

## Module 7: Drugs and Medications - Study Materials

### Keyterms

Use the Glossary (top menu bar) to check out these terms

- Single bond
- Double bond
- Triple bond
- Functional Group

### Slide 3:

#### Introduction to Organic Chemistry

##### Overview

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Organic chemistry deals with the study of carbon containing compounds and their reactions. Organic molecules are present in living organisms and in many products used in our everyday lives such as foods, household cleaning products, personal care products etc.

As the element carbon is present in the majority of drugs used today, some basic principles of organic chemistry (the study of carbon compounds) are discussed in this section.

Right: Correlation between the carbon cycle and formation of organic compounds. In plants, carbon dioxide formed by carbon fixation can join with water in photosynthesis (green) to form organic compounds, which can be used and further converted by both plants and animals (Source: Mikael Häggström, Wikimedia)

#### Introduction to Organic Chemistry

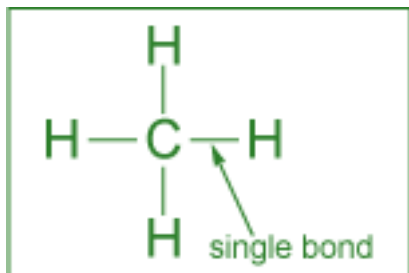
##### The Element Carbon

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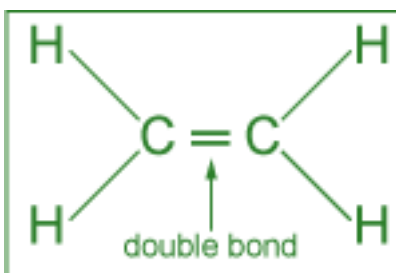
The main characteristics of carbon that lead to the formation of such a large number of organic compounds (over 10 million known) with dramatically different physical and chemical properties include the ability to form:

- Covalent single, double and triple bonds with some other elements, including carbon.
- Covalent bonds with other carbon atoms to build chains and cyclic structures.
- Covalent bonds with elements such as hydrogen, nitrogen, oxygen and halogens.

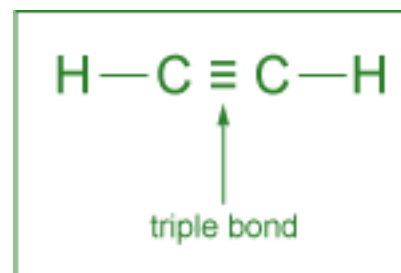
In the structures shown below, each line (bond) represents a pair of electrons.



**Single bond:** formed by the sharing of one pair of electrons.



**Double bond:** formed by the sharing of two pairs of electrons.



**Triple bond:** formed by the sharing of three pairs of electrons.

## Slide 5:

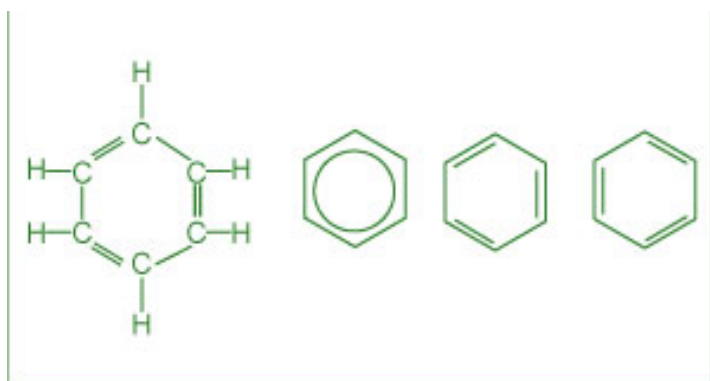
### Introduction to Organic Chemistry

#### Arrangement of Atoms

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Among the cyclic structures, the arrangement of carbon atoms in 5- or 6-membered rings is quite common. The hexagonal (6-membered) ring with three single and three double bonds is called a benzene ring.

