

Medical Entomology

A Handbook of
Medically Important Insects and
other Arthropods

B.K. Tyagi



MEDICAL ENTOMOLOGY

A HANDBOOK OF MEDICALLY IMPORTANT INSECTS AND OTHER ARTHROPODS

Dr. B.K. Tyagi

Deputy Director (Senior Grade)
& Head, Division of Insecticide and Vector Control
Centre for Research in Medical Entomology (ICMR)
Madurai 625 002, India

*(Formerly the Officer in-Charge, Desert Medicine Research Centre, Jodhpur;
National Representative in-Charge, National Office in India for the Societas
Internationalis Odonatologica and Member in-Charge in South Asia, Odonata
Specialist Group of the Species Survival Commission, IUCN)*



SCIENTIFIC PUBLISHERS (INDIA)

P.O. Box 91

JODHPUR

Published by:

Pawan Kumar

Scientific Publishers (India)

5-A, New Pali Road, P.O. Box 91

JODHPUR – 342 001

Tel.: +91-291-2433323 Fax: +91-291-2512580

E-mail: scienti@sancharnet.in

© Tyagi, B.K., 2003

ISBN: 81-7233-351-X

eISBN: 978-93-87741-32-4

Lasertype set : Rajesh Ojha

Printed in India

Dedicated to

Parents and Teachers

FOREWORD

Medical Entomology is an integral part of applied ecology involving the study of diverse ecto- and endoparasites and comprise a fundamental complement of numerous diseases which have a significant impact on human health. Insect vector-host interactions have become a basic component of many important diseases like malaria, filaria, leishmaniasis, dengue to mention only a few. In recent years increasing insights into the eco-physiology and behaviour of insect transmitted diseases have established a major challenging assumption regarding the interactions between insect vectors and the concerned parasites. The development of agriculture, of industrial establishments leading to urban migration and consequent increase in populations have led to communicable diseases establishing in a very significant way. Further increased denudation of forests has resulted in increased human-vector contact which has become almost irreversible. It is therefore of particular relevance that the author has chosen to discuss diverse aspects of vector-human relationship in relation to the changing environment of climatic variability.

One of the earliest publications on Medical Entomology in India is that of Patton and Cragg (1913), besides brief references to insect vectors of medical importance in text books of Entomology. Sen and Fletcher's (1969) book on Veterinary Entomology also deals in a small way the vector importance of insects. The present volume by an experienced Medical Entomologist has therefore become very relevant in terms of current information on all aspects of medical entomology. This thoughtful volume comprises 17 Chapters which deal with the ecology, physiology and behaviour, public health importance, distribution and control of several vector insects prevalent in India and abroad.

Dr. B.K. Tyagi has to be congratulated on producing a very informative and authoritative publication on Medical Entomology, which will fulfill a long felt need by both applied and general Entomologists in the country.



Chennai
1.7.2003

Prof. T.N. Ananthakrishnan

D.Sc., Ph.D., FNA, FASc, FNAAS

Emeritus Scientist

*Former Director, Zoological Survey of India, Kolkata
Director, Entomology Research Institute, Chennai*

PREFACE

It is amazing to acknowledge the bare fact that insects and other arthropods together constitute over 75% of the world animal species! Insects, who along with spiders, scorpions, mites, ticks, centipedes, millipedes and numerous other 'jointed legs' are grouped under phylum Arthropoda, have more species, and individuals on earth, than any other metazoan phylum. There are over 2 million described species of insects alone, with possibly several millions still remaining to be described. Amongst arthropods of all kinds, insects are undisputedly the most significant creatures due sheer to their remarkable structural and behavioural diversity. According to an estimate there are about 200 million insects for each human alive. They are of various different forms and sizes, and are present in all environments including water, land and air, leaving virtually nothing imaginable on the Earth that is not inhabited by these tiny yet evolutionarily highly successful animals! Born some 400 million years ago, in the Devonian-Silurian periods, insects have in course achieved, to the utter envy of all other organisms struggling to speciate during the late Paleozoic era, a formidable diversity on Earth so much so that on dry land they have virtually reigned supreme. In general, the eminence of the phylum Arthropoda among animals is very much a reflection of the supremacy of insects alone.

