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# Heterocyclic Compounds: A Study of its Biological Activity

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**Abstract**

Heterocyclic compounds have gained a lot of attention because of their numerous significant medical and biological uses. Research interest on heterocyclic compounds is rapidly increasing due to the extensive synthetic study and functional utility. Heterocycles also play a role in different fields, inclusive of medicinal chemistry, biochemistry, and others. Pharmaceuticals, agrochemicals, and veterinary items are the main applications of heterocyclic compounds. In our review, we cover the majority of bio-active heterocycles that have recently been synthesized and introduced a new phase of possible antifungal, anti-inflammatory, anti-bacterial, antiviral, antioxidant, and other medical applications.

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## 1. Introduction

Heterocyclic compounds are an essential group of organic chemicals where the atoms in their molecules form rings with at least a single atom that is not carbon [1]. The term "heterocyclic" denotes the presence of one ring structure in a structure of a compound, heteroatoms or in the structure [2,3]. Heterocyclic chemistry is a fascinating and significant field of organic chemistry, with both practical and theoretical significance [4]. Therefore, a significant amount of study in chemistry is focused on heterocyclic chemistry. Heterocycles are prevalent in nature. Heterocyclic chemistry is a rapidly growing science with wide applications in pharmacy, health, agriculture, plastics, polymers, and several other industries. Heterocycles are used in the treatment of infectious disorders due to their biological activity. Heterocycles synthesized in labs are effectively used as medicinal medicines [5]. Medicinal chemistry developed when scientists isolated and refined active compounds from tissues of plants and animals, as well as from microbes and their fermentation byproducts [6]. Some of these chemicals have been associated with therapeutic qualities in the field of medicinal chemistry, which draws on traditional branches of chemistry such as biology, organic chemistry, and certain aspects of physics [7]. While only a few natural and manufactured chemicals function directly as therapeutic agents, their lack of specificity generally restricts their utility in human and veterinary medicine, as well as in associated pesticide and agricultural uses. Pharmacophores, which are the therapeutically relevant molecular components of these drugs, may be obtained by chemically deconstructing their structure. The removable part is thought to be a byproduct of the parent organism's efforts to produce substances for its own metabolic or defensive purposes and is not considered significant for the medication's effects. Various compounds with different properties are used in many treatments [1, 8, 10].

## 2. Materials and Methods

### 1.2. History of Heterocyclic Compounds

Heterocyclic Chemistry began with the emergence of organic chemistry in the 1800s [11]. Significant progress has been established in:

a. Brugnatelli created alloxan from uric acid in 1818 [12].
b. Dobereiner created furfural (a furan) in 1832 by processing starch with sulfuric acid [13].
c. Runge got pyrrole ("fiery oil") by dry distilling bones in 1834 [12].
d. Friedlander synthesized indigo dye in 1906, paving the way for synthetic chemistry to disrupt a vast agricultural business.

e. Treibs isolated chlorophyll derivatives from crude oil in 1936, indicating petroleum's biological origin.
f. The laws of Chargaff were outlined in 1951, emphasizing the significance of heterocyclic chemicals such as, purines and pyrimidines in the genetic code [14].

### 2.2. Heterocyclic Classification

Heterocyclic compounds are described as follows: Heterocycles usually consist of six-membered or five-membered rings with various atoms such as nitrogen (N), oxygen (O), or sulfur (S) [15]. Heterocyclic derivatives like pyridine, pyrrole, furan, and thiophene are examples of simple compounds [3]. A pyridine molecule consists of a six-atom ring composed of five atoms of carbon together with a nitrogen atom. Pyrrole, furan, and thiophene often have a ring with five members composed of four atoms of carbon together with a N, O, or S atom. Pyridine and pyrrole are nitrogen-containing heterocyclic compounds composed of nitrogen and carbon atoms inside their ring structures. Several biological chemicals include pyridine and pyrrole rings in their molecules, and when heated strongly, they produce small amounts of pyridine and pyrrole [16]. Currently, pyridine and pyrrole are being manufactured. They are particularly interested in turning the chemicals into dyestuffs and pharmaceuticals [17].

