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Development of Web Based Digital Key from Dichotomous Key through Computer Programming: Model Aphid Predator Neuroptera (INSECTA)

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Abstract: ***In fact, the majority of scientific questions asked by biologists could never be formulated or even conceived without reference to some sort of hierarchical arrangement of taxa, making classification the most fundamental of all biological sciences. The majority of biologists might agree that taxonomy's goal should be to identify the components of biodiversity, especially since accurate identification of the organisms is essential for biosecurity and best crop management practices. However, field knowledge in both taxonomy and application is dwindling. As a result, it is critical to identify any pests or other organisms. Since adopting new taxonomic technology in 2011, USDA Animal and Plant Health Inspection Service, Plant Protection and Quarantine (APHIS-PPQ) has created an impressive array of identification tools, many of which are gaining enormous popularity. Indian algorithms have not yet been used to create India's own software or appropriate database for this purpose. We created our own algorithm by using Neuroptera (Insecta) of West Bengal, India as our model organism because it is region-specific database dependent, both for the creation of our own "Digital Key" experiment and for the identification of insects that can control aphids, as bio control agents, we have chosen the predator group of Aphids (Homoptera: Aphididae). As a result, we experimentally created www.lacewingsofwestbengal.in, a web platform, and a "Digital Key" of "Genus" of a chosen Neuropteran group.***

Keywords: Aphid-predator, Hemerobiidae, Chrysopidae, Dilaridae, Coniopterygidae, Digital key

I. INTRODUCTION

Classification is the most basic of all the biological sciences; indeed, most scientific questions biologists ask could never be formulated or even conceived without reference to some sort of hierarchical arrangement of taxa (Rieppel, 1992, 2004). Yet the future of taxonomy-or whether taxonomy has a future-has become a recurring topic in both specialized and popular scientific literature. It has been argued that taxonomy should not be a "handmaiden" to other branches of biology (Wheeler 2008). On the other hand, most biologists might feel that identifying the components of biodiversity should be a rather basic part of taxonomy's mission. specially correct identification and organisms is critical for bio-security and best crop management practice. On the other hand Taxonomic and practical field expertise is declining (Odeh et al, 2015). Consequently, there is an urgent need for identification of pest or other organisms. USDA Animal and Plant Health Inspection Service, Plant Protection and Quarantine (APHIS-PPQ) has embraced new taxonomic technology and in the past few years (since 2011) has produced an impressive array of identification tools, many of which are becoming very popular (Sharma et al, 2019). The technique is development of beta key as well as digital key. The algorithm has been developed and patented. This commercial software is now used by 130 countries (LUCID BUILDER VERSION 3.5). India has not yet developed its own software. As it is region specific database dependent, we have to develop our own algorithm. Insects belonging to the superorder Neuropterida (orders Neuroptera, Megaloptera, Raphidioptera, and Glosselytrodea) such as lacewings, antlions, fishflies, and snakeflies have a wealth of digital information available to them online. This information is easily accessible through the Lacewing Digital Library (LDL), a web portal of Texas A & M University. Since 2010, the LDL portal (http://lacewing.tamu.edu) has provided access to numerous online sources of knowledge about neuropterid insects, international neuropterists, and related subjects of interest. Digital documentation of Neuroptera or any Insect group has not yet been developed IN INDIA.

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The almost constant emergence of novel diseases and pests in agricultural areas has driven up demand for taxonomists to unprecedented levels. Identification of new, existing, and potentially invasive pest species is a daily challenge for insect specialists. Before taking any action, it is necessary to correctly identify any insects. End-users have historically identified insects using a variety of methods, such as matching (type specimens), dichotomous keys, pathway keys, matrices and multiple entry keys (computer assisted), tabular keys (taxa vs. character states), and punch card keys. Computer-based taxonomic programs that include taxonomic keys, resources, and tools have grown in popularity lately. Alpha taxonomy, on the other hand, has progressively moved down the systematic branches. Most biological sciences require the ability to recognize species, particularly invasive ones. It does play a bigger part in pest management, though.

Neuroptera is important group as biological control agent. At present 14 Canadian, 33 Mexican and 95 U.S. companies are selling neuropterans as controlling agent commercially (http://www.cdpr.ca.gov/docs/pestmgt/ip). Our state is also having Neuropteran Resource. We have collected and identified more than 35 species of Aphid associated Neuroptera from West Bengal. Thus we developed a model beta digital key for the “Genus”.

II. MATERIALS

A. Key To The Aphidophagous Genera Of West Bengal Of The Suborder Planipennia

Collection of Neuropteran specimens have been made from different localities of West Bengal State of India. These specimens were identified by using proper morphological characters. They were found to belong under 14 genera of 4 Families. A dichotomous key has been prepared for identification of Genus from morphological characters. The GENUS KEY is as follows:

1. Small insect; wing venation reduced.....*Coniocompsa* Enderlein.

- Medium or large insect; wing venation well developed.....2.