Most of the insects, or for that matter arthropods, are not harmful to humans and, in fact, many are highly beneficial organisms. Yet, many isolated groups of insects, in particular, concern humans because of their harmful nature of causing injuries through their poisonous bites and/or stings, disturbing tranquility of humans' living environment and, above all, playing a key role in the transmission of a large number of diseases which have for long been responsible for the massive human sufferings, both in the form of morbidity and mortality. These infections affect all strata of social groups and both sexes, yet perhaps it is health of children and women which is most severely affected, both physically and mentally. These diseases are particularly rampant in tropical and subtropical countries. Although the list of vector-borne diseases existing the world over is considerably long, but generally malaria, dengue, filariasis, leishmaniasis and Japanese encephalitis are the major public health hazards in India, where very recently a non-insect arthropod (copepod)-borne infection dracunculiasis or guineaworm disease, has

been declared eradicated and another insect (mosquito)-borne lymphatic filariasis disease is targeted for complete elimination in about 20 years from now, or sooner, although the flea-borne plague disease has deceived by having re-emerged after more than three decades in epidemic forms in a couple of States. As to the injurious and poisonous arthropods very little is indeed known on the medical importance of these creatures, particularly the insects, and more especially in the Indian context. After all, how many of us will appreciate knowing that while tabanid flies can potentially transmit anthrax, some species of edible crabs are vectors of trematode lung flukes, *Paragonimus*, to humans!

Venoms of various different kinds of arthropods offer an array of highly useful antidotes and novel pharmaceutical molecules. The notion that those insects or arthropods which inflict injuries and/or play an intermediate host's role by vectoring disease pathogens (viruses, bacteria, protozoans, helminthes etc.) of deadly or debilitating infectious and/or communicable diseases only are medically important is highly biased and unfounded. On the contrary, insects present a totally new world of information on astonishingly large variety of molecules that hold good promise in providing life saving drugs in near future. Insects' significance in medicocriminal investigations has now been far more greatly recognized than ever before as it often provides a foolproof evidence on various aspects of the nature of the crime committed. Unfortunately, the science of forensic entomology is very poorly developed in India when compared to some of the developed nations where a forensic entomologist plays an integral role all along the proceedings of the criminal investigation. Such insects deserve a special attention by biomedists, particularly medical entomologists and parasitologists due to inherent necessities of correct taxonomic identification, and bio-ecological, evolutionary and physiological characterizations of the necrophagous insects.

The insect life and the pathways involved in their transmitting various human diseases are amply dependent on the climatic and environmental support in their propagation. In fact, the whole interaction between man and insects/arthropods pivot around the climatic and environmental variabilities both locally and globally. As a model for interpretation of this well founded theory, the Great Indian Thar Desert in northwestern Rajasthan State, with all its uniqueness of "a fast changing ecosystem under the impact of extensively canalized irrigation" vis-à-vis its insect-faunal wealth and their intensified roles in exacerbating many a vector-borne infection in the changed physiography, lends a good model in redefining dynamics of connectivity of the vector-pathogen-human host 'triad' with the environment. It is noteworthy to remember here that malaria, particularly *Plasmodium falciparum*-dominated one, has only recently emerged in the Thar Desert, and cutaneous leishmaniasis, earlier limited to certain northern parts of the desert, has in course of time spread over other areas under canalized irrigation. Dengue has now certainly established in the Thar. Japanese

encephalitis disease has so far not been reported from the Thar *per se*, although presence of specific neutralizing antibodies has been detected from the region. A pandemic disease like plague, which has already created havoc during 1994 and more recently during early 2002 in the country, bears no documented epidemic history in the Thar Desert in past, but the recent high alert enforced by the State health department leaves but little space for any complacency especially in the light of presence of a far more conducive environment harbouring rodent and flea species known to be susceptible to *Yersinia pestis*, in some parts of the Thar Desert. Dracunculiasis is no more in India today; the last case having been detected in 1996 from the Thar Desert only!

The present book, written in a lucid and easy style, is a unique attempt directed for the use of both the professionals and amateurs alike particularly the University students of Medicine and Zoology. It is hoped that this book, rife with latest information on Indian faunal examples, will serve a good purpose to induce intensive and extensive research in the hitherto unexplored biomedical aspects of insect/arthropod life – for an everlasting benefit to the science of medical entomology.

