1. Introduction

The study of heterocyclic compounds has attracted the attention of organic chemists very earlier and continues ever, producing a plethora of new compounds. Such eminent chemists dedicated much of their career to the synthesis and structural determination of interesting heterocyclic compounds. Moreover heterocyclic compounds were not only attracting the attention of chemists but also pharmacists and biologists in view of their interesting pharmacological potentials. Mechanistic investigations of their structures and activities have enhanced the general understanding of these compounds. Pyrimidine and purine bases of the genetic material DNA, the essential amino acids, proline, histidine tryptophan and the oxygen transporting pigment haemoglobin are some of the important biomolecules which contain nitrogen heterocyclic system in their structures. Also, a large number of nitrogen heterocyclic compounds find wide range of applications such as dyestuffs, plant-growth regulators, agrochemicals, herbicides, reductives, antibacterial and antitumour agents. The alkaloid class of heterocyclic compounds also occupy an important position in commerce and forensic science. Because of their unique and manifold reactions, these alkaloids have attracted the interest of several researchers leading to in-depth research studies, resulting in valuable findings. From these preliminary comments, it is clear that heterocyclic chemistry continues to evolve in different direction interacting with synthetic experiments, physico-chemical methods and pharmaceutical chemistry all at the same time. To give an account on the rich history of heterocyclic chemistry in a short introduction is a daunting task and hence we present an outline of some of the advances that have been made in the chemistry of indole and carbazole containing heterocyclic systems in the recent past.

Among the heterocycles, those containing indole and carbazole subunits have emerged as an important class based upon their fascinating structure and high degree of biological activities including antifungal, antibacterial, antiviral, antimalarial, anticancer, antitumour, anti HIV and DNA interactions. Indole alkaloids have attracted much interest as synthetic targets, since many of their derivatives exhibit broad range of potential
biological activities. They play a vital role in the metabolism of all living cells, which are widely distributed in nature and are essential for life. In the recent years, indoles have gained more significance in medicinal chemistry. The identification of serotonin as a metabolite is important in brain biochemistry\(^1\) and the discovery of the psychotomimetic indoles, psilocin and psilocybin\(^2\) have led to extensive investigations of tryptamine derivatives. Several potential central nervous system depressants have resulted from these investigations. In addition, some important pigments including the melawns\(^3\) and adrenochromes\(^4\) were found to be indole derivatives which resulted from oxidative cyclization of oxygenated phenethylamines. Indole\(^5\) and homologues of indole\(^6\) have been found in coal tar. Indole was also found to present in molasses tar\(^7\).

*Murraya koenigii spreng* (Rutaceae) an Indian medicinal plant, commonly known as ‘curry leaf tree’, has been found to be a rich and rewarding source of many carbazole alkaloids\(^8\). Carbazole alkaloids isolated from the leaves of this plant exhibit anti-inflammatory, antioxidant, mosquitocidal, antimicrobial and topoisomerase I and topoisomerase II inhibition activities\(^9\). Recently carbazole alkaloid, glycoborine, was isolated from the roots of *Glycosmis arborea*\(^10\). *Hyella caespitosa* represents the first carbazole alkaloid of the marine origin\(^11\). Some of the naturally occurring alkaloids\(^12\)-\(^42\) containing carbazole skeletons are summarized in Table 1.1.

Chowdhury et al\(^{43}\) have investigated the toxicity and structure activity relationships of fourteen carbazole derivatives. Carbazomycin A and carbazomycin B\(^{25}\)-\(^{27}\) were found to be useful as antibacterial and antiyeast agents. The alkaloids ellipticine and olivacine, were found to show remarkable anticancer activity\(^{44}\). Olivacine was also known for its antiulcer and antirheumatic properties\(^{45}\). Recently, 7H-pyrido[4,3-c]carbazole was reported to elicit anti-HIV activity\(^{46}\). In Table 1.2, we have presented a collection of carbazole derivatives correlated with their therapeutic properties\(^{47}\)-\(^{62}\).

Carbazole derivatives have also been extensively used in polymer industries\(^{63}\)-\(^{69}\). Polymers containing carbazole moiety such as poly(N-vinylcarbazole) have been used as multifunctional materials such as photoconductive\(^{63}\), non-linear optical\(^{64}\), photorefractive\(^{65}\) and electroluminescent materials\(^{66}\). Also, many cycloalkan[b]indoles have been found to possess...
antidepressant\textsuperscript{67}, anticancerous\textsuperscript{68} and anti-inflammatory activities\textsuperscript{69,70}. In particular, cyclopent[b]indoles were reported to exhibit anti-inflammatory, antioxidant, antiimplantation and tremorgenic activities\textsuperscript{71-74} (Table 1.3).