2. Rs only 1 in number.....5.
- Rs either 2 or more than 2 in number.....3.

3. Abdominal tergite with worts; tibiae very long, 2 fold or more than 2 fold than length of femur...
.....*Dilar* Rambur.

- Abdominal tergite without worts; tibiae as long as or slightly longer but less than 2 fold than femur.....4.

4. Maxillary palpi 5-segmented; labial palpi 3-segmented; humeral vein unforked, simple, usually not recurrent.....*Micromus* Rambur.

- Maxillary palpi 6-segmented; labial palpi 4-segmented; humeral vein branched, forked and recurrent.....*Hemerobius* Linnaeus.

5. Jugal lobe well developed; tympanal organ absent; frenulum on hind wing present; 1A forked at fore wing.....*Nothochrysa* McLachlan.

- Jugal lobe reduced; tympanal organ present; frenulum on hind wing absent, if present, reduced; 1A unforked at fore wing.....6

6. Costal area broad at base; legs often marked with black annulation on fore and mid tibiae;
.....*Ankylopteryx* Braüer.

- Costal area at first narrow then gradually widening; legs without definite black annular markings.....7.

7. Tignum present, either arcuate or T-shaped.....8.

- Tignum absent or reduced.....9.

8. 1st Rs crossvein usually meets psm well distal to im cell; spinellae occur on the gonosaccus; gonapsis absent.....*Chrysoperla* Steinmann.

- 1st Rs crossvein usually meets psm at the apex or on the im cell; spinellae absent from gonosaccus; gonapsis present.....*Mallada* Navás.

9. Scape swollen; distal cubital cell closed at wing margin.....*Tumeochrysa* Needham.
- Scape not swollen; distal cubital cell open at wing margin.....10.

10. im cell quadrangular in shape; c1 cell 1.5 - 2.0 times longer than c2.....
.....*Italochrysa* Principi.

- im cell ovate, broad or narrow; c1 cell shorter than c2, if longer always less than 1.5 times than c2.....11.

11. Arcessus 'axe-head' shaped when viewed laterally and bears a large ventral hook and dorsal striation.....*Cunctochrysa* Hölzel.

- Arcessus absent or not as above.....12.

12. Median plate present.....*Retipenna* Brooks.

- Median plate absent.....13.

13.Fore wing with 2 rows of gradate veinlets; costal setae short, slightly inclined; scape not elongated; entoprocessus broad basally with dorsal horn.....*Chrysopa* Leach.

- Fore wing with 3 rows of gradate veinlets; costal setae long, inclined or erect; scape elongated; entoprocessus bifurcated basally without horns.....*Chrysopidia* Navás.

III. METHODS

The above dichotomous key has been converted in to digital key by using the following "proper programme"

A. JQuery & Ajax

It is a JavaScript (JS) library that is open-source and was created with the motto "Write Less, Do More." John Resig created the technology, which he demonstrated in 2006 at the BarCamp NYC conference. It was a development in front end development methodology where developers merely needed to call their method rather than repeatedly rewriting each job block.

jQuery syntax basically follows the same pattern as a code snippet for each statement. A method or function is applied to an event after a selected element from the HTML DOM is chosen: $(selector).method_Or_Function(); The majority of jQuery's statements apply various functions and methods to particular HTML elements and their attributes. Depending on the selection and the action, which is the applied method or function, this technique is easily modifiable. Jquery technology makes it simple to manage and manipulate DOM items.

Currently jQuery is used on about 20% of all sites on the internet and has an extensive adoption rate from companies large and small. JQuery has been used deeply by companies like Twitter, Kickstarter, Uber, Hootsuite,AngelList and others.

There are 3 main tasks perform using jquery mostly on front end –

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DOM traversal and manipulation

```
$( "button.continue" ).html( "The content following…" )
```

The above code will find/select all 'button' element with class 'continue' and change their html content to the given string passed into html().

- *Event Handling*

```
var hb = $( "#welcome-message" );
$( "#bt button" ).on( "click", function( event ) {
        hb.show();
});
```

The above code will display a hidden box with welcome message whenever 'click' event fired on any button in group #bt button.

- *Ajax*

It is basically used to call server side script in order to get some result/response from the server query or process without reloading the whole content. Sample code is given as -

```
$.ajax({
        url: "Some api or url",
        data: {
              somevar: value of var
        },
       success: function( result ) {
          $( "#some_id" ).html( "content to display as result from 'result'" );
        }
});
```

In the current scope, we have used these two technologies (jquery & ajax) almost everywhere for front end development. Representation of all tables and key generation interface are also developed with these techs in order to maintain the flexibility for a variety of devices, such as – desktop,laptop, tab, mobiles etc. It also provides the state of the art look and feels for the entire portal.