However, as is well understood through the time-tested adage, all authors depend on those who came before. I am extremely grateful to my teacher and guide, Professor Dr. T.N. Ananthakrishnan, D.Sc., FNA, the doyen of Indian entomological sciences and, as more respectfully referred to amongst his innumerable scholars and disciples all over the country, "The Father of Modern Entomology", who was magnanimous enough to write the *Foreword* for this book. Professor Ananthakrishnan has known me and my work since my research scholar days at the Zoological Survey of India, Kolkata where he was the Director.

Dr. B.K. Tyagi

ACKNOWLEDGEMENT

In writing this book many of my colleagues both in India and abroad have rendered a great help through long discussions and/or correspondence, by providing scientific material, photographs and permission to use published or unpublished material. I am, therefore, grateful to all of them particularly to Dr. R. Bos (WHO, Geneva), Dr. Eline Boelee (SIMA, Sri Lanka), Dr. P. Amerasinghe (IWMI, Sri Lanka), Dr. Wim van der Hoek (IWMI, Sri Lanka), Dr. Vijay Veer (DRDE, Gwalior, India), Prof. Devendra Mohan (Zoology Dept. Jodhpur), Dr. Q.H. Baqri (ZSI, Jodhpur) and Dr. R.C. Sharma (ZSI, Jodhpur).

As ever in past, I am also thankful to my wife, Ajita, and two daughters, Anupama and Akansha, for their constant support and healthy criticism, without which it would not be possible to accomplish this task in time.

Last, but not the least, my grateful thanks are due to Shri Pawan Kumar Sharma, Scientific Publishers (India), Jodhpur for his excellent support and encouragement throughout this exercise of book writing and for timely bringing out this book.

Dr. B.K. Tyagi

CONTENTS

<i>Foreword</i>	<i>v</i>
<i>Preface</i>	<i>vii</i>
<i>Acknowledgement</i>	<i>xi</i>
CHAPTER 1 – INTRODUCTION	1-14
WHY ARE INSECTS AND OTHER ARTHROPODS IMPORTANT MEDICALLY?	2
1. Biological disease transmission	5
2. Mechanical or passive disease transmission	6
3. Accidental transmission	6
WHAT IS A VECTOR OR A PEST?	7
VECTOR-BORNE DISEASES AND SIGNIFICANCE OF ZOOONOSIS	8
VECTOR PATHOLOGY AND ITS SIGNIFICANCE IN DISEASE TRANSMISSION	8
ECONOMICS OF VECTOR-BORNE DISEASES	10
CHAPTER 2 – ENVIRONMENT AND VECTOR-BORNE DISEASES, WITH REFERENCE TO CLIMATIC VARIABILITY	15-30
VECTOR-ENVIRONMENT INTERACTION	16
DOES CLIMATE PLAY ANY SIGNIFICANT ROLE?	16
CLIMATIC SENSITIVITY AND VECTOR-BORNE DISEASES	21
Dengue fever	21
Malaria	22
Japanese encephalitis and other encephalitides	24
Plague	24
Tick-borne infections	24
VULNERABILITY OF THE THAR DESERT TO VECTOR-BORNE DISEASES: A CASE STUDY	24
Desert hysiology and the impact of three major canal systems in the Thar Desert	25
Rainfall, air temperature and relative humidity changes in the Thar Desert’s IGNP command area	28

CHANGES IN OCCURRENCE OF MEDICALLY IMPORTANT ARTHROPODS AND THE DISEASES THEY TRANSMIT	29
CHAPTER 3 - CLASSIFICATION AND IDENTIFICATION OF MEDICALLY IMPORTANT ARTHROPODS	31-43
INSECTS AND OTHER ARTHROPODS	31
ORGANIZATION SCHEME	32
IDENTIFICATION AND SYSTEMATICS	34
Class Insecta	34
Class Arachnida	40
Class Maxillopoda	42
Class Chilopoda	42
Class Diplopoda	43
CHAPTER 4 - MAJOR INSECT VECTORS AND PESTS OF PUBLIC HEALTH IMPORTANCE: ZOOGEOGRAPHY, BIOLOGY AND ECOLOGY	44-81
ARTHROPOD INFESTATIONS AND VECTORS OF DISEASE	46
1. Mosquitoes	47
(1) Anopheles mosquitoes	50
Biology and life cycle of anophelines	50
i. The egg	51
ii. The larva	51
iii. The pupa	51
iv. The adult	52
(2) Aedes mosquitoes	53
Biology and life cycle of <i>Aedes aegypti</i>	53
i. The egg	53
ii. The larva	54
iii. The pupa	54
iv. The adult	55
(3) Culex mosquitoes	55
(4) Mansonia and Coquillettidia mosquitoes	56
(5) Haemagogus mosquitoes	56
(6) Sabethes mosquitoes	57
(7) Psorophora mosquitoes	57
(8) Culiseta mosquitoes	57
Public health importance of mosquitoes	57
2. Sandflies	58
Biology and life cycle of sandflies	60
i. The egg	60
ii. Larvae and pupae	60
iii. The adult	60
3. The housefly	62