Table 1.1. Naturally occurring carbazole derivatives

<table>
<thead>
<tr>
<th>S.N</th>
<th>Compound</th>
<th>R\textsuperscript{1}</th>
<th>R\textsuperscript{2}</th>
<th>R\textsuperscript{3}</th>
<th>R\textsuperscript{4}</th>
<th>R\textsuperscript{5}</th>
<th>Ref</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Glycozoline</td>
<td>H</td>
<td>H</td>
<td>CH\textsubscript{3}</td>
<td>H</td>
<td>OCH\textsubscript{3}</td>
<td>12,13</td>
</tr>
<tr>
<td>2</td>
<td>Glycozolidine</td>
<td>H</td>
<td>OCH\textsubscript{3}</td>
<td>CH\textsubscript{3}</td>
<td>H</td>
<td>OCH\textsubscript{3}</td>
<td>14</td>
</tr>
<tr>
<td>3</td>
<td>Murrayafoline A</td>
<td>OCH\textsubscript{3}</td>
<td>H</td>
<td>CH\textsubscript{3}</td>
<td>H</td>
<td>H</td>
<td>15</td>
</tr>
<tr>
<td>4</td>
<td>Murrayanine</td>
<td>OCH\textsubscript{3}</td>
<td>H</td>
<td>CHO</td>
<td>H</td>
<td>H</td>
<td>16,17</td>
</tr>
<tr>
<td>5</td>
<td>Koenoline</td>
<td>OCH\textsubscript{3}</td>
<td>H</td>
<td>CH\textsubscript{2}OH</td>
<td>H</td>
<td>H</td>
<td>18</td>
</tr>
<tr>
<td>6</td>
<td>Mukoecic acid</td>
<td>OCH\textsubscript{3}</td>
<td>H</td>
<td>COOH</td>
<td>H</td>
<td>H</td>
<td>19,20</td>
</tr>
<tr>
<td>7</td>
<td>Mukonine</td>
<td>OCH\textsubscript{3}</td>
<td>H</td>
<td>COOCH\textsubscript{3}</td>
<td>H</td>
<td>H</td>
<td>21</td>
</tr>
<tr>
<td>8</td>
<td>Mukonidine</td>
<td>H</td>
<td>OH</td>
<td>COOCH\textsubscript{3}</td>
<td>H</td>
<td>H</td>
<td>22</td>
</tr>
<tr>
<td>9</td>
<td>Lansine</td>
<td>H</td>
<td>OH</td>
<td>CHO</td>
<td>H</td>
<td>OCH\textsubscript{3}</td>
<td>23</td>
</tr>
<tr>
<td>10</td>
<td>Carazostatin n-C\textsubscript{7}H\textsubscript{15}</td>
<td>CH\textsubscript{3}</td>
<td>OH</td>
<td>H</td>
<td>H</td>
<td>24</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Hyellazole</td>
<td>C\textsubscript{6}H\textsubscript{5}</td>
<td>CH\textsubscript{3}</td>
<td>OCH\textsubscript{3}</td>
<td>H</td>
<td>H</td>
<td>11</td>
</tr>
<tr>
<td>12</td>
<td>Chlorohyellazole</td>
<td>C\textsubscript{6}H\textsubscript{5}</td>
<td>CH\textsubscript{3}</td>
<td>OCH\textsubscript{3}</td>
<td>H</td>
<td>Cl</td>
<td>11</td>
</tr>
<tr>
<td>13</td>
<td>Carbazomycin A</td>
<td>CH\textsubscript{3}</td>
<td>CH\textsubscript{3}</td>
<td>OCH\textsubscript{3}</td>
<td>OCH\textsubscript{3}</td>
<td>H</td>
<td>25,26,27</td>
</tr>
<tr>
<td>14</td>
<td>Carbazomycin B</td>
<td>CH\textsubscript{3}</td>
<td>CH\textsubscript{3}</td>
<td>OCH\textsubscript{3}</td>
<td>OH</td>
<td>H</td>
<td>25,26,27</td>
</tr>
<tr>
<td>15</td>
<td>Carbazomycin C</td>
<td>CH\textsubscript{3}</td>
<td>CH\textsubscript{3}</td>
<td>OCH\textsubscript{3}</td>
<td>OH</td>
<td>OCH\textsubscript{3}</td>
<td>28</td>
</tr>
<tr>
<td>16</td>
<td>Carbazomycin D</td>
<td>CH\textsubscript{3}</td>
<td>CH\textsubscript{3}</td>
<td>OCH\textsubscript{3}</td>
<td>OCH\textsubscript{3}</td>
<td>OCH\textsubscript{3}</td>
<td>28</td>
</tr>
<tr>
<td>17</td>
<td>Carbazomycin E</td>
<td>CHO</td>
<td>CH\textsubscript{3}</td>
<td>OCH\textsubscript{3}</td>
<td>OH</td>
<td>H</td>
<td>29</td>
</tr>
<tr>
<td>18</td>
<td>Carbazomycin F</td>
<td>CHO</td>
<td>CH\textsubscript{3}</td>
<td>OCH\textsubscript{3}</td>
<td>OH</td>
<td>OCH\textsubscript{3}</td>
<td>29</td>
</tr>
</tbody>
</table>
Synthetic Studies on Cyclopent[b]indoles and Carbazoles

<table>
<thead>
<tr>
<th>S.No</th>
<th>Compound</th>
<th>R&lt;sup&gt;1&lt;/sup&gt;</th>
<th>R&lt;sup&gt;2&lt;/sup&gt;</th>
<th>R&lt;sup&gt;3&lt;/sup&gt;</th>
<th>Ref</th>
</tr>
</thead>
<tbody>
<tr>
<td>22</td>
<td>Grinimbine</td>
<td>CH&lt;sub&gt;3&lt;/sub&gt;</td>
<td>H</td>
<td>H</td>
<td>31</td>
</tr>
<tr>
<td>23</td>
<td>Murrayacine</td>
<td>CHO</td>
<td>H</td>
<td>H</td>
<td>32</td>
</tr>
<tr>
<td>24</td>
<td>Koenimbine</td>
<td>CH&lt;sub&gt;3&lt;/sub&gt;</td>
<td>OCH&lt;sub&gt;3&lt;/sub&gt;</td>
<td>H</td>
<td>33</td>
</tr>
<tr>
<td>25</td>
<td>Koenine</td>
<td>CH&lt;sub&gt;3&lt;/sub&gt;</td>
<td>OH</td>
<td>H</td>
<td>34</td>
</tr>
<tr>
<td>26</td>
<td>Koenigicine</td>
<td>CH&lt;sub&gt;3&lt;/sub&gt;</td>
<td>OCH&lt;sub&gt;3&lt;/sub&gt;</td>
<td>OCH&lt;sub&gt;3&lt;/sub&gt;</td>
<td>35</td>
</tr>
<tr>
<td>27</td>
<td>Koenigine</td>
<td>CH&lt;sub&gt;3&lt;/sub&gt;</td>
<td>OCH&lt;sub&gt;3&lt;/sub&gt;</td>
<td>OH</td>
<td>34</td>
</tr>
<tr>
<td>28</td>
<td>Heptaphylline</td>
<td>CHO</td>
<td>OH</td>
<td></td>
<td>36</td>
</tr>
<tr>
<td>29</td>
<td>Glycomarin</td>
<td>H&lt;sub&gt;3&lt;/sub&gt;C</td>
<td></td>
<td></td>
<td>37</td>
</tr>
</tbody>
</table>
Synthetic Studies on Cyclopent[b]indoles and Carbazoles

30 Neocarazostatin A  
[R = OH]  
31 Neocarazostatin B  
[R = H]  
32 Neocarazostatin C  
[R = OCH₃]  
33 Lavanduquinocin  

34 Carbazoquinocin C  

35 Olivacine  
[R¹, R² = CH₃]  
36 Ellipticine  
[R¹ = H, R² = CH₃]

Table 1.2. Therapeutic properties of carbazole derivatives

<table>
<thead>
<tr>
<th>S.No</th>
<th>Compound</th>
<th>Biological activity</th>
<th>Ref</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td><img src="image1" alt="Chemical Structure" /></td>
<td>Bactericide and inflammation inhibitor</td>
<td>47</td>
</tr>
<tr>
<td>2</td>
<td><img src="image2" alt="Chemical Structure" /></td>
<td>Psychotropic CNS agent, cardiotonic, antihistamine and analgesic</td>
<td>48, 49, 50</td>
</tr>
<tr>
<td>3</td>
<td><img src="image3" alt="Chemical Structure" /></td>
<td>Antidepressant</td>
<td>51</td>
</tr>
</tbody>
</table>

