is to lower the uric acid levels in vivo. It is generally reported that allopurinol is an inhibitor of xanthine oxidase.
- ✓ However, allopurinol is oxidized by xanthine oxidase, to alloxanthine and this product binds tightly to the reduced form of xanthine oxidase.

The inhibition of xanthine oxidase by alloxanthine decreases the formation of uric acid, while increasing the levels of hypoxanthine and xanthine excreted.