Biology and life history of <i>Musca domestica</i>	62
i. The egg	62
ii. The larva	63
iii. The pupa	63
iv. The adult	64
Public health importance of mosquitoes	64
4. The bed bug	65
Biology and life cycle of <i>bed bugs</i>	66
(i) The egg	66
(ii) The nymph	67
(iii) The adult	67
Public health importance of bed bugs	67
5. Lice	68
Biology and life cycle of lice	68
(i) The egg	69
(ii) The nymph	70
(iii) The adult	70
Public health importance of lice	71
6. Fleas	71
Biology and life cycle of fleas	72
(i) The egg	72
(ii) The larva	72
(iii) The pupa	73
(iv) The adult	73
Public health importance of fleas	73
7. Cockroaches	74
Biology and life cycle of cockroaches	77
(i) The egg	77
(ii) The nymph	77
(iii) The adult	77
Public health importance of cockroaches	77
8. Tabanids	77
Biology and life cycle of tabanids	79
Public health importance of tabanids	79
9. Stable flies	80
10. Ceratopogonids	80
CHAPTER 5 – OTHER INSECTS OF LESS ACKNOWLEDGED PUBLIC HEALTH IMPORTANCE	82-87
1. Ants	82
2. Bees	83
3. Beetles	85
4. Fruitflies	85

5. Moths and Butterflies	86
6. Thrips	86
7. Wasps and hornets	86
8. Spring-tails	87
9. Earwigs	87
10. Dragonflies	87
11. Termites	87
CHAPTER 6. NON-INSECT ARTHROPODS OF MEDICAL IMPORTANCE	88-106
1. Cyclops	89
2. Scorpions	90
Action and effects of toxin	91
Treatment	91
3. Whipscorpions and solpugids	92
4. Spiders	93
5. Millipedes	95
6. Centipedes	96
7. Tongue worms	96
8. Mites	97
i. Human itch or mange mites (Scabies mites)	97
ii. Follicle mites	98
iii. Chigger mites	99
9. Ticks	103
CHAPTER 7 - ENVENOMATION AND VECTORIZATION IN ARTHROPODS	107-117
VENOMOUS BITE <i>VERSUS</i> STING	107
VECTOR BITING	108
THE STINGING INSECTS	108
VENOM POISONING	109
HOST'S RESPONSE TO BITES AND ALLERGIC REACTIONS TO VENOMS	110
TREATMENT OF ARTHROPOD BITE AND STING	111
1. Millipedes	111
2. Centipedes	111
3. Fleas	112
4. Tabanids	112
5. Ceratopogonids	112
6. Sand flies	112
7. Tsetse flies	112
8. Ants	112
9. Honey bees, wasps and hornets	113
10. Blister beetles	114

11. Reduvid bugs	114
12. Caterpillars	115
13. Mites	115
14. Mosquitoes	116
15. Scorpions	116
16. Spiders	117
17. Moths and butterflies	117
CHAPTER 8 - PEST/VECTOR CONTROL AND MANAGEMENT	118-128
CONTROL PROSPECTS OF PESTS AND VECTORS	118
Use of repellents	120
Insecticide control of vectors	120
1. Mosquitoes	120
2. Bed bugs	123
3. Lice	124
4. Fleas	125
5. Tsetse flies	125
6. Blackflies	126
7. Triatomine bugs	126
8. Sandflies	127
9. Biting midges	127
10. Tabanid flies	127
11. Flies	127
12. Cockroaches	128
13. Mites	129
14. Ticks	129
CHAPTER 9 - MAJOR VECTOR-BORNE DISEASES PREVALENT IN INDIA	130-174
MALARIA	130
Distribution	131
Biology of malarial disease	132
Causative agent	132
Mosquito vectors	132
Transmission	132
i. The human cycle	133
ii. The mosquito cycle	134
Symptoms	135
<i>Malaria scenario in India</i>	137
Control of malaria in India	138
i. National Malaria Control Programme	138
ii. National Malaria Eradication Programme	138
iii. Modified Plan of Operation	139