Sangeetha V 5
<table>
<thead>
<tr>
<th>No.</th>
<th>Chemical Structure</th>
<th>Biological Activity</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td><img src="image1.png" alt="Image" /></td>
<td>Anti-inflammatory</td>
<td>52</td>
</tr>
<tr>
<td>5</td>
<td><img src="image2.png" alt="Image" /></td>
<td>Antiencephalomyocarditis</td>
<td>53</td>
</tr>
<tr>
<td>6</td>
<td><img src="image3.png" alt="Image" /></td>
<td>Antiviral</td>
<td>54</td>
</tr>
<tr>
<td>7</td>
<td><img src="image4.png" alt="Image" /></td>
<td>Antihistamine and Antiserotonin</td>
<td>55</td>
</tr>
<tr>
<td>8</td>
<td><img src="image5.png" alt="Image" /></td>
<td>Anticonvulsant and diuretic</td>
<td>56</td>
</tr>
<tr>
<td>9</td>
<td><img src="image6.png" alt="Image" /></td>
<td>Fungicide and antiinflammation inhibitor</td>
<td>57</td>
</tr>
<tr>
<td>10</td>
<td><img src="image7.png" alt="Image" /></td>
<td>Trypanocidal</td>
<td>58</td>
</tr>
</tbody>
</table>
Synthetic Studies on Cyclopent[b]indoles and Carbazoles

11. Vasodilator and β-blocker

12. Antidepressant

13. Anticancer

14. Anticancer

15. Anticancer

16. Anticancer

17. Anti-HIV
Table 1.3. Therapeutic properties of cyclopent[b]indole derivatives

<table>
<thead>
<tr>
<th>S.No</th>
<th>Compound</th>
<th>Biological activity</th>
<th>Ref</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td><img src="image1.png" alt="Compound 1" /></td>
<td>Antifertility and Anti-implantation</td>
<td>71</td>
</tr>
<tr>
<td>2</td>
<td><img src="image2.png" alt="Compound 2" /></td>
<td>Tremorgenic</td>
<td>71</td>
</tr>
<tr>
<td>3</td>
<td><img src="image3.png" alt="Compound 3" /></td>
<td>Tremorgenic</td>
<td>72</td>
</tr>
<tr>
<td>4</td>
<td><img src="image4.png" alt="Compound 4" /></td>
<td>Tremorgenic</td>
<td>73</td>
</tr>
<tr>
<td>5</td>
<td><img src="image5.png" alt="Compound 5" /></td>
<td>Anti-inflammatory</td>
<td>74</td>
</tr>
</tbody>
</table>

On the basis of the interesting structures and biological activities exhibited by several heterocyclic systems possessing indole nucleus, we have chosen the indole nucleus fused with six membered ring (carbazole) and with five membered ring (cyclopent[b]indole), as the core subject matter for investigation in this synthetic study. A systematic survey of literature regarding the carbazole and cyclopent[b]indole derivatives have been given in this part of the introductory chapter followed by the objective of the present work.
1.1. 1,2,3,4-Tetrahydrocarbazoles

The synthetic routes to carbazoles are manifold and diverse in nature. Generally, tetrahydrocarbazoles were prepared by Borsche method, which is a modification of Fischer indole synthesis. Many tetrahydrocarbazoles have been derived from arylhydrazones of cyclohexanone with or without a methyl group in the ninth position. Phenylhydrazone of cyclohexanone (1) on treatment with dil sulphuric acid yielded unsubstituted tetrahydrocarbazole (2). Among the other reagents used frequently, only glacial acetic acid was found to yield a pure product.

![Chemical structure of 1 and 2](image)

1.2. 1-Oxo-1,2,3,4-tetrahydrocyclopent[b]indoles

The cyclopent[b]indole ring system occurs in a large number of indole alkaloids, including the structurally complex tremorgenic mycotoxins such as paxilline, paspaline, the lolitrems, janthitrems and yuehchukene (3). In accordance with an importance of compounds possessing this skeleton, several of methods have been developed for its construction. Some important methods have been discussed here.

![Chemical structure of 3](image)

Harrison et al. have reported the synthesis of substituted cyclopent[b]indoles (5) via formal [3+2] addition by treating indol-3-methanols (4) with \( \beta \)-methylstyrene as the alkene in the presence of tin(IV) chloride as Lewis acid.

![Chemical structure of 4 and 5](image)
In the same way diastereomeric cyclopent[b]indoles 6a and 6b were prepared from substituted indol-3-methanols (4) and β-methylstyrene.

This method was also extended to the preparation of the cyclopent[b]indoles, (9) and (10), using indol-3-methanol (4a) with indene (7) and allylic ether (8) as alkenes, respectively.

An interesting cyclopent[b]indole derivative (12) was prepared from the acid-induced dimerisation of 3-substituted maleimides (11a, 11b) as mentioned below.

Treatment of methyl-3-(1H-indol-3-yl)acrylate (13) with strong acid afforded the diastereomeric mixture of the dimer 14 (which readily underwent dehydrogenation to the highly coloured compound 15) as depicted below.
1.3. 1-Oxo-1,2,3,4-tetrahydrocarbazoles

Kent and McNeil\textsuperscript{107} have prepared 1-oxo-1,2,3,4-tetrahydrocarbazoles (17) from cyclohexan-1,2-dione monophenylhydrazones (16). Using the above method, Chakraborty \textit{et al}.\textsuperscript{108} have synthesized several isomeric methyl-1-oxo-1,2,3,4-tetrahydrocarbazoles (17).

Clemo and Felton\textsuperscript{109} have applied Japp-Klingemann procedure to cyclohexan-1,3-dione (18) and prepared the 4-oxo-1,2,3,4-tetrahydrocarbazole (19).