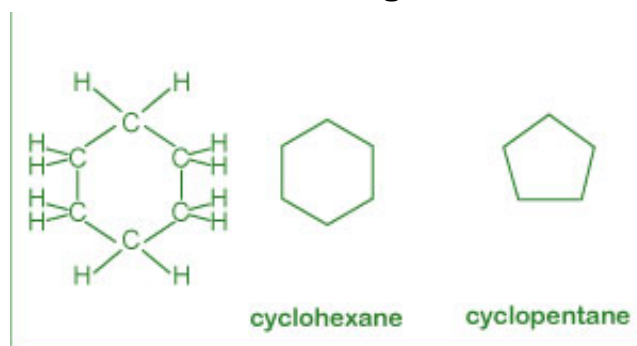
#### Various Ways to Represent Benzene (C<sub>6</sub>H<sub>6</sub>) Ring



The cyclohexane ring contains:

b) Twelve hydrogen atoms

#### Other Rings



cyclohexane

cyclopentane

### Functional Groups

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#### Introduction:

- Organic compounds are divided into some important families based on their characteristic functional group
- A functional group can be visualized as a small structural unit or arrangement of atoms in a molecule that is the chemically functioning part of the molecule
- In the case of drugs, the functional groups are responsible for their action. In addition, the function groups may also determine important parameters such as the rate of uptake and reaction as well as the time of residence of the drug in the body

## Alcohol

### Alcohol

Functional Group	General Formula*	Example
$\text{-OH}$	$\text{R-OH}$	$\begin{array}{c} \text{H} \quad \text{H} \\   \quad   \\ \text{H}-\text{C}-\text{C}-\text{OH} \\   \quad   \\ \text{H} \quad \text{H} \end{array}$ <p>(Ethyl alcohol)</p>

\*R and R<sup>1</sup> represent hydrocarbon fragments which can be the same or different.

## Aldehyde

### Aldehyde

Functional Group	General Formula*	Example
$\begin{array}{c} \text{O} \\    \\ \text{-C-H} \end{array}$	$\begin{array}{c} \text{O} \\    \\ \text{R-C-H} \end{array}$	$\begin{array}{c} \text{O} \\    \\ \text{H-C-H} \end{array}$ <p>(Formaldehyde)</p>

\*R and R<sup>1</sup> represent hydrocarbon fragments which can be the same or different.

## Amine

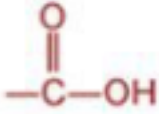
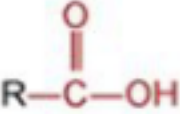
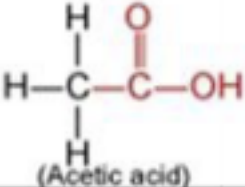
### Amine

Functional Group	General Formula*	Example
$\text{-NH}_2$	$\text{R-NH}_2$	$\begin{array}{c} \text{H} \\   \\ \text{H}-\text{C}-\text{N} \begin{array}{l} / \text{H} \\ \backslash \text{H} \end{array} \\   \\ \text{H} \end{array}$ <p>(Methyl amine)</p>

\*R and R<sup>1</sup> represent hydrocarbon fragments which can be the same or different.

## Carboxylic acid

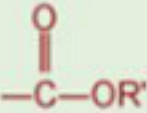
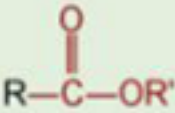
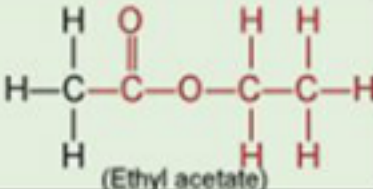
### Carboxylic acid

Functional Group	General Formula*	Example
		 (Acetic acid)

\*R and R<sup>2</sup> represent hydrocarbon fragments which can be the same or different.

## Ester



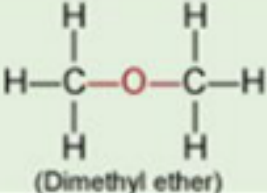
### Ester

Functional Group	General Formula*	Example
		 (Ethyl acetate)

\*R and R<sup>2</sup> represent hydrocarbon fragments which can be the same or different.

## Ether


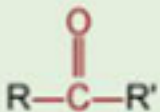

### Ether

Functional Group	General Formula*	Example
		 (Dimethyl ether)

\*R and R<sup>2</sup> represent hydrocarbon fragments which can be the same or different.