iv.	Plasmodium falciparum Containment Programme	140
v.	Malaria Action Programme based on Expert Committee Report	140
vi.	Enhanced Malaria Control Project	140
vii.	Roll Back Malaria	140
	Malaria scenario in the thar desert	141
	Anopheline fauna of the Thar desert	144
	Species complexes in vectors of the Thar Desert	145
	Emergence of <i>Plasmodium falciparum</i> -dominated malaria in the Thar Desert	146
	Malaria epidemics and their pathways in the Thar Desert	147
1.	Malaria epidemics of 1975-77	148
2.	Malaria epidemics of 1983-84	148
3.	Malaria epidemic of 1990	148
4.	Malaria epidemics of 1992-93	149
5.	Malaria epidemics of 1994	149
6.	Malaria epidemics of 1995-96	150
7.	Malaria epidemics of 1999	150
8.	Malaria epidemics of 2000-2001	150
	Possible factors responsible for conflagration of malaria, particularly <i>P. falciparum</i> -dominated malaria, in the Thar desert	151
	DENGUE	154
	Distribution	154
	Biology of dengue virus	155
	Dengue vectors	155
	Pathogen	156
	Transmission	156
	Symptoms	156
	Prevention and Control	157
	JAPANESE ENCEPHALITIS	157
	Distribution	158
	Epidemiological considerations	158
	Pathogenic agent	158
	Human host	159
	Vertebrate animal host	159
	Environment	159
	Transmission	159
	Symptoms and diagnosis	160
	Prevention and Control	160
	FILARIASIS	161

Distribution	161
Biology of lymphatic filariasis worm	161
Vectors	161
Causative agent	162
Transmission	162
Symptoms	165
Prevention and Control	165
LEISHMANIASIS	166
Distribution	166
Biology of parasite	168
Morphology of the parasite	168
Vector species	168
Life cycle	168
<i>Cutaneous leishmaniasis in the thar desert</i>	169
Gender bias	170
Distribution of lesions	170
Sandfly fauna and vectors of cutaneous leishmaniasis	171
Zoonotic reservoirs of cutaneous leishmaniasis in the Thar Desert	171
Control of vectors in the Thar desert	171
Impact of IGNP initiative on the disease epidemiology	172
CHAPTER 10 – LESS PREVALENT VECTOR-BORNE DISEASES	175-182
KYASANUR FOREST DISEASE	175
Distribution	176
Epidemiological considerations	176
Transmission dynamics	176
Prevention and control	177
WEST NILE VIRUS DISEASE	177
Distribution	178
Transmission cycle	178
Symptoms	179
Prevention from the West Nile Fever	179
LOUSE-BORNE TYPHUS	179
LOUSE-BORNE RELAPSING TYPHUS	180
TRENCH FEVER	180
TULARAEMIA	180
TUNGIASIS	181
DERMATITIS	181
FLEA-BORNE TYPHUS	181
CHAPTER 11 - VECTOR-BORNE DISEASES RECENTLY ERADICATED FROM INDIA	183-192
DRACUNCULIASIS	183

Life cycle of the parasite	184
The parasite	184
The intermediate host	184
Causation of infection	184
Signs and symptoms of the disease	186
Epidemiology of the disease	186
Sites of extrusion of the worm and after-effects of the disease	187
Dracunculiasis scenario since 1984	188
Major epidemics of dracunculiasis in recent times	190
Prevalence of guineaworm disease in Rajasthan (1984-1999)	190
Diagnosis of early dracunculiasis	191
Immunity to dracunculiasis infection	191
Prevention and control measures	192
CHAPTER 12 - VECTOR-BORNE DISEASES THREATENING TO RE-EMERGE IN INDIA	193-196
PLAGUE	193
Geographical distribution	194
Epidemiological considerations	194
Clinical features	194
i. Bubonic plague	195
ii. Septicemic plague	195
iii. Pneumonic plague	195
Diagnosis	195
Prevention and control	196
Treatment of plague	196
Control of rats and fleas	196
CHAPTER 13 - VECTOR-BORNE DISEASES PREVALENT OUTSIDE INDIA	197-216
YELLOW FEVER	197
Distribution	197
Transmission cycle of yellow fever	198
Disease agent	198
Disease vectors	198
Mode of transmission	198
Prevention and control of yellow fever	199
ONCHOCERCIASIS	199
Distribution	199
Transmission of river blindness disease	200
Vector species	200
Parasite and transmission cycle	200
Control of river blindness disease	200