Condensation of the arylhydroxylamines (20) with cyclohexan-1,3-diones (21) in benzene containing small amount of ascorbic acid to give 22 was reported by Okamato and Shudo\textsuperscript{110}. The \textit{o}-acetyl derivative 23 prepared from its alcohol 22 and Ac\textsubscript{2}O on cyclisation using CF\textsubscript{3}COOH and (CF\textsubscript{3}CO\textsubscript{2})\textsubscript{O} yielded 25.
Earlier studies reported by Rajendra Prasad et al.\textsuperscript{111,112} have showed the synthesis of 1-oxo-1,2,3,4-tetrahydrocarbazoles (27) from cyclisation of monophenylhydrazones of cyclohexanone (26) using glacial acetic acid and conc hydrochloric acid mixture (Kent's reagent).

\[
\begin{array}{c}
\text{R}_1 = \text{H, CH}_3, \text{COOCH}_3, \text{Br}; \quad \text{R}_2 = \text{H, CH}_3 \\
\end{array}
\]

**1.4. Nitro and amino carbazoles**

Reaction of carbazole (28) with sodium nitrite in glacial acetic acid followed by treatment with nitric acid yielded principally 3-nitro-9-nitrosocabazole (29) which on heating with KOH or glacial acetic acid gave 3-nitrocarbazole (30) along with small quantity of 1-nitrocarbazole (31)\textsuperscript{113}.

Graebe-Ullmann reaction\textsuperscript{114} was applied to 1-phenyl-5-amino-1,2,3-benzotriazole (32) for the synthesis of 3-aminocarbazole (33).
Diaminobenzidines 34 and 36 on heating with sulphuric acid at 180-190°C\textsuperscript{115} afforded the 2,7-diaminocarbazole (35) and 3,6-diaminocarbazole (37), respectively.

1,4-Dimethyl-2-aminocarbazole (39) was conveniently prepared by treating 38 with sodium hydride in diphenyl ether at 220°C\textsuperscript{116}.

3,6-Dichlorocarbazole (40) upon treatment with nitric acid – glacial acetic acid mixture afforded 3,6-dichloro-4-nitrocarbazole (41) which on reduction with SnCl\textsubscript{2} followed by acetylation and nitrification yielded 4-acetylamino-3,6-dichloro-1-nitrocarbazole (42). The compound 42 was further reduced to 1,4-diamino-3,6-dichlorocarbazole (43)\textsuperscript{117}.

\[ \text{3,6-Dichlorocarbazole (40) \rightarrow 3,6-dichloro-4-nitrocarbazole (41) \rightarrow 4-acetylamino-3,6-dichloro-1-nitrocarbazole (42) \rightarrow 1,4-diamino-3,6-dichlorocarbazole (43)} \]
An extensive investigation involving multi-steps as outlined in the following equation was carried out by Moron et al.\textsuperscript{118} to derive 2-amino-6-methoxy-1-methyl- and 2-amino-6-methoxy-1,4-dimethyl-carbazole derivatives (51) from suitably substituted anilines (44).
Recently Rajendra Prasad and co-workers\textsuperscript{119,120} have reported some novel aminocarbazole derivatives (53 and 54) from 1-oxo-1,2,3,4-tetrahydrocarbazoles (27).

\[
\begin{align*}
\text{R} & = \text{H, CH}_3, \text{COOCH}_3, \text{Cl} \\
\text{27} & \xrightarrow{\text{NH}_2\text{OHHCl, C}_2\text{H}_5\text{OH/C}_6\text{H}_5\text{N}} \text{52} & \xrightarrow{\text{CH}_3\text{COCl}, (\text{CH}_3\text{CO})_2\text{O}} \text{53} \\
\text{R} & = \text{H, CH}_3, \text{COOCH}_3, \text{Cl} 
\end{align*}
\]

Bergman \textit{et al.}\textsuperscript{121} have reported that the reaction of bisphenylhydrazone (55) with phosphorous trichloride in toluene to afford two main products namely indolo[2,3-c]carbazole (56) and 3-aminocarbazole (33). However the use of xylene instead of toluene also resulted in the same products, but the reaction time was significantly reduced from 6 h to 30 min.

\[
\begin{align*}
\text{55} & \xrightarrow{\text{PCl}_3, \text{Toluene reflux 6h}} \text{56} + \text{33} 
\end{align*}
\]

### 1.5. Benzocarbazoles

Ghigi\textsuperscript{122} has studied the cyclisation of the phenylhydrazone of 1-tetralone (57) with sulphuric acid or zinc chloride to obtain the dihydroderivative of benzo[\textit{a}]carbazole (58).

\[
\begin{align*}
\text{57} & \xrightarrow{\text{H}_2\text{SO}_4, \text{ZnCl}_2} \text{58} 
\end{align*}
\]
A series of benzo[a]carbazole (60), benzo[b]carbazoles (62) and benzo[c]carbazoles (63) were obtained from the cyclisation of arylhydrazones of 2-tetralone (59, 61) in presence of sulphuric acid and zinc chloride.

\[
\begin{align*}
\text{benzyldenehydrazine} & \xrightarrow{\text{H}_{2}\text{SO}_{4}, \text{ZnCl}_2} \text{benzo[a]carbazole} \\
\text{benzyldenehydrazine} & \xrightarrow{\text{H}_{2}\text{SO}_{4}, \text{ZnCl}_2} \text{benzo[b]carbazole} + \text{benzo[c]carbazole}
\end{align*}
\]

\[
\begin{align*}
p-\text{tetradecylphenylhydrazine} (65) & \text{afforded tetradecylbenzo[a]carbazole (68) on reaction with 1-tetralone (66) followed by dehydrogenation with Pd/C. On the other hand, its treatment with 2-tetralone (69) gave tetradecylbenzo[c]carbazole (71) through 70.}
\end{align*}
\]
Benzocarbazole derivative (77) was obtained from naphthaquinone (72) and 2-methoxy-4-methylaniline (73) as shown in the equation below.

\[
\begin{align*}
\text{72} + N_2^+ + C_2H_5OH & \rightarrow \text{74} \\
\text{Pd(OAc)}_2 + \text{gla CH}_3\text{COOH} & \rightarrow \text{75} \\
\text{BrCN, DMAP} + \text{CH}_2\text{Cl}_2 & \rightarrow \text{76} \\
\text{C}_6\text{H}_5\text{N/HCl} & \rightarrow \text{77}
\end{align*}
\]

Sekar and Rajendra Prasad\cite{126} were successful in the synthesis of 6,11-dihydro-6-oxo-5\textit{H}-benzo[\textit{b}]carbazoles (81) in good yield by cyclisation of tetralin-1,2-dione-2-arylhydrazones (80) which inturned were prepared by the Japp-Klingemann reaction of 2-hydroxymethylene-1-tetralone (79) with diazotised anilines (78).

\[
\text{R} = \text{H, CH}_3, \text{OCH}_3, \text{Cl, Br}
\]