B. PHP & CI4

Very popular web based server side scripting technology termed as PHP - Hypertext Preprocessor, mainly contains the backend and all business logic for the portal where CI4 is a framework under PHP with advanced OOP concept and a bit distributed architechture. Some of the important task in current scope -

- Dealing with database
- Converts algorithms to code
- Some exception handling
- Distributing structure with CI4
- Routing urls using CI4 utility

According some surveys, PHP is used by 78.1% of all websites, including high-traffic websites like Facebook and Wikipedia. It is an open-source server-side scripting language widely used in web development;

A script is a set of commands or instructions to be executed on other programs or applications. There are mainly two types of scripting languages currently available – ones intended for the client-side or the front-end and other is for the server-side or the back-end.

PHP is a server-side scripting language, which means that it is the server that executes the instructions in a script not the client's computer. The server provides data on request, channels the requests, and organizes the information in a database, all of these task has been done by varieties of such scripts.

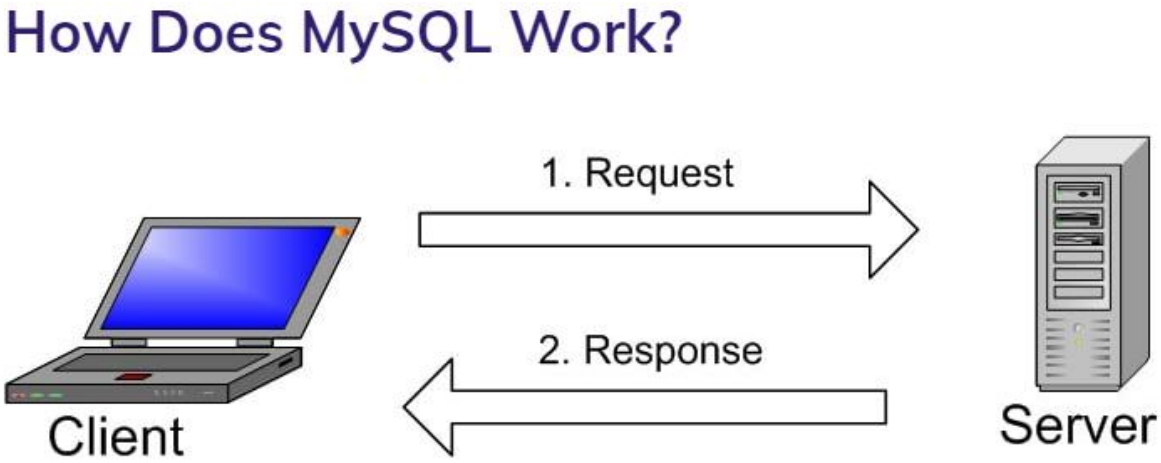
When a web server receives a script, it will process the request and send output to a web browser in an HTML format. A web server database stores the information so other users can't access the data and source code. With scripts, users can perform operations like customizing a site, making dynamic changes to website content, and accessing a database. Users also often use a scripting language to develop web applications.

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C. MySql

Very much popular database (RDBMS-Relational Data Base Management System) in industry. A Swedish company called MySQL AB originally developed MySQL in 1994. The US company Sun Microsystems took full ownership when they bought MySQL AB in 2008. US tech giant Oracle in 2010 acquired Sun Microsystems itself, and MySQL has been practically owned by Oracle since.
We can call a database is collection of structured data. A database is a place where data is stored and organized in a well defined procedure. The word "relational" means that the data stored in the dataset is organized as tables. Every table relates in some ways.
Computers that install and run RDBMS software are typically called clients. Whenever they need to access data, they connect to the RDBMS server. That's the "client-server" part.
Obviously MySQL is one of many RDBMS software options among Ms-SQL, Oracle, Cybase etc. Many big web applications like Facebook, Twitter, YouTube, Google, and Yahoo! all use MySQL for data storage purposes. Even though it was initially created for limited usage, it is now compatible with many important computing platforms like Linux, macOS, Microsoft Windows, and Ubuntu.



We planned to use MySql as our data storage for this project as it is open source and flexible for use. All records are securely stored in separate tables under specific database in mysql. Certain dedicated scripts were written which are responsible for data transfer and transformation.

D. Html & CSS

Is W3C recommendation for any publication to publish on web platform. Defines the structure of each page and section. In the current scope, all structure were designed using latest version of HTML which is 5.
CSS is used for different styling purpose which stands for Cascading Style Sheet. Initially we planned to develop with scratch techs but later decides to go with BS5(Bootstrap 5) framework for faster development with nice look and feels and availability of most user friendly components which were proven from a long period of time.