## Ketone

### Ketone

Functional Group	General Formula*	Example
		 (Acetone)

\*R and R<sup>1</sup> represent hydrocarbon fragments which can be the same or different.

Propane, Ethyl Alcohol, Butyraldehyde, Acetone, Acetic Acid, Ethyl Butyrate

### Examples

CH <sub>3</sub> CH <sub>2</sub> CH <sub>3</sub>	Propane	Fuel in gas barbecue
CH <sub>3</sub> CH <sub>2</sub> OH	Ethyl alcohol	Present in alcoholic beverages
CH <sub>3</sub> (CH <sub>2</sub> ) <sub>2</sub> CHO	Butyraldehyde	Responsible for the unpleasant odor of rancid butter
CH <sub>3</sub> COCH <sub>3</sub>	Acetone	Component of nail polish remover
CH <sub>3</sub> COOH	Acetic acid	Vinegar is 5% aqueous solution of acetic acid
CH <sub>3</sub> (CH <sub>2</sub> ) <sub>2</sub> COOCH <sub>2</sub> CH <sub>3</sub>	Ethyl butyrate	Responsible for the sweet aroma of pineapple

## Treatment of Infections and Diseases

### Overview



This text is from the Edwin Smith papyrus, the world's oldest surviving surgical document. Written in hieratic script in ancient Egypt around 1600 B.C. The ancient Egyptians were contemporaries of the Sumerians.

From the Sumerians (2200 BC) to the present, the discovery and usage of drugs has gone through a number of phases such as:

- Medicinal preparations and concoctions from plants, minerals and animal sources.
- Isolation and the use of plant ingredients as medications.
- Synthesis and testing of a variety of chemicals as potential cures for ailments.
- New areas of research into marine plants and organisms as potential drugs.
- Molecular modeling in designing drugs.

Extensive research with the available sophistication in the field of medicine has led us to engineer molecules that can be used to improve the quality of life by preventing, moderating or curing illnesses.

**About the document:** The text describes anatomical observations and the examination, diagnosis, treatment, and prognosis of 48 types of medical problems in exquisite detail. Among the treatments described are closing wounds with sutures, preventing and curing infection with honey and moldy bread, stopping bleeding with raw meat, and immobilization of head and spinal cord injuries. Translated in 1930, the document reveals the sophistication and practicality of ancient Egyptian medicine. Plate 6 and 7 of the papyrus, pictured here, discuss facial trauma (Source: Wikimedia)

## Antibiotics

Antibiotic drugs are used to fight (prevention or treatment) bacteria that cause infectious diseases such as meningitis, pneumonia, tuberculosis, and so on

Different categories of antibiotics include:

- Penicillin:
  - Treat infections caused by bacteria
  - Do not fight infections caused by viruses
  - Mode of action: affect the development (damaging) of bacteria cell walls
- Cephalosporin
  - Have the structure similar to that of penicillin
  - Treat much broader range of infections compared to penicillin
  - Mode of action: affect the development of bacterial cell walls

- Tetracycline
  - Chemical structure consisting of 4 rings
  - Used to treat penicillin-resistant infections
  - Mode of action: inhibit the synthesis of required bacterial proteins

The discovery of a large number of chemically modified derivatives of these antibiotics led the control of a large variety of bacterial infections. Antibiotics are isolated from bacterial sources, but can also be human-made. Antibiotics act directly on bacteria and destroy them or inhibit their growth. Antibiotics will **not kill viruses**

### How do antibacterial drugs work

The actual mechanism of antibacterial drugs is to alter or inhibit one of the following cellular structures/processes:

- **Cell wall synthesis:** prevent new bacterial cells from forming by preventing formation of the cell wall
- **Cell membrane permeability:** kills bacteria cells by causing breakdown of the outer cell membrane
- **Protein synthesis:** prevents the bacteria from converting proteins to energy, causing starvation and ultimate cell death
- **Nucleic acid synthesis:** keeps bacteria cells from growing by interrupting DNA synthesis
- **Competitive inhibitor:** mimics bacteria's growth factors, thus preventing spreading of the bacteria

### Antibiotics vs. superbugs

The emerging concern in the use of antibiotics is the resistance many of the so-called superbugs have shown towards the known antibiotics.