Echavarren \textit{et al}\cite{127} devised an efficient route to synthesize 5-carbonitrile-1,7-dihydroxy-3-methyl-5\textit{H}-benzo[\textit{b}]carbazole-6,11-dione (95) by coupling the naphthaquinones (82, 83) with arylstannanes (84, 85) in the presence of Pd(PPh\textsubscript{3})\textsubscript{4} and CuBr as a first-step and their synthetic scheme is depicted below.
Rao et al. synthesized benzo[1,2-c]carbazole (102) and naphtho[1,2-c]carbazole (104) from phenylglycine-o-carboxylic acid (96) as follows.
1.6. Oxygenated carbazole alkaloids

Sowmithran and Rajendra Prasad\cite{112} have achieved the synthesis of a new structurally isomeric analogues of mukoeic acid (110) by Japp-Klingemann reaction of diazonium salt of aminobenzoic acids (105) with 2-hydroxymethylene cyclohexanone, followed by cyclisation with PPA, methylation with diazomethane, dehydrogenation with Pd/C and methylation with dimethyl sulphate in the last step.
Kano et al.\textsuperscript{129} had described the synthesis of hyellazole (116) in the following way.

A versatile method for the synthesis of 4-deoxycarbazomycin (121) was published by Moody and Shah.\textsuperscript{130} They made use of the regioselective Diels-Alder reaction of 117 with ethyl 3-(trimethylsilyl)propyrate to give the carbazole 118 which was converted into 2-methylcarbazole derivative (119) by reduction with LiAlH\textsubscript{4}. Treatment of 2-methylcarbazole derivative (119) with mercuric acetate followed by hydroboration furnished hydroxycarbazole (120), which on treatment with methyl iodide in presence of K\textsubscript{2}CO\textsubscript{3} yielded 121.
In the same paper, Moody and Shah also reported the synthesis of carbazomycin B (124) and carbazomycin A (125) as depicted below:\(^\text{130}\)

Some 1-oxygenated carbazole derivatives (129, 130 and 131) were obtained by Stobbe condensation of indol-3-carbaldehyde (126) with dimethylsuccinate (127) followed by reaction with ethyl chloroformate\(^\text{131}\).

Knolker and Bauermeister\(^\text{132}\) have carried out the synthesis of mukonine (130), murrayanine (138) and koenoline (139) as outlined below.
Another method for the synthesis of mukonine (130) starting from indol-3-carbaldehyde (126) involving the Horner-Emmons reaction as the crucial step was established by Bringmann et al. From 130, they obtained several 1-oxygenated carbazoles as outlined below.
Knolker et al.\textsuperscript{134} have reported the synthesis of an antioxidative substance carbazoquinocin C (152) by palladium catalysed oxidative cyclisation of anilinoquinone (147) and subsequent regioselective introduction of the heptyl side chain into it.
The synthesis of 9-ethylcarbazole-3,6-dicarboxylate (154) from 3,6-dibromo-9-ethylcarbazole (153) was carried out by Park et al.\textsuperscript{135}

![Synthesis of 9-ethylcarbazole-3,6-dicarboxylate](image)

A new carbazole alkaloid glycoborine (161) isolated from the roots of *Glycosmis arborea* was characterised using spectroscopic methods by Chakravarthy et al.\textsuperscript{10}. They also developed a synthetic route for glycoborine (161) and glycozolicine (162) by condensing 4-methylcyclohexanone with *m*-methoxyphenyl hydrazine (155) and *o*-methoxyphenylhydrazine (156) respectively followed by cyclisation and dehydrogenation.

![Synthesis of glycoborine and glycozolicine](image)

Rajendra Prasad and Sowmithran\textsuperscript{136} have demonstrated the synthesis of 2,2-dimethyl-2//-pyrano[2,3-a]carbazoles (166) by reacting 1-hydroxycarbazoles (163) with 3,3-dimethylacrylic acid. The resulting indolochromanones (164) were reduced with sodium borohydride and dehydrated with *p*-TsCl in pyridine.

![Synthesis of 2,2-dimethyl-2//-pyrano[2,3-a]carbazoles](image)
In a different case, Rajendra Prasad and Sekar\textsuperscript{137} have reported the preparation of the same 2,2-dimethyl-2H-pyrano[2,3-a]carbazoles (166) in a single step from the reaction of 1-hydroxycarbazoles (163) with 3,3-dimethylacraldehyde in pyridine.

In addition to the above methods, the same compounds (166) were also prepared in good yield by a new way involving the reaction of 1-hydroxycarbazoles (163) with 3-chloro-3-methyl-1-butyne by Rajendra Prasad and Balamurali\textsuperscript{138}.

1.7. Pyrido[4,3-b]carbazoles

Ellipticine (167) belonging to the 6H-pyridocarbazole family, isolated from the plants of the genus \textit{Aspidosperma} was found to possess anticancer and antitumour activities. Certain 6H-pyrido[4,3-b]carbazoles, for example ellipticine (167), 9-hydroxy ellipticine (168) and olivacine (169), occur as alkaloids in the plants of the \textit{Aspidosperma}, \textit{Ochrosia} and \textit{Tabemaemontana} genera belonging to the \textit{Apocyanaceae} family.\textsuperscript{139-142}
These compounds have gained considerable interest not only due to their structural simplicity but also because of their mode of biogenesis. Among these drugs which exhibit antitumour properties, 2-methyl-9-hydroxyellipticine has been inducted in the treatment of breast cancer. In literature, several synthetic routes to arrive at the pyrido[4,3-b]carbazoles have been presented.

**Synthesis via Fischer indolisation reactions**

Stillwell reported the synthesis of ellipticine from decahydro-2,N-methyl-5,8-dimethylisoquinol-6-one (173). In the first step, reductive Stork alkylation reaction of 172 with methylidiodide in the presence of lithium in liquid ammonia afforded 173. Further reaction of 173 with phenyl hydrazine followed by acid catalysed cyclisation yielded 2-methyl-1,2,3,4,5,5a,11,11a-octahydroellipticine (175) which was then dehydrogenated with Pd/C to get ellipticine (167).
A multi-step synthesis involving the following reactions was carried out by Rastogi et al\textsuperscript{145} to prepare 9-methyl-6\textit{H}-pyrido[4,3-\textit{b}]carbazole (181).

