Entomology for Non-Entomologists

Balkan & Black Sea Regional Meeting

May 8th-12th, 2023

Montenegro

MediLabSecure

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Main of the training

To be able to discuss with entomologist as an equal

- Understand basic aspects of insect biology
- Understand what is the Medical Entomology
- Integrate fundamental notions of vector transmission
- Understand the process of species identification
- Consider arthropod-borne diseases from an entomological perspective

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Arthropodology

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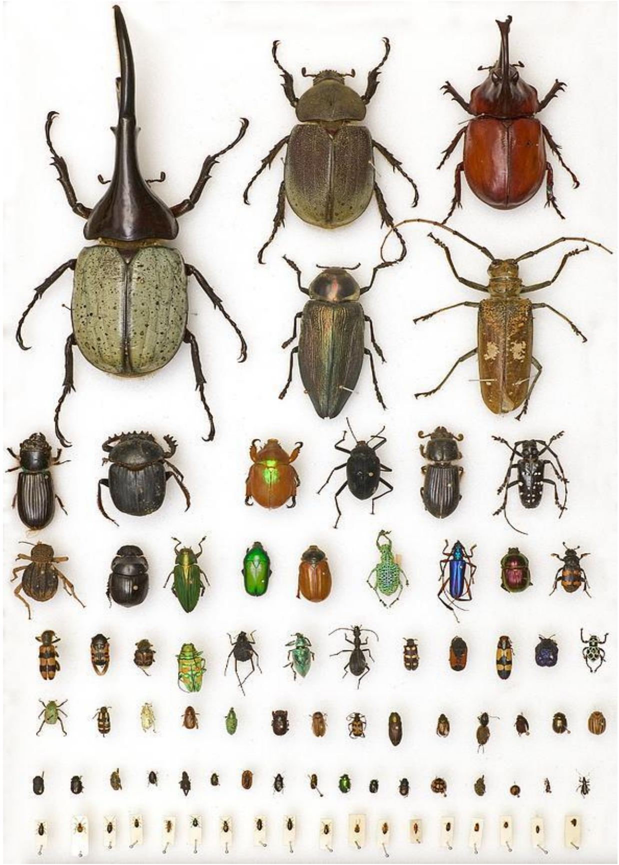
Definitions



https://fineartamerica.com

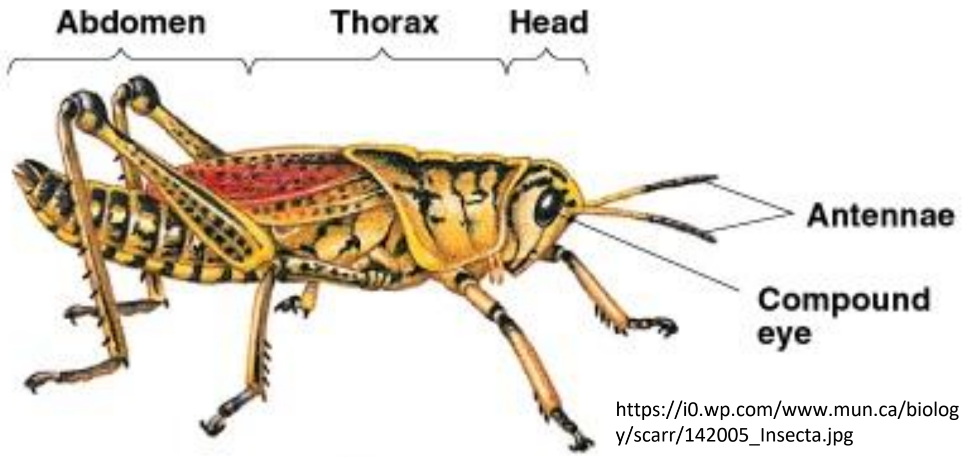
- **Arthropodology:** a zoological science that studies Arthropods
- **Entomology**: a zoological science that studies Insects

https://www.cabinetmagazine.org/issues/25/wasps_drumscan.jpg

Main characteristics of Arthropods

- **Exoskeleton**: cuticle, development by moults
- **Articulated body**: 3 segments (tagma) with appendices (antenna, legs)
- **Internal organisation with a similar pattern**

- *dorsal blood vessel*
- *digestive tube in 3 parts*
- *muscles*
- *double ventral nerve cord + peri-oesophageal collar*
- *excretory organ (Malpighi tubes)*
- *reproductive system (sexes are separated)*
- *tracheal tubes for respiration (no lungs)*