The suggested ways to decrease antibiotic resistance include:

- More cautious use of antibiotics
- Monitoring outbreaks of antibiotic resistances
- Developing new antibiotics

### Antiviral Drugs

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Antiviral drugs are used to treat (cure or control) viral infections such as flu, polio, herpes and AIDS (Acquired Immune Deficiency Syndrome). A different strategy has to be used to combat viruses, as these do not respond to antibiotics. Two commonly used strategies to fight viral infections include:

#### Prevention through vaccination

When a vaccine (consisting of inactivated virus) is injected, antibodies to fight off a virus are developed and stored in the body. The stored antibodies become available to fight future infection.

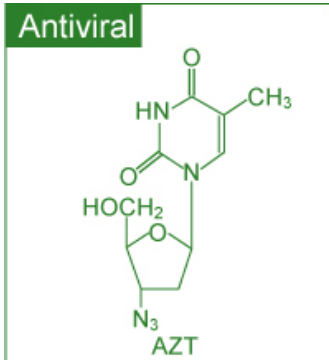
#### Use of antiviral drugs

Commonly used antiviral drugs (particularly for the treatment of the AIDS virus) fall into three classes:

1. **Nucleoside derivatives** inhibit the synthesis of viral DNA, thus preventing the virus from spreading.
2. **Protease inhibitors**, on the other hand, interfere with the viral protein formation, thus preventing their reproduction.
3. **A three-drug cocktail** consisting of different nucleoside derivatives and protease inhibitors has shown considerable promise in the treatment of AIDS. This triple cocktail treatment is also known as Highly Active Antiretroviral Therapy (HAART). The success of the therapy is

probably due to the cocktail's ability to disrupt the viral replication at different stages. It is important to note that the therapy is very expensive and patients must adhere to their dosing schedule.

Some major problems associated with multiple drug therapy are: Moderate effectiveness, lack of response in some cases, serious to severe side effects and drug resistance by the virus. Recent efforts in the fight against AIDS have been directed towards the development of: Viral entry inhibitors (i.e., the drugs that will prevent HIV from attaching and consequently entering into the cell) and Vaccines.



## Anticancer Drugs

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Overview: Cancer involves an uncontrolled division of some cells of the body due to mutation of DNA within the healthy cells. These cells invade nearby tissue and spread throughout the body via the bloodstream or lymphatic system. Thus the chemical treatment of cancer (chemotherapy) involves drugs targeting rapidly dividing cells to kill the cancerous cells.

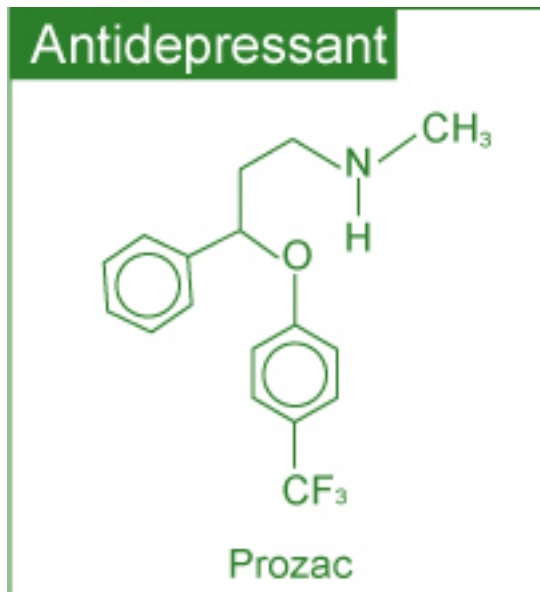
Some chemotherapeutic agents include:

- Alkylating agents:
    - Mode of action: due to their high reactivity, alkylating agents introduce defects in the DNA, thus killing the rapidly growing cells by preventing cell growth and multiplication
    - Alkylating drugs also affect the growth of normal cells and cause mutations
  - Antimetabolites
    - Metabolite is a general term for the organic compounds that are synthesized, recycled, or broken down in cells
    - Antimetabolites inhibit DNA synthesis, thus stopping cell replication
    - Mode of action: compete for binding sites on enzymes and are incorporated into nucleic acids
  - Topoisomerase inhibitors
    - Topoisomerase inhibitors damage DNA which causes cell death
    - Mode of action: act against the topoisomerase enzymes to prevent cancer cell growth
  - Hormone Therapy
    - Used against certain cancers that depend on hormones for their growth
    - Used primarily for the treatment of breast cancer and that of the sexual organs
    - As these tissues require hormones for their growth, the chemotherapeutic agent acts by inhibiting the hormone supply thus stopping the tissue growth
    - Mode of action: Stop the production of certain hormones or change their mode of function
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## Antidepressants

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A deficiency of certain neurotransmitters (any chemical that carries impulses between nerve cells), particularly serotonin in the brain, seems to be partly responsible for causing clinical depression. Neurotransmitters are needed for normal brain function and mood control, in addition to other functions.



Although the effects of antidepressants are not fully understood, there is substantial evidence to show that antidepressants help to restore the brain's chemical balance.

### Commonly used antidepressants include:

- Selective Serotonin Reuptake Inhibitors (SSRIs) (e.g. Prozac, Paxil and Zoloft)
- Monoamine Oxidase Inhibitors (MAOIs) (e.g. Nardil, Marplan and Parnate)
- Serotonin and Norepinephrine Reuptake Inhibitors (e.g. Effexor)
- Norepinephrine and Dopamine Reuptake Inhibitors (e.g. Welbutrin)
- Tricyclics (e.g. Norpramine, Pamelor and Tofranil)

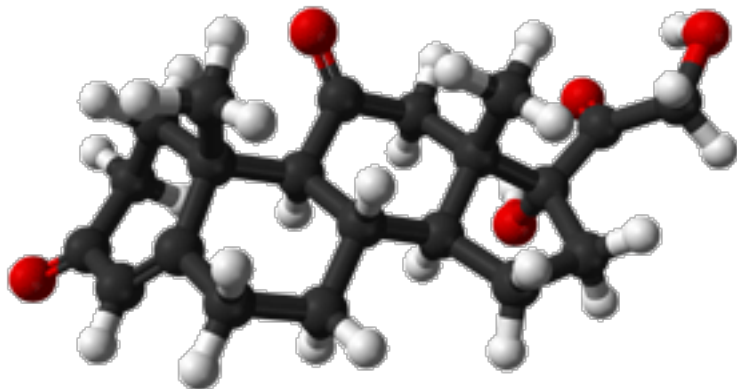
Whereas SSRIs target the serotonin levels only, tricyclics affect the brain levels of other neurotransmitters (including serotonin) as well.

## Anti-Inflammatory Drugs

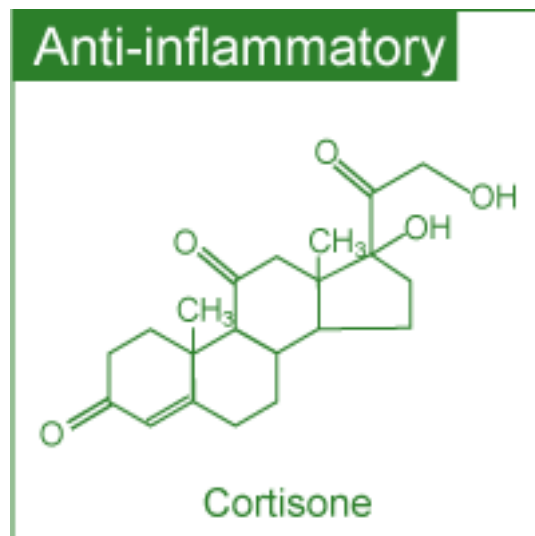
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Inflammation is the first response of the immune system to infection or irritation characterized by pain, swelling, redness and heat. An inflammation results from the rapid transport of blood proteins and other substances to a damaged tissue site or an area under attack by a foreign organism.

Certain steroids are used as potent anti-inflammatory drugs. These suppress the inflammatory responses of the body, thus reducing inflammation.