A new synthesis of ellipticine (167) through 2-formyl-1,4-dimethylcarbazole (188) as given below was proposed by Govindachari et al\textsuperscript{146}.

\begin{itemize}
\item \textbf{182} \quad \text{1. NH}_2\text{OH} \quad \text{2. (CH}_3\text{CO)}_2\text{O} \\
\item \textbf{183} \quad \text{1. [H]} \quad \text{2. H}^+\text{/NaNO}_2 \quad \text{3. Cu}_2\text{Cl}_2 \\
\item \textbf{184} \quad \text{1. HNO}_3 \quad \text{2. [H]} \\
\item \textbf{185} \quad \text{1. H}^+\text{/NaNO}_2 \quad \text{2. SnCl}_2 \quad \text{3. Cyclohexanone/H}^+ \\
\item \textbf{186} \quad \text{1. H}_2\text{O} \quad \text{2. CH}_3\text{OH/H}^+ \quad \text{3. dehydrogenation} \\
\item \textbf{187} \quad \text{1. LiAlH}_4 \quad \text{2. [O]} \\
\item \textbf{188} \quad \text{1. CH}_3\text{NO}_2 \quad \text{2. LiAlH}_4
\end{itemize}
Gribble et al\textsuperscript{147} have carried out another synthesis of ellipticine (167) using 3-carboxy-4-pyridyl-2-indolylketone (191) as the starting material through the following sequence of reactions.

1,9-Dimethylcarbazole-2-carbaldehyde (194) on condensation with ethyl azidoacetate in the presence of sodium ethoxide at -15°C gave ethyl-2-azido-3-[2'-{(1',9'-dimethyl)carbazolyl}acrylate (195) which on further treatment with aromatic or aliphatic isocyanates in dry toluene yielded pyridocarbazole (197)\textsuperscript{148}.
9-Hydroxyellipticine (168) has been prepared from ellipticine (167) via a direct regioselective formylation reaction followed by a Baeyer-Villiger oxidation\textsuperscript{149}.

The reaction of N-benzylindol-2,3-dicarboxylic anhydride (199) with (3-bromo-4-pyridyl)triisopropoxytitanium gave 2-(3-bromoisonicotinyl)indol-3-carboxylic acid (201) as an exclusive product, which was further converted into ellipticine (167) by the following method\textsuperscript{150}.
In an another attempt, Miki et al. have obtained ellipticine (167) by reacting 1-benzylindol-2,3-dicarboxylic anhydride (199) with 3-bromo-4-lithiopyridine (205).

Trecourt and co-workers have described the study on the cross coupling reactions of substituted 7-bromoquinoline (211) and (2-aminophenyl)boric acids to yield substituted 7-(2'-aminophenyl)quinolines (212a, 212b) and their conversion into either 11H-pyrido[2,3-a]carbazoles (214a, 214b) via C₈-cyclisation or 6H-pyrido[3,2-b]carbazoles (216a, 216b) via C₆-cyclisation were achieved.
Rajendra Prasad et al.\textsuperscript{112, 153} have synthesized 2-hydroxypyrido[2,3-a]carbazoles (220) from 1-hydroxycarbazole-2-carbaldehydes (217) as depicted below.

1.8. Other carbazole and cyclopent[b]indole derivatives

Haider et al.\textsuperscript{61} have prepared some antitumour agents, 1- and 4-[3-(diethylamino)propylamino]-5-methyl-6H-pyridazino[4,5-b]carbazole derivatives (228, 229) from 3-indoleacetic acid derivatives (221a, 221b) as envisaged below.
A promising route for the synthesis of some novel quinolono[4,3-b]- and quinolono[3,4-b]-carbazoles (235 and 241), from indole derivatives 230 and 236 was developed by Elango and Srinivasan.\textsuperscript{154}
Synthetic Studies on Cyclopent[b]indoles and Carbazoles

[Chemical diagrams and reactions depicted in the text]

Sangeetha V 33
Agarwal et al\textsuperscript{155} have reported the synthesis of 9-benzyl/methyl carbazoles (242-245) and 6-benzyl/methyl-2-methoxycarbonylamino/furyl-3H-imidazo[4,5-c]carbazoles (249 and 250) by the following sequence of reactions.

An experiment involving numerous steps to yield 2-methylpyrrolo[3,4-c]carbazole derivatives (260) from N-benzylindole-2-carbaldehyde derivatives (252) were carried out by Mahboobi et al\textsuperscript{156}.
Synthetic Studies on Cyclopent[b]indoles and Carbazoles

\[
\begin{align*}
R_1 & \quad R_1 \\
\text{a} & \quad \text{a} \\
\text{b} & \quad \text{b} \\
\text{c} & \quad \text{c} \\
\text{d} & \quad \text{d} \\
\text{e or f} & \quad \text{e or f} \\
\text{g} & \quad \text{g} \\
\text{h} & \quad \text{h} \\
\text{i or j} & \quad \text{i or j} \\
\text{j} & \quad \text{j} \\
R_1 & \quad R_1 \\
R_2 & \quad R_2 \\
\text{Bz} & \quad \text{Bz} \\
\text{OH} & \quad \text{OH} \\
\text{O}_2\text{N} & \quad \text{O}_2\text{N} \\
\text{O}_2\text{N} & \quad \text{O}_2\text{N} \\
\text{NH} & \quad \text{NH} \\
\text{OCH}_3 & \quad \text{OCH}_3 \\
\text{OCH}_3 & \quad \text{OCH}_3 \\
\end{align*}
\]

251 - 260

a. \( R_1 = \text{OCH}_3, R_2 = \text{H} \)
b. \( R_1 = \text{H}, R_2 = \text{OCH}_3 \)
An array of heterocyclo-fused carbazoles namely, pyrrolo[2,3-c]carbazole (261), thieno[2,3-c]carbazole (262) and indolo[3,2-a]carbazole (263) have been efficiently prepared from 2-bis(methylthio)methylene-2,3-dihydro-1-methyl-3-oxoindole (100) by Rao et al.\(^{28}\).

An interesting approach for the preparation of a novel dimeric carbazole alkaloid, bismurrayaquinone (265) from 3-methyl-1-hydroxycarbazole (143) via oxidation of bis-o-dimethylmurrayafoline A (264) was proposed.\(^{157}\)
Tholander and Bergman\textsuperscript{158} developed an elegant method for the synthesis of 6-formylindolo[3,2-b]carbazole (273) from dichloroacetylation of 2,3-diindolylmethane (271) followed by a tandem cyclisation-hydrolysis reaction under acidic condition. They prepared 2,3-diindolylmethane (271) needed in this reaction from indole derivatives 266 and 267 as depicted below.