### 2.3. Applications of Heterocyclic Compounds

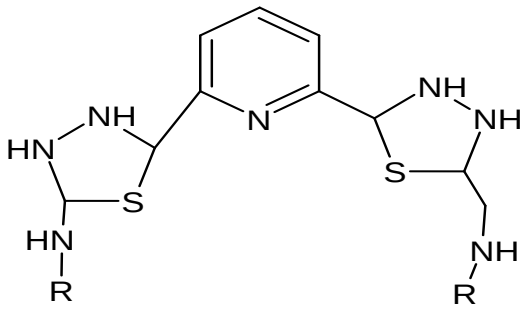
Heterocycles are used in several fields such as agrochemicals, pharmaceuticals, and veterinary medicine. Heterocyclic compounds are found in sanitizers, copolymers, antioxidants, dyestuffs, corrosion inhibitors, and several other items [18]. Heterocycles are used in producing a range of organic derivatives. Various natural substances, such as vinblastine, and reserpine, along with antibiotics, have been identified [19]. Many heterocycles, whether natural or synthetic, possess therapeutic properties. Heterocyclic compounds having physiological and pharmacological effects are becoming popular in medical research [20]. Various biological molecules present in cells, including vitamins and antibiotics, consist of heterocyclic compounds [21]. Nitrogen-containing heterocyclic compounds have been considered as the most important category of chemical substances. Previously, several systematic approaches were developed and put into use for producing nitrogen-containing heterocyclic compounds. Scientists have demonstrated significant interest in heterocyclic compounds containing sulfur, in addition to large-scale investigations on heterocycles, particularly those with nitrogen heteroatoms [22]. Sulfur-containing heterocyclic compounds are included in several Food and Drug Administration (FDA) approved drugs and biologically active substances. The compounds exhibit various characteristics. The substance exhibits several therapeutic benefits such as anti-diabetic, cancer prevention, antibiotic, antiviral, anti-bacterial, anti-inflammatory, anti-hypertension, anti-malarial, anti-Alzheimer's, and anti-fungal properties [23]. Composed of sulfur heterocyclic molecules are frequently employed in chemical research and may be found in a diverse range of natural chemicals and pharmaceuticals 23. Sulfur in heterocyclic derivatives were used to enhance the taste of meals including vegetables, meat, peanuts, coffee, and chocolate [24]. The Food and Drug Administration (FDA) approved S heterocycles such as raloxifene and others for treating peripheral vascular disease and other conditions. Ritonavir is another well-recognized antiviral medication. Thiabendazole may also be used for treating fungal infections. Furthermore, the FDA has approved many medications containing sulfur heterocycles for the treatment of certain medical problems [25, 26]. Nitrogen heterocycles such as pyridine and pyrrole are that include N and C atoms in their ring structures. Many biological materials include pyridine and pyrrole rings, which produce little quantities of pyridine and pyrrole. Pyridine and pyrrole are now produced by chemical synthesis [27].

Furan is a heterocycle containing oxygen that is mostly used for producing other compounds, such as pyrrole. Furfural, a chemical molecule identical to furan. Thiophene, have sulfur atom in his structure, has similar physical and chemical characteristics with benzene [28]. It is a common impurity found in naturally sourced benzene and was first identified when purification of benzene process [29].Some natural compounds including antibiotics (such as, penicillins, cephalosporins) and alkaloids (such as, vinblastine, morphine, reserpine) have heterocyclic structures [30]. Octanol may simulate the

amphiphilic properties of lipids due to its polar primary alcohol head group and a lengthy hydrocarbon chain tail, like fatty acids found in lipid membranes [31]. Chlorophyll and heme, both products of the porphyrin ring structure, are essential components for photosynthesis and oxygen transfer in higher plants and animals.