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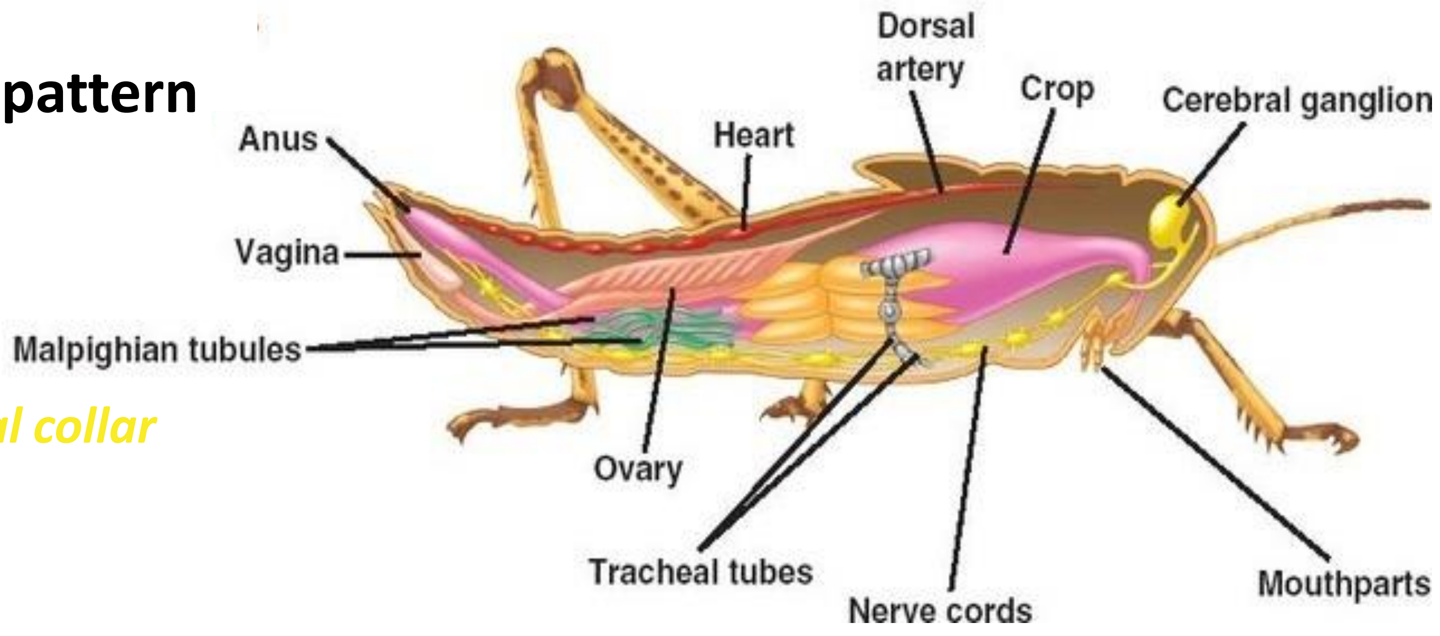


https://i.pinimg.com/736x/fc/5e/b6/fc5eb6d643b218fce8c6025f8ebf62d9.jpg

Phylum Arthropoda – 5 main sub-phylla

https://i.pinimg.com/originals/05/86/be/0586be11ca7b0f42bd258b53f0342573.jpg

Simplified classification

Arthropoda
- Insecta *(6 legs)*
- Chelicerata *(8 legs)*
- Crustacea *(10 legs)*
- Myriapoda *(many legs)*
- Artiopoda *(fossils - 20 legs)*

Count the legs















Quiz – How many legs?

Quiz – How many legs?