![Chemical structures and reactions](image)

An easy access to indolo[2,3-c]carbazole (56) from the coupling reaction of 1,2-bis(2-indolyl)ethane (275) was described by Bergman et al.\textsuperscript{121,159}.

![Chemical structures and reactions](image)
In a different study, Bergman et al.\textsuperscript{160} obtained 3,4-dihydro-2-(1'-methyl-3'-indolyl)-4,4,9-trimethylcarbazole (280) from 1,2-dimethylindole (277) as presented in the following equation.

By interacting 1-hydroxycarbazoles (163) and epichlorohydrin, Rajendra Prasad and Sowmithran\textsuperscript{161} were successful to obtain carbazolyl-1-oxypropylamines (282) through an intermediate 281.
More detailed studies regarding the synthesis of a series of oxazolo[4,5-α]- and isoxazolo[5,4-α]carbazole derivatives (283,284) using 1-oxo-1,2,3,4-tetrahydrocarbazoles (27) as intermediates have been presented by Rajendra Prasad and co-workers\textsuperscript{162,163}.

1.9. Cyclopent[b]indole derivatives

A simple route\textsuperscript{164} to a range of substituted cyclopent[b]indole derivatives (287-289) was developed based on the utility of 1-methyl-3-(benzotriazol-1-ylmethyl)indoles (285, 286). In these reactions the alkenes behaved as nucleophiles to induce formal (2+3) cycloadditions with 285 and 286. The sequence of steps was given in the following scheme.
Bergman et al.\textsuperscript{160} investigated the acid-catalysed condensation reaction between indole and acetone under different conditions and found that the treatment of indole with acetone in presence of trifluoroacetic acid gave the compound 290 in 70\% yield. In the same article the synthesis of substituted derivatives of 290 (like 5,5'-dibromo and 7,7'-dimethyl) had also appeared. A suitable proposed mechanism for the formation of 290 was depicted below.
Treatment of indol-3-methanol (5) with styrene or indene in the presence of tin(IV)chloride as Lewis acid results in the formal [3+2]addition of the indole stabilized cation to the alkene to give cyclopent[b]indoles with a high degree of stereoselectivity. If 1-methylcyclohexene (291) is used as the alkene, cis fused cyclopent[b]indole (292) was formed.

Paspaline (293) is the simplest member of a rapid growing class of indole diterpene alkaloids isolated from the ergot claviceps paspalin. Smith et al. devised a suitable method for the total synthesis of (-)-paspaline (293) which is the simplest member of a family of tremorgenic indole diterpene alkaloids by a sequence of reactions in 14 steps starting from the easily accessible decalone derivative.

Mineral acid catalysed Michael-type addition of indole at α and β- positions into the unsaturated ketone system of indol-3-yl-1-methyl-1,2,5,6-tetrahydropyridine-4-yketone (294a) and its isomer indol-2-yl-1-methyl-1,2,5,6-tetrahydropyridin-4-yl ketone (294b) respectively yielded the cyclopent[b]indole derivatives 295a and 295b.
A series of cyclopent[b]indole derivatives 298, 299, 300 and 301 were synthesized as follows. Cyclopent[b]indole (298) was prepared by refluxing phenyl hydrazine (296) and cyclopentanone (297) in benzene which on further transformations yielded the corresponding products 299, 300 and 301. A conformational study of the compounds 301a and 301b has been carried out in solution and solid states.
Yuehchukene (3) and a number of structural analogues have been synthesized\textsuperscript{102} by intramolecular ring closure of $\alpha$, $\beta$-unsaturated 2-acylindoles (304) in the key step. Reduction of the resulting cyclopent[b]indol-3-one (305), followed by acid-catalysed incorporation of a second indole unit (290), gave yuehchukene (3). The same method had been extended to prepare the analogues of (3)\textsuperscript{170}.

Sigaut and Levy\textsuperscript{171} have reported a simple methodology for the Fischer-indolization of cyclopentanone (297) to give cyclopent[b]indole (298).

A number of unsaturated 3-acylindoles (309) have been prepared and annulated (with HCl or NaCl-AlCl\textsubscript{3}) to 3,4-dihydrocyclopent[b]indol-1(2\textit{H})-ones\textsuperscript{172} (310) or 1,2,3,9-tetrahydro-4\textit{H}-carbazole-4-ones (311) depending on the structure of the substrate and / or the reaction conditions. Starting from indole substituted Grignard reagent (307) and substituted acryloyl chlorides (308) a series of 3-acylindoles (309), have been prepared.
The presence of the carbonyl group in compounds 310 and 311 functions as a handle for further synthetic elaborations.

Cyclisation of \( \alpha, \beta \)-unsaturated 3-acylindoles (312, 314) using trifluoroacetic acid (TFA) in acetonitrile afforded the cyclopent[\( b \)]indol-1-one derivatives (313, 315) in low yield\(^{172}\).

Refluxing the above 3-acylindoles (312, 314) using HCl / dioxane to undergo cyclisation yielded the above cyclopent[\( b \)]indol-1-ones (313, 315) in good yields.

Similarly the \( \alpha, \beta \)-unsaturated 2-acylindoles (316, 318 and 320) have been cyclised under comparatively mild conditions to afford the respective cyclopent[\( b \)]indol-3-ones (317, 319 and 321).
The compound (321) serves as a potential precursor in the synthesis of naturally occurring indole alkaloid yuehchukene (3).

Dopachrome (323b) and related o-benzoquinones obtained from the corresponding catecol were trapped by treating each quinone with 2,3-dihydro-1H-cyclopent[b]indole (322) to afford the adduct $^{173}$ (324).
1.10. Objective

From the survey of literature, we realised that many alkaloids containing cyclopent[b]indole unit in their architecture have displayed a broad spectrum of pharmacological properties. Also, it was noticed that heterocyclo- as well as benzo-fused carbazole systems are of considerable contemporary interest and importance as many of these structural frameworks were present in natural products displaying remarkable pharmacological properties. Until recently, synthetic studies on heterocyclo-fused cyclopent[b]indoles were limited by a paucity of viable methods for the construction of these systems. Hence, in the present synthetic study, it is contemplated to develop some simple and elegant procedures for the preparation of some cyclopent[b]indole and carbazole bearing heterocycles which will give a new dimension and impetus to the proliferation of studies on these systems.

Development of new methods for the synthesis of functionalised carbazoles is currently attracting organic chemists due to the discovery of many carbazole alkaloids with varied biological activities.