IV. THE PROGRAMME

The following are the logic/algorithm implemented in client-server format like a simple interrogation or conversation. Each characteristics are assigned with a key-value to be represented in the characteristic database for species and genus separately. Server prompts a specific characteristic with options to acquire Client's knowledge on sample with him/her. Depending on client's feedback or choice, it ask module to find suitable branching to follow next thus reaches to conclusion or final diagnosis.
Unique search key is used individually for species and genus ranging from A – Z with the following basic relational algebraic query pattern =>

$$\left[\pi_{\text{key,sample_id}}\ \sigma_{\text{key=keyvalue}[\wedge\text{sample_id=id}]}^{\text{(set of all sample)}}\right]_{\text{Recursive}}$$

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A. Front End (Client) part

```
$(document).on('click','#ngenuscardbody>.card',function(e){
        var dataSymbol=$(this).find("#ngenush5>code").html();
        var dataStr="dataSymbol="+dataSymbol;
        if(dataSymbol!='X'){
                $.ajax({
                        url:"digikey/genus",
                        type:"post",
                        data:dataStr,
                        dataType: 'json',
                        error:function(){alert("Something went wrong!!!");},
                        success:function(response){
                                var s='';
                                $.each(response, function(index, element) {
                                        var last=element.symbol[element.symbol.length -1];
                                        if(last=='X'){
                                                s=s+'<div class="card">'+'<button class="btn btn-danger">'+'<div
class="card-body">'+ '<h5 class="card-title" id="ngenush5" style="display:none"> <code>'+ element.symbol+'</code></h5>'+'<p
class="card-text" id="ngenusp">'+ element.key+'</p>'+ '</div>'+'</button>'+'</div>'+'<br/>';}
                        else if(last=='x')   {
                                s=s+'<div class="card">'+'<button class="btn btn-success">'+'<div class="card-body">'+'<h5
class="card-title" id="ngenush5" style="display:none"> <code>'+ element.symbol+'</code></h5>'+'<p class="card-text"
id="ngenusp">'+element.key+'</p>'+
'</div>'+'</button>'+'</div>'+'<br/>';}
                        else{
                                s=s+'<div class="card">'+'<button class="btn btn-light">'+'<div class="card-body">'+'<h5 class="card-
title" id="ngenush5" style="display:none"> <code>'+ element.symbol+ '</code> </h5>'+'<p class="card-text"
id="ngenusp">'+element.key+'</p>'+'</div>'+'</button>'+
'</div>'+'<br/>';   }
                                });
                                $('#ngenuscardbody').html(s);
                                }//end success
                        });
                }
        });
});
```