### 2.4. Biological Activity: Anti-fungal properties

Fungal infections most often affect the skin, hair, and nails. certain substances are used to address certain ailments. Common fungal infections include ringworm, athlete's foot, and several others. Antifungal drugs can directly eliminate fungus or indirectly affect the composition of the cell membrane by changing its chemical structure. some of the derivatives of dipicolinic acid (1-3) have been manufactured and used as antifungal as shown below[32].

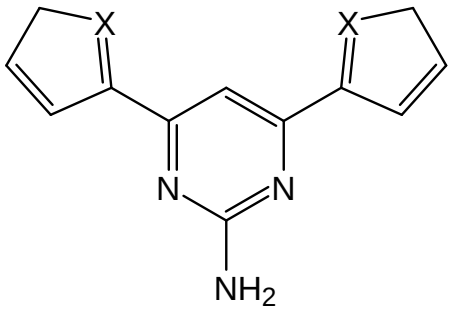



1-3

R: Me, Et, ph

**Figure 1.** Derivatives of dipicolinic acid.

In order to synthesize chalcone derivatives (4-6) as heterocyclic compounds with five-membered rings, and use them as antifungal activity [33].



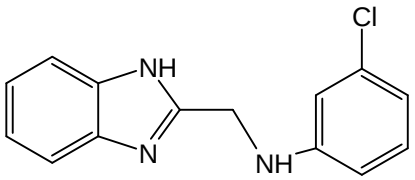

4-6

X: N, O, S

**Figure 2.** Synthesize chalcone derivatives (4-6).

### Anti-inflammatory

The ability of a chemical or therapy to decrease inflammation is referred to as anti-inflammatory. Unlike opioids, which affect the central nervous system, almost analgesics used as anti-inflammatory drugs that relieve pain by decreasing inflammation. synthesized a group of 2-methylaminobenzimidazole (7, and 8) and tested them in vivo for their analgesic and anti-inflammatory properties. When compared to the reference drug nimesulide, the chemicals synthesized among them had significant analgesic and anti-inflammatory effects[34].

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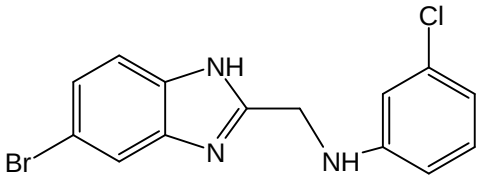


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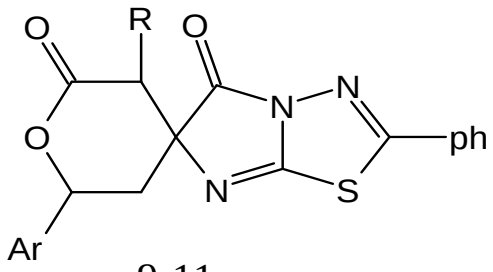
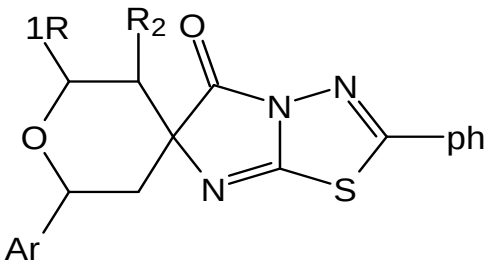
**Figure 3.** Synthesized a group of 2-methylaminobenzimidazole (7, and 8).

Prepared spiroheterocycles and heterocyclic chalcone derivatives (9-14) and evaluated them for antibacterial activity. Against all of the examined microbes, the majority of the manufactured compounds demonstrated the greatest antibacterial effectiveness [35].




9-11




12-14

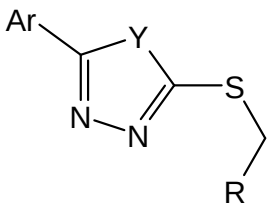
R: COCH3, CN, COOEt
R1: CH3, NH2, CN
R2: COOEt, COCO3, CN

**Figure 4.** Heterocyclic chalcone derivatives (9-14).

**Activity of antioxidants**

Oxidation may generate free radicals and initiate a chain reaction that harms cells. The word "antioxidant" usually denotes two distinct categories: synthetic substances added to inhibit oxidation and naturally occurring molecules found in food and bodily tissues that are thought to have positive health impacts. Thiols and Ascorbic Acid are chemicals that function as inhibitors of oxidation processes in other molecules, halting chain reactions and protecting cells from harm. Prepared was a new complexes (15, and 16) that included heterocyclic of organosulfur in side and organoselenium in other side that show antioxidant activity. In both applicable techniques, the molecules exhibit considerable antioxidant capabilities [36].