To achieve our objective, we identified the following synthons as core entries and they have been subjected to a variety of chemical reactions under different conditions. The precursors, 1-oxo-1,2,3,8-tetrahydrocyclopent[b]indoles have been obtained by the Fischer-indole cyclisation of the respective hydrazones, which in turn obtained by the Japp-Klingemann reaction of diazotised aniline derivatives with 2-hydroxymethylenecyclopentanone. With an intention to prepare pyrano[2',3':5,4]cyclopent[b]indoles, the precursors, 1-oxo-1,2,3,8-tetrahydrocyclopent[b]indoles, were treated with glacial acetic acid in the presence of polyphosphoric acid. Further, 1-oxo-1,2,3,8-tetrahydrocyclopent[b]indoles were subjected to a series of reactions as presented here. 1-Oxo-1,2,3,8-tetrahydrocyclopent[b]indoles were reacted with o-aminoacetophenone in the presence of an acid catalyst to yield 5-methyl-6,11-dihydroquinolino[2',3':5,4]cyclopent[b]indoles.

2-(4'-Methoxy)benzylidene-1-oxo-1,2,3,8-tetrahydrocyclopent[b]indoles, obtained from the mixed aldol reaction of 1-oxo-1,2,3,8-tetrahydrocyclopent[b]indoles with 4-methoxybenzaldehyde were employed to construct pyrazolino- and isoxazolo-
frame work on cyclopent[b]indole skeleton. In an attempt to synthesize pyrimido annelated cyclopent[b]indoles, 2-(4'-methoxy)benzylidene-1-oxo-1,2,3,8-tetrahydro-cyclopent[b]indoles were treated with guanidine nitrate in the presence of sodium methoxide in ethanol.
1-Hydroxyimino-1-oxo-1,2,3,8-tetrahydrocyclopent[b]indoles, obtained from the corresponding 1-oxo-1,2,3,8-tetrahydrocyclopent[b]indoles, were reacted with acetyl chloride at room temperature to obtain the products 4,9-dihydro-2-methylloxazolo[4',5':5,4]-cyclopent[b]indoles.

1-Semicarbazono-1,2,3,8-tetrahydrocyclopent[b]indoles obtained from the reaction of 1-oxo-1,2,3,8-tetrahydrocyclopent[b]indoles with semicarbazide hydrochloride were utilized in the construction of 4,9-dihydro-1,2,3-selenadiazolo[4',5':5,4]-cyclopent[b]indoles.

As a part of our objective to synthesis some heterocyclo-fused carbazoles using simple and efficient procedures, we took an effort to prepare a suitable functionalized intermediate that can be readily utilized to derive the target systems. Interestingly, the reaction of 1-oxo-1,2,3,4-tetrahydrocarbazoles with ethyl formate in dry ether in the presence of sodium methoxide afforded the important synthons, 2-hydroxymethylene-1-oxo-1,2,3,4-tetrahydrocarbazoles. The potentiality of this intermediate was fully exploited to obtain the following annelated carbazole alkaloids: (1) 4,5-Dihydro-2H-pyrazino[3,4-a]-carbazoles, (2) Isoxazolo[3,4-a]carbazoles, (3) 2,4-Dihydroxy-1,4,5,6-tetrahydropyrimido[4,5-a]-carbazoles, (4) 4-Hydroxy-2-mercapto-1,4,5,6-tetrahydropyrimido[4,5-a]carbazoles, (5) 2-Amino-4-hydroxy-1,4,5,6-tetrahydropyrimido[4,5-a]carbazoles, (6) 7,8-Dihydropyrimino-[3,4-a]carbazoles, (7) 5,6-Dihydro-2-oxopyrano[2,3-a]carbazoles and (8) 6-Oxobisindolo-[1,2-b;5,4-b']cyclohexanones.

In addition to the above experiments, we also planned to synthesis some novel heterocyclo-fused carbazoles like pyrazolino- and isoxazolino-annelated carbazoles, we utilized 2-(4'-methoxy)benzylidene-1-oxo-1,2,3,4-tetrahydrocarbazoles as synthons, which have been obtained from the reaction of 1-oxo-1,2,3,4-tetrahydrocarbazoles with 4-methoxybenzaldehyde.

(1) Our next objective is to exploit the easily accessible 1-hydroxycarbazole to obtain the following annelated carbazoles, (i) 2-acetylfuro[2,3-a]carbazoles, (ii) benzo[1,2-b]-1,4-thiazepino[7,6-a]carbazoles and (iii) 2-oxo-3-phenylpyrano[2,3-a]carbazoles through 1-hydroxycarbazole-2-carbaldehydes.
(2) 3,11-Dihydro-2,4-dioxopyrano[2,3-\textit{a}]carbazoles, obtained from 1-hydroxycarbazoles and malonic acid with an expectation to utilize as a synthon to derive novel dimerized product.

(3) Next, 1-hydroxycarbazoles reacted with anthranilic acid with an expectation to yield 12,13-dihydro-5-oxoquinolino[2,3-\textit{a}]carbazoles.

A large number of hitherto unknown compounds synthesised and reported in the chapters 2 - 4 were tested for their efficiency as antibacterial and antifungal agents against some human pathogenic bacterial species and plant pathogenic fungal species by \textit{in vitro} methods. A preliminary study on the DNA interaction and cytotoxicity of some compounds have also been discussed.

4,5-Dihydro-2\textit{H}-pyrazino[3,4-\textit{a}]carbazoles

Isoxazolo[3,4-\textit{a}]carbazoles

2,4-Dihydro-1,4,5,6-tetrahydropyrimido-[4,5-\textit{a}]-carbazoles

4-Hydroxy-2-mercapto-1,4,5,6-tetrahydropyrimido-[4,5-\textit{a}]carbazoles

7,8-Dihydroquinolino[3,4-\textit{a}]-carbazoles

2-Amino-4-hydroxy-1,4,5,6-tetrahydropyrimido[4,5-\textit{a}]-carbazoles

5,6-Dihydro-2-oxo-pyrano-[2,3-\textit{a}]carbazoles

1-Oxo-2-phenylhydrazino-1,2,3,4-tetrahydrocarbazoles

6-Oxo-bisindolo[1,2-\textit{b}:5,4-\textit{b}']-cyclohexanones
Details regarding the experimental conditions and isolation of products in all the above reactions have been adequately presented in the respective parts of the thesis. All the new compounds synthesized in our study were well characterized by various physico-chemical methods to assign their structures. The work carried out in connection with the aforementioned objective and the results obtained along with a relevant literature survey have been presented in detail in the following chapters.