AFRICAN SLEEPING SICKNESS	201
i. East African sleeping sickness	201
ii. West African sleeping sickness	201
Biology of disease	202
Parasite	202
Vector	203
Transmission cycle	204
Symptoms	205
Treatment	205
AMERICAN TRYPANOSOMIASIS (CHAGAS' DISEASE)	206
Distribution	206
Biology of disease	207
Causative agent	207
Vectors	208
Transmission	209
i. Vectorial transmission	209
ii. Infection acquired through blood transfusion	211
iii. Congenital transmission	211
Symptoms	211
Prevention and control	211
LOA LOA DISEASE	212
Biology of loiasis	212
Parasite	212
Vector	212
Transmission	212
Symptoms	213
Treatment	213
ENCEPHALITIDES	213
Rift Valley fever	214
St. Louis Encephalitis	214
Australian encephalitis	215
California encephalitis	215
Colorado tick fever	215
Eastern equine encephalitis	215
Western equine encephalitis	216
CHAPTER 14. HAEMATOPHAGUS INSECTS AND THE HIV/AIDS TRANSMISSION: ANY CONNECTION ?	217-221
MOSQUITO FACTOR IN DISEASE TRANSMISSION: THEORY AND PRACTICE	218
VECTOR DIGESTED PATHOGENS CAN NOT CAUSE INFECTION	219

MOSQUITOES DO NOT INGEST ENOUGH HIV PARTICLES TO TRANSMIT AIDS BY CONTAMINATION	219
MOSQUITOES' MOUTHPARTS <i>VERSUS</i> HYPODERMIC NEEDLES	220
CAN OTHER INSECTS TRANSMIT HIV/AIDS?	220
FINAL VERDICT	221
CHAPTER 15 - INSECTS IN MEDICO-LEGAL INVESTIGATIONS	222-227
FORENSIC ENTOMOLOGY: ORIGIN AND APPLICATIONS	222
1. Urban entomology	223
2. Stored products entomology	223
3. Medico-legal entomology	223
INSECTS IN FORENSIC SCIENCE: EVOLUTIONARY REQUIREMENTS	223
FORENSICALLY IMPORTANT INSECTS	224
i. Blow flies	224
ii. Beetles	224
SCOPE OF FORENSIC ENTOMOLOGY IN INDIA	225
PROFESSIONAL RECOGNITION TO FORENSIC ENTOMOLOGY	226
CHAPTER 16. MIMICRY IN MEDICALLY IMPORTANT ARTHROPOD GROUPS	228-237
DEFINITION AND TYPES OF MIMICRY	228
THE INEVITABILITY OF MIMICRY	229
AGGRESSIVE MIMICRY	231
ARTHROPODS WHICH "MIMIC" AND/OR "MODEL"	231
MIMICRY BETWEEN TWO DIFFERENT ARTHROPOD CLASSES	235
CONVERGENT MIMICRY	237
CHAPTER 17. MEDICINAL INSECTS	238-244
INSECTS AS PROTEIN FACTORIES	239
INSECTS AS SOURCE OF ANTIMICROBIALS	240
SOURCE AND CHEMISTRY OF VENOMS	240
INSECT LUMINESCENCE AND FLUORESCENCE AS SOURCES OF NEW MOLECULES IN MEDICINE	241
BIOMATERIALS	241
INSECTS IN ETHNOMEDICINE	242
INSECT PROSPECTING AND FARMING	243
REFERENCES	245-253
GLOSSARY, ABBREVIATIONS AND ACRONYMS	254-257
INDEX	258-262

EXPLANATION TO COLOUR PLATES

Plate I

- (a) A *Culex* mosquito in blood feeding process. Some of the species are well-known vectors for human lymphatic filariasis, Japanese encephalitis and other arbovirus infections.
- (b) Rice field, a favourite breeding site for *Culex tritaeniorhynchus*, the vector for JE infection.
- (c) An *Aedes* mosquito in blood feeding process. Two species, *Ae. aegypti* and *Ae. albopictus*, are serious vectors of dengue infection.
- (d) Vehicle tyres, a favourite site for *Ae. aegypti* breeding.
- (e) Latex collecting cups in rubber plantations, a favourite site for *Ae. albopictus* breeding.
- (f) Latex collecting cup, showing immatures of *Ae. albopictus*.
- (g) An *Anopheles* mosquito in blood feeding process. Several species are vectors of malaria.
- (h) Malaria parasite (*Plasmodium falciparum*) in different stages, as seen in a thick blood smear.