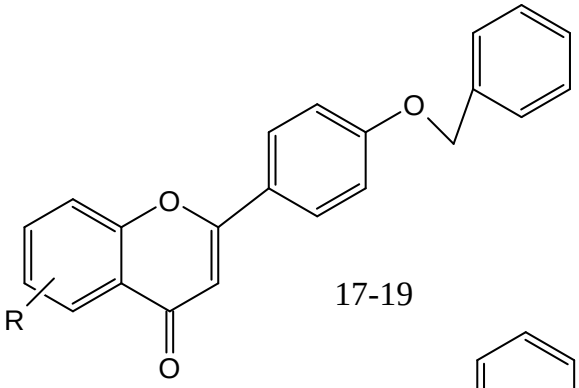
15-16



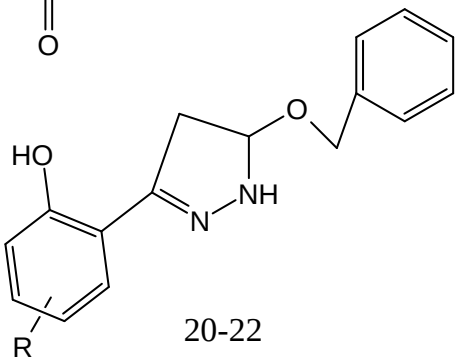

Y: O, S
R: SeAr: 2-methylthiazole-4-yl;
5-ayl-1,3,4--oxadiazol-2-yl

**Figure 5.** Prepared new complexes (15 and 16).

The synthetic procedure of novel flavone and pyrazoline compounds produced by chalcones, has been submitted [37].




17-19

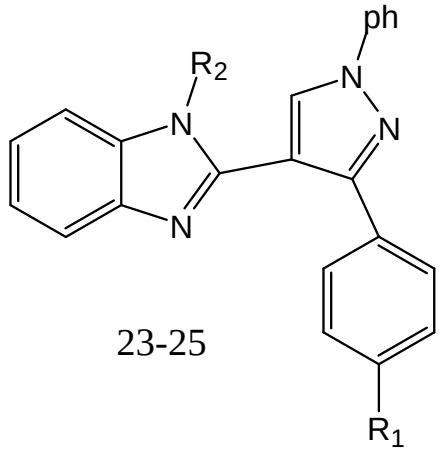



20-22

R:Br; Cl; OH

**Figure 6.** Synthetic procedure of novel flavone and pyrazoline compounds.

Prepared a new group of pyrazole derivative (23-25) containing benzimidazoles and investigated for antioxidant activity[38].




R1: NO2; OMe; Cl
R2: C3H11; CH2CH=CHCH2

**Figure 7.** Prepared new pyrazole derivatives (23-25).

### Anticancer Properties

Cancer is a group of disorders characterized by irregular and unregulated cell proliferation that may infiltrate or metastasize to other areas of the body. The illness is a result of exposure to both radiant radiation and certain chemical substances. Several pharmaceuticals have been developed to treat diseases via reducing cells of cancer or by growth inhibiting.

## 3. Conclusions

Heterocyclic compounds are a significant type of organic molecules used in medicinal chemistry as pharmaceuticals for treating various diseases. Heterocyclic compounds have many medical applications, as shown by several significant successes. The pharmaceutical sector is very interested in using heterocycles for various medicinal purposes such as anticancer, antifungal, antibacterial, anti-inflammatory, anti-Alzheimer's, antiviral, and antidiabetic treatments. It is noteworthy that an increasing number of heterocycles are being evaluated as potential therapeutic agents in drug development.

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