Ball-and-stick model of the cortisone molecule  
(Source: Ben Mills, Structure from the [Spartan database](#),  
Wikimedia)



## Over the Counter Drugs

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**Use of OTC Drugs:** Whereas all types of drugs discussed earlier require a prescription, a considerable number of drugs are sold over the counter OTC without a prescription

- According to the Non prescription drug manufacturers association, in the US alone there are more than 600 OTC drugs

**OTC Drug Criteria:** The criteria generally used by the regulatory agencies to designate a drug with OTC status or switch its status from R<sub>x</sub> to OTC (from prescription drug to one sold without prescription) involves a benefit risk comparison and making sure that patients alone can achieve the desired medical result without endangering their safety

- Although OTC drugs allow patients to participate in their own health care, experts emphasize that the labels must be followed closely because OTC drugs are not without risk

### Aspirin – The Best known OTC drug

Aspirin, was introduced more than a century ago. Recent studies have shown its usefulness in treating heart attack and stroke

It has long been used as an:

- Analgesic (relieving minor pain)
- Antipyretic (lowering fever)
- Anti-inflammatory (reducing swelling)

**Effectiveness:** believed that aspirin's effectiveness as an analgesic, anti-inflammatory agent and its protective effects against heart attacks and strokes are due to its ability to reduce the production of prostaglandins (a hormone-like substance that promotes inflammation, fever and pain) and thromboxane (responsible for platelet aggregation in the formation of blood clots) in the body

Some possible side effects:

- Stomach irritation
- Ringing in the ears
- Allergy
- Reye syndrome (brain disorder) in children

10. The ability of Aspirin to reduce the production of prostaglandins and thromboxanes is believed to be:

- The reason for its effectiveness as an analgesic
- The reason for its effectiveness as an anti-inflammatory agent
- The reason for its protective effects against heart attacks and strokes
- All of the answers apply

## Treatment of Infections and Diseases

### Drug Delivery Systems

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A 21mg dose Nicoderm CQ patch applied to the left arm (Source: Wikimedia)

Active pharmaceutical ingredient (API) in a medicine is delivered to the body in many forms, such as tablets, gels, liquids and so on. Some newer alternate methods for drug delivery have been developed with three major advantages:

- User convenience
- Improved drug performance
- Better patient compliance

Some of these methods include:

- **Pulmonary delivery:** The system is noninvasive and facilitates the rapid absorption of the drug on the large surface area of the lungs followed by rapid desorption into the bloodstream.
- **Skin absorption:** Skin patches are being used to deliver the medication via skin absorption.
- **Nanocrystals:** This method reduces the drug particle size to nanoscale (<400 nm) making it more soluble in body fluids.

## Effects & Trends

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### Environmental Effects of Pharmaceuticals

Recent research has led scientists to be concerned about the environmental impact of old and/or expired medications that are discarded. The pharmaceuticals enter the environment mostly through raw or treated sewage.

**Some of the effects observed include:**

- **Feminization of male fish due to estrogenic compounds:** The signs of feminization in male fish have been concluded as a response to estrogen (in birth control pills) exposure.
- **Slow development of fish and frogs due to certain antidepressants:** Profound effects on spawning and other behaviors in shellfish can occur with antidepressants such as Selective Serotonin Reuptake Inhibitors (SSRIs).

### Recent Trends in Pharmaceutical Development

In the field of pharmaceutical development the present trends include:

- A shift from blockbuster drugs (drugs that work for a large number of patients) to personalized medicine: In personalized medicine, therapies are catered towards genetic profiles of patients and their diseased cells.
- Exploring marine organisms in an attempt to obtain new compounds with therapeutic potential: Several of these compounds are being investigated as potential anticancer agents, analgesics and anti-inflammatory drugs.

## **Medications & Health**

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Drugs should not be considered risk-free chemical substances. It is strongly recommended by health professionals that patients should always bear in mind the fact that medications have side effects and may have serious interactions with other medications, dietary supplements, food and beverages consumed.

In order to reduce risks, it is strongly recommended that all individuals:

- Read drug labels carefully.
- Learn about the warnings of all drugs taken.
- Inform health care providers of all prescription and OTC drugs and dietary supplements taken.
- Keep a record of all medications taken.