Plate II

- (a) 'Beri' agglomeration in the concavity of a village pond in the Thar Desert. It's a good site for malaria vector *Anopheles stephensi* resting and breeding.
- (b) Mouth of a 'beri'.
- (c) A 'tanka' in the Thar Desert is a prominent resting and breeding place for *An. stephensi*.
- (d) 'Tanka' agglomeration in the outskirts of a Thar Desert village.

Plate III

- (a) A crab.
- (b) A solpugid. Its found abundantly in the Thar Desert, preying on insects but occasionally small rodents as well.

Plate IV

- (a) A dragonfly is an important biological control agent of mosquitoes and is occasionally an intermediate host for some helminth parasites. In India their enormous biological control potential is yet to be explored in field.
- (b) A cicada (note woody colouration as a defensive mechanism)

Plate V

- (a) A lepidopterous caterpillar. Note numerous hair-like process which on touch result in urticaria (lepidopterism).
- (b) An ant. It is a wonderful insect of great biomedical importance.

Plate VI

- (a) A millipede.
- (b) A scorpion.

Plate VII

- (a) A caterpillar with a characteristic snake like triangular head; a defensive mimicry to ward off the predators.
- (b) A bedbug.
- (c) A spider, showing silky web and a rare metallic sheen on some parts of its body.
- (d) A brightly coloured spider.
- (e) A caterpillar, which following disturbance ejects out its two brightly coloured antennae, as an offensive tool to frighten away the predators.
- (f) A preying mantid, a classical example of mimicry.
- (g) A fly, showing biochrome based metallic shine on abdomen.

Plate VIII

- (a), (b) A girl aged 19 years developed an allergy mainly on forehead and on side face following cleaning of a long shut house harbouring innumerable spiders with webs, ants, silverfishes and other arthropods (such as dust mites etc.)
- (c) A millipede.
- (d) A caterpillar.
- (e) A mollusc, a great example of novel adhesives.
- (f) The red ant, *Oecophylla smaragdina*, in agglomeration and in offensive position on disturbance.

Plate - I



SAMPLED

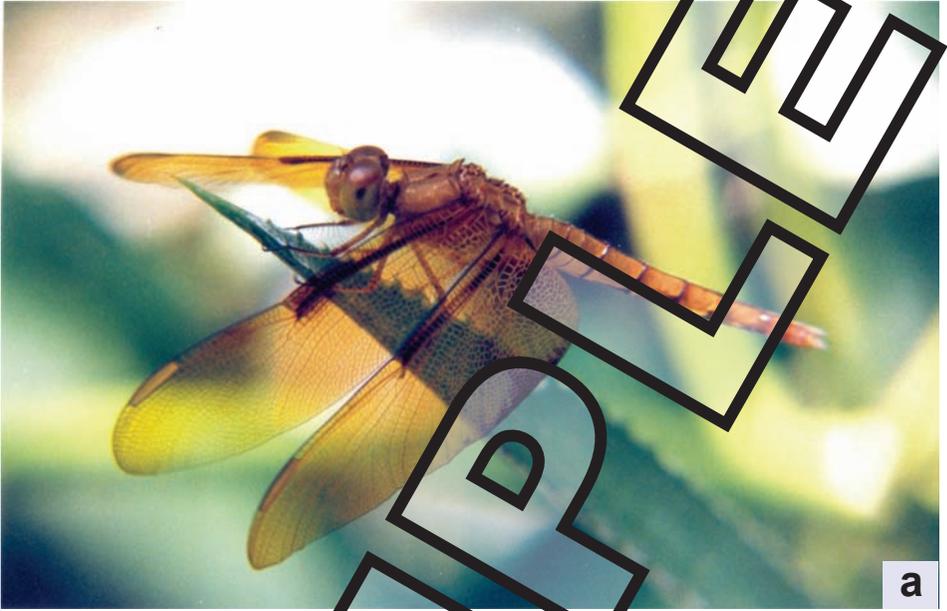
Plate - II



Plate - III



Plate - IV



SAMPLE