B. Back End (Server) part

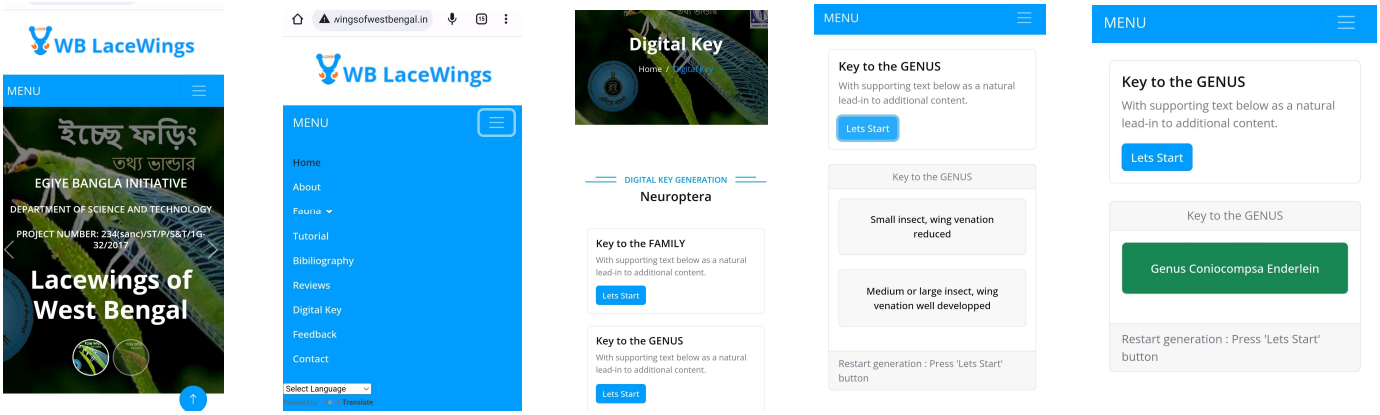
```
genus() {
if(isset($_POST) && $_POST['DataSymbol']!=''){
$dataSymbol=$_POST['DataSymbol'];
$data=array();if(substr($dataSymbol,-1)=='x'){
                                $data=array(
array('symbol'=>'X','key'=>'You are at end of a branch/genus')
);}else if($dataSymbol=='0'){$data=array(
array('symbol'=>'A','key'=>'Small insect, wing venation reduced '),
array('symbol'=>'B','key'=>'Medium or large insect, wing venation well developped ')
);}else if($dataSymbol=='A'){$data=array(array('symbol'=>'Ax','key'=>'Genus Coniocompsa Enderlein'));}else
if($dataSymbol=='B'){$data= array(array('symbol'=>'C','key'=>'Radial Sector (Rs) 2 or more than 2 in number'),
array('symbol'=>'D','key'=>'Radial sector (Rs) 1 in number')
```

```
);}else if($dataSymbol=='C'){$data=array(                                    array('symbol'=>'E','key'=>'Antenna pectinate,
abdomain with worts'),
                                        array('symbol'=>'F','key'=>'Antenna filiform, abdomain without worts'));}else
if($dataSymbol=='E'){$data=array(
                                        array('symbol'=>'Ex','key'=>'Genus Dilar Rambur'));}else
if($dataSymbol=='F'){$data=array(
            array('symbol'=>'G','key'=>'Maxillary palp 5 segmented, Labial palp 3 segmented'),
array('symbol'=>'H','key'=>'Maxillary palp 6 segmented, Labial palp 4 segmented'));}    else if($dataSymbol=='G'){
        $data=array(                                    array('symbol'=>'Gx','key'=>'Genus Micromus Rambur')    );}else
if($dataSymbol=='H')
{$data=array(    array('symbol'=>'Hx','key'=>'Genus Hemerobius Linnaeus')
);                      }else if($dataSymbol=='D'){$data=array(
                            array('symbol'=>'I','key'=>'Jugal Lobe reduced, frenulum on hind wing absent'),
        array('symbol'=>'J','key'=>'Jugal lobe well developped, frenulum on hindwing present'));}else
if($dataSymbol=='I'){$data=array(
array('symbol'=>'K','key'=>'Costal area broad at base, legs with black annular markings on fore and mid tibiae'),
array('symbol'=>'L','key'=>'Costal area narrow at base, legs without annular wings')
);}else if($dataSymbol=='K'){    $data=array(array('symbol'=>'Kx','key'=>'Genus Ankylopteryx Brauer'));}else
if($dataSymbol=='L'){            $data=array(
        array('symbol'=>'M','key'=>'Tignum present'),
            array('symbol'=>'N','key'=>'Tignum absent')
);}else if($dataSymbol=='M'){$data=array(
                                        array('symbol'=>'O','key'=>'Gonapsis present, 1st Rs crossvein usually meets "PSM"
well distal to "im" cell '),
        array('symbol'=>'P','key'=>'Gonapsis absent, 1st Rs crossvein usually meets "PSM" at the apex of "im" cell'));}else
if($dataSymbol=='O'){    $data=array(
            array('symbol'=>'Ox','key'=>'Genus Chrysoperla Steinman'));}else
if($dataSymbol=='P'){$data=array(array('symbol'=>'Px','key'=>'Genus Mellada Navas')
                            );          }else if($dataSymbol=='N'){$data=array(
array('symbol'=>'Q','key'=>'Distal cubital cell closed at wing margin'),
array('symbol'=>'R','key'=>'Distal cubital cell open at wing margin'));}else if($dataSymbol=='Q')
{$data=array(
        array('symbol'=>'Qx','key'=>'Genus Tumeochrysa Needham')
);}else if($dataSymbol=='R'){$data=array(
array('symbol'=>'S','key'=>'"im" cell ovat, broad or narrow'),
array('symbol'=>'T','key'=>'"im" cell quadrangular in shape')
);}else if($dataSymbol=='S'){$data=array(
array('symbol'=>'U','key'=>'Arcessus present'),
array('symbol'=>'V','key'=>'Arcessus absent')
);}else if($dataSymbol=='U'){$data=array(array('symbol'=>'Ux','key'=>'Genus Cunetochrysa Holzel')
);}else if($dataSymbol=='V'){$data=array(array('symbol'=>'W','key'=>'Median plate present'),
array('symbol'=>'X','key'=>'Median plate absent'));}else if($dataSymbol=='W')
{$data=array(
array('symbol'=>'Wx','key'=>'Genus Retipenna Brooks')
);
}else if($dataSymbol=='X'){$data=array(array('symbol'=>'Y','key'=>'Forewing with two rows of gradate
veinlet'),array('symbol'=>'Z','key'=>'Forewing with three rows of gradate veinlet')
);}else if($dataSymbol=='Y'){$data=array(
                            array('symbol'=>'Yx','key'=>'Genus Chrysopa Leach')
);}else if($dataSymbol=='Z'){$data=array(
```

```
array('symbol'=>'Zx','key'=>'Genus Chrysopidia Navas')
);}else if($dataSymbol=='T'){$data=array(array('symbol'=>'Tx','key'=>'Genus Italochrysa Principi'));}else if($dataSymbol=='J'){
        $data=array(
        array('symbol'=>'Jx','key'=>'Genus Nothochrysa Melachlan')    );}
}return json_encode($data);}
```

V. RESULT

The result is a web based platform www.lacewingsofwestbengal.in hosting the digital key to the "Genus" of Neuropteran Insects. A sample sequence of digital genus key is shown below.