10 legs

8 legs

6 legs

> 10 legs

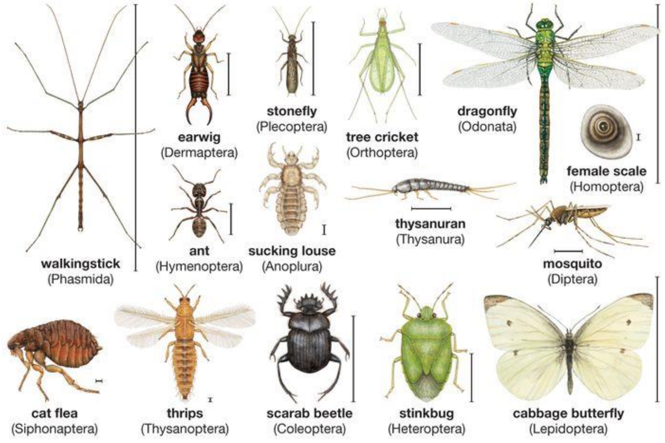
6 legs

> 10 legs

10 legs

8 legs

Insecta



https://cdn.britannica.com/s:700x500/45/102445-050-E3375B6D/Insect-diversity.jpg

Simplified classification

Arthropoda

- Insecta *(6 legs)*
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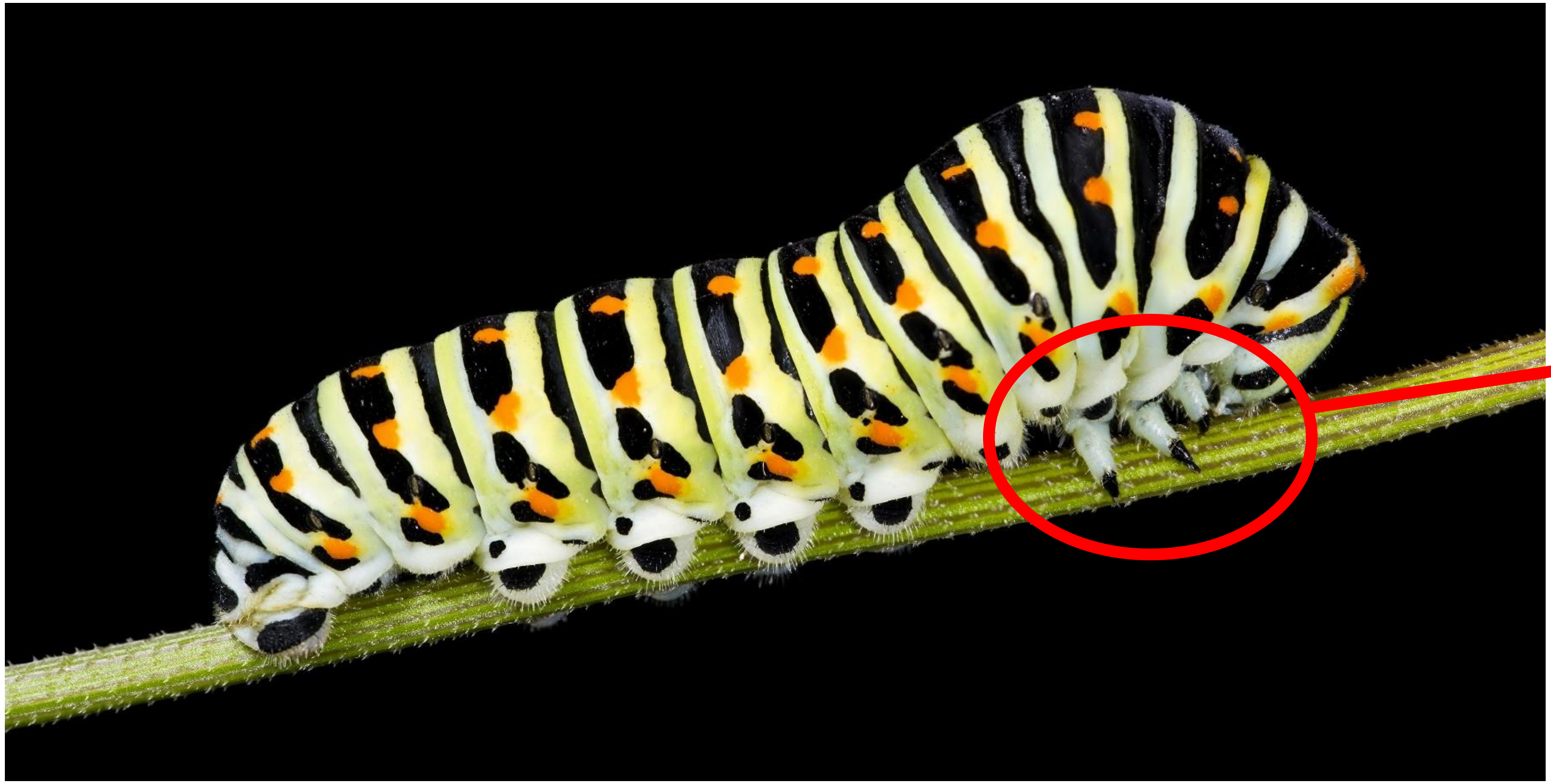
Quiz – How many legs?

Three are not insects

Quiz – How many legs?

Quiz – How many legs?



3 pairs of legs

Quiz – How many legs?

Example:
Papillo machaon or Old World swallowtail

Metamorphosis

Quiz – How many legs?

Three are not insects

Caterpillar =>

Insecta

Birds, insects and bats are the only flying organisms