A B C D E

A. Webpage www.lacewingsofwestbengal.in
B. All MENU showing DIGITAL KEY
C. TWO digital key TAB, one of them showing "GENUS KEY"
D. Open "GENUS KEY" it is showing Morphological Characters
E. By selecting Character I, Result showing Name of a specific Genus

VI. CONCLUSIONS

For the purpose of hosting the "Digital Key to the Genus," a website platform has been created. The "Selecting the Language" tab allows anyone to translate the website's content into any language in the world. For the benefit of laypeople, the "Home" contains general descriptions of the four (four) aphidophagous (aphid predator) families of the order Neuroptera (insects). The Genus of Aphid Predator Neuroptera found in West Bengal, India are included in the "Fauna" section. For those who are interested in the taxonomy of insects, the "Tutorial" contains all the taxonomic characteristics (with drawings) considered for identification of Neuroptera. The "Review" includes information for laypeople about the biology, evolution, and utility of aphid predator neuroptera. For the "Genus" found in West Bengal, India, the "Digital Key" has been created. If someone is interested in learning more about Neuropteran Taxonomy, they can use the "Digital Key" to select particular morphological characteristics to determine the "Genus." The works we consulted for this project are listed in the "Bibliography."

VII. ACKNOWLEDGMENT

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SUPPLIMENTARY TABLE
(ARRANGEMENT OF GENUS IN CHART FORM)

Chart I

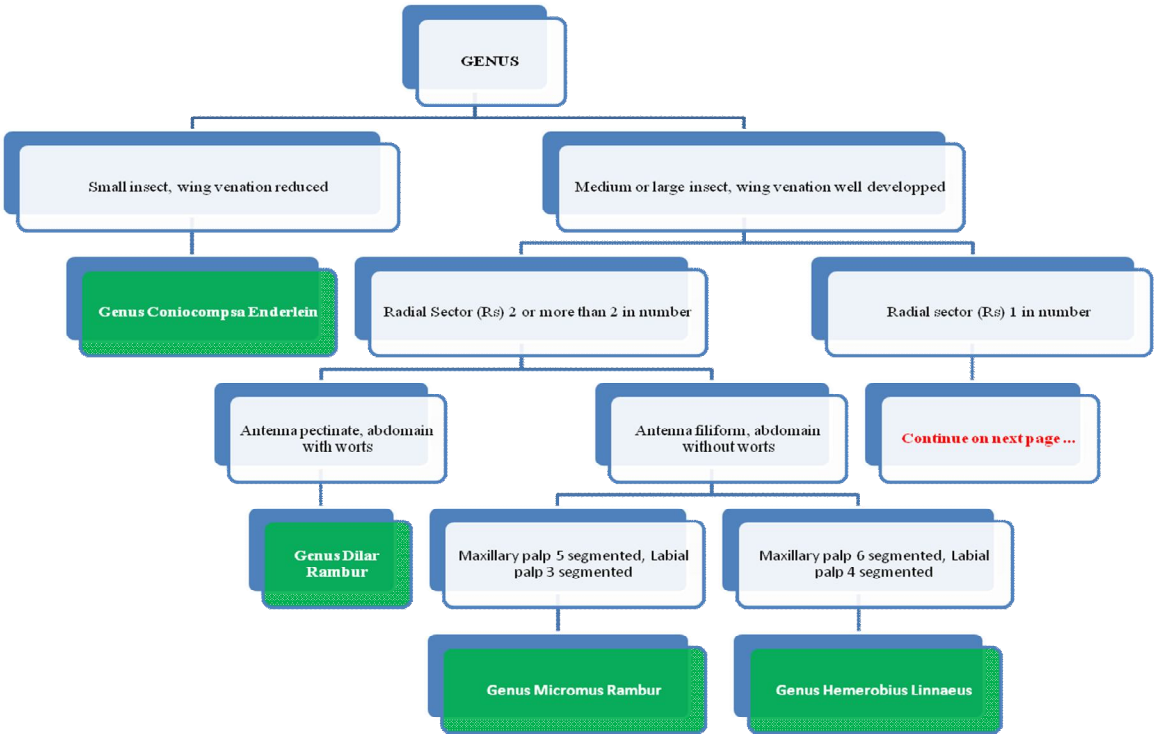
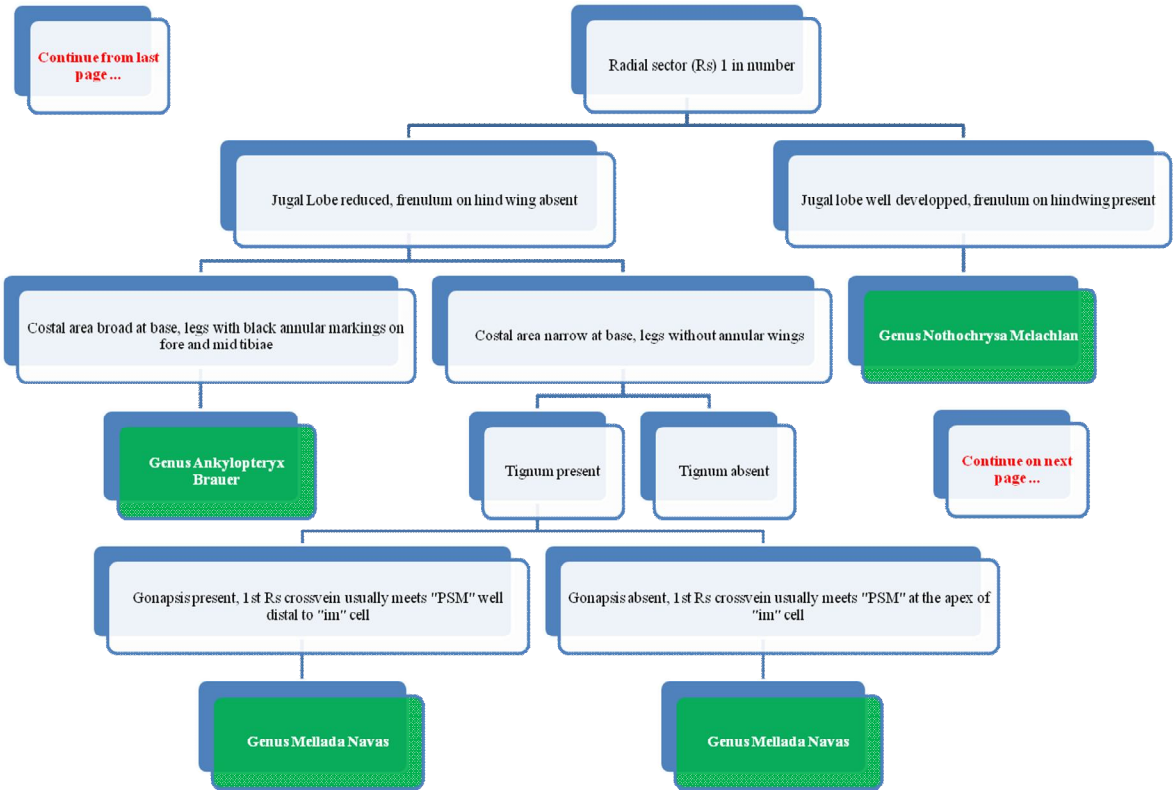
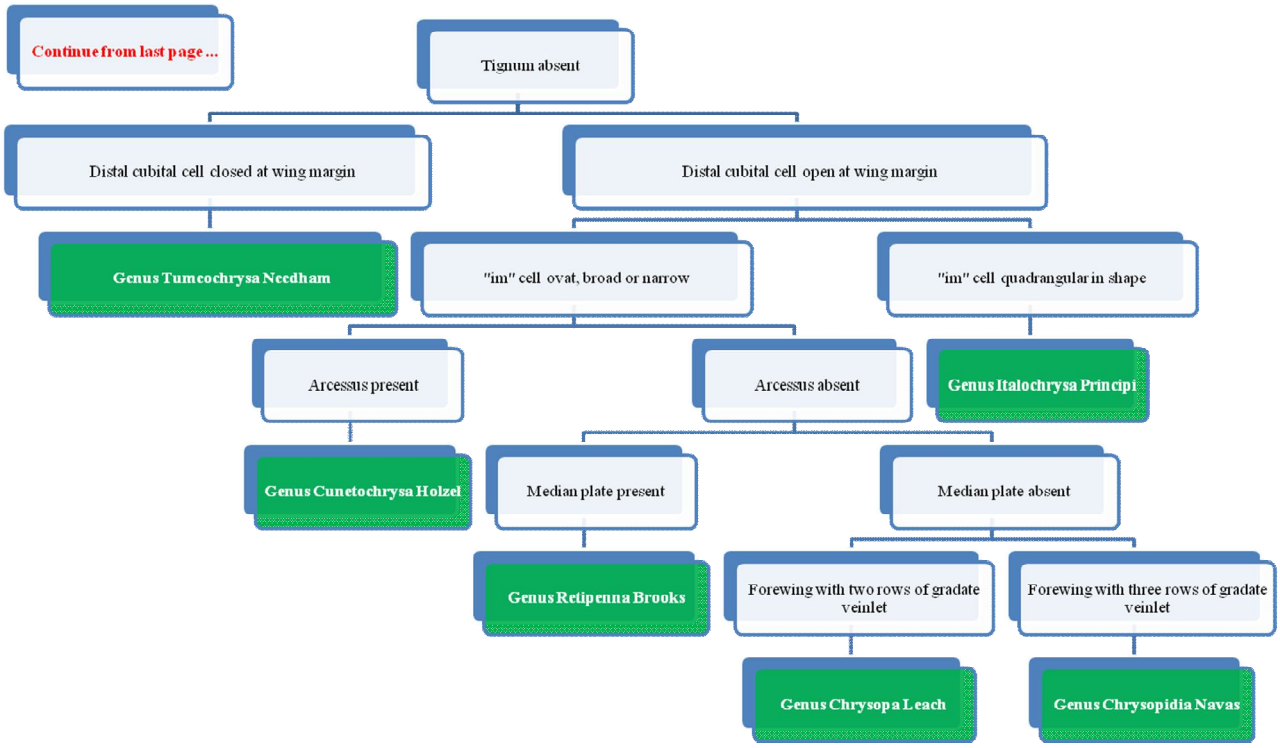


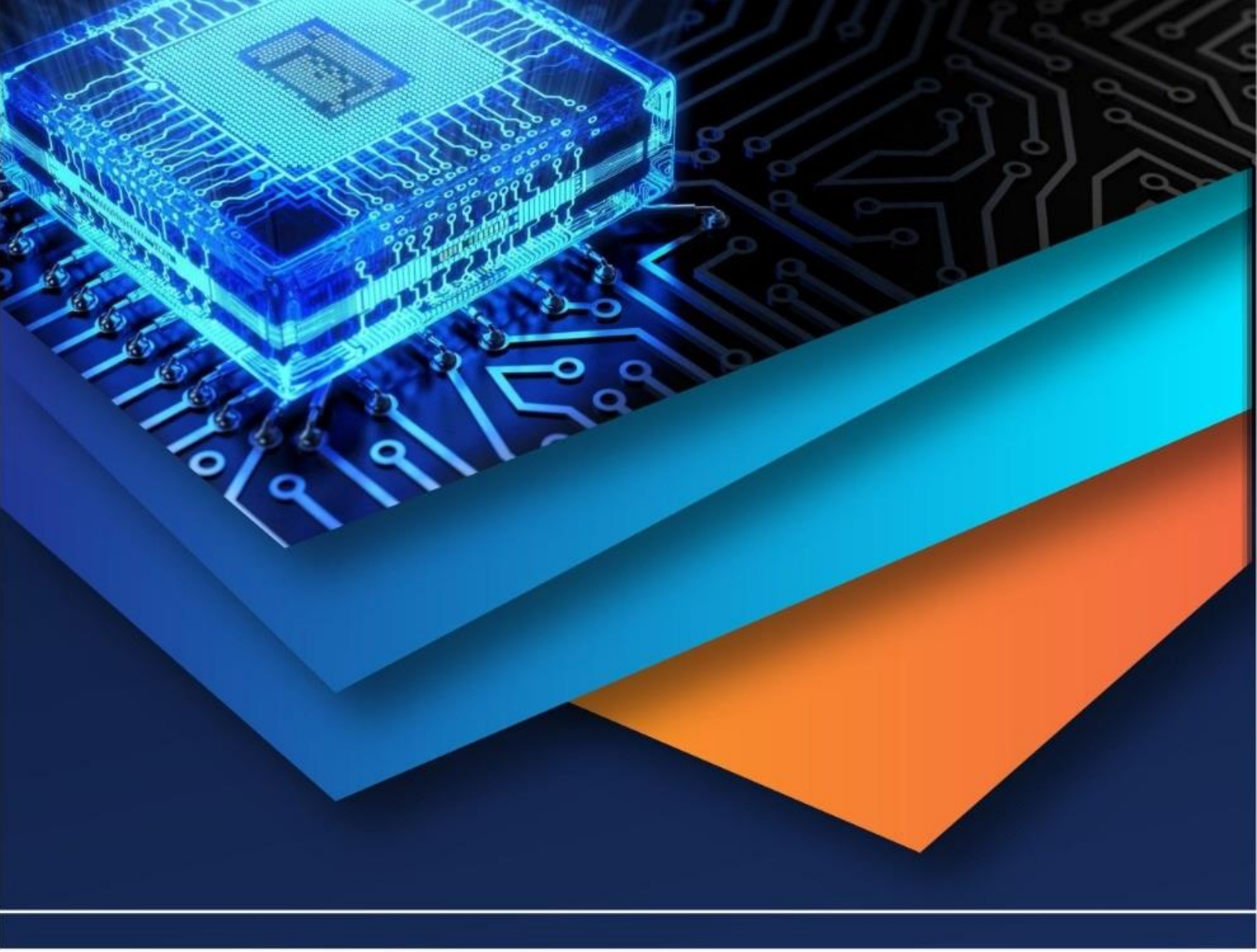
Chart II



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Chart III


Continue from last page ...
Tignum absent
Distal cubital cell closed at wing margin
Distal cubital cell open at wing margin
Genus Tumeochrysa Needham
"im" cell ovat, broad or narrow
"im" cell quadrangular in shape
Arcessus present
Arcessus absent
Genus Italochrysa Principi
Genus Cunetochrysa Holzel
Median plate present
Median plate absent
Genus Retipenna Brooks
Forewing with two rows of gradate veinlet
Forewing with three rows of gradate veinlet
Genus Chrysopa Leach
Genus Chrysopidia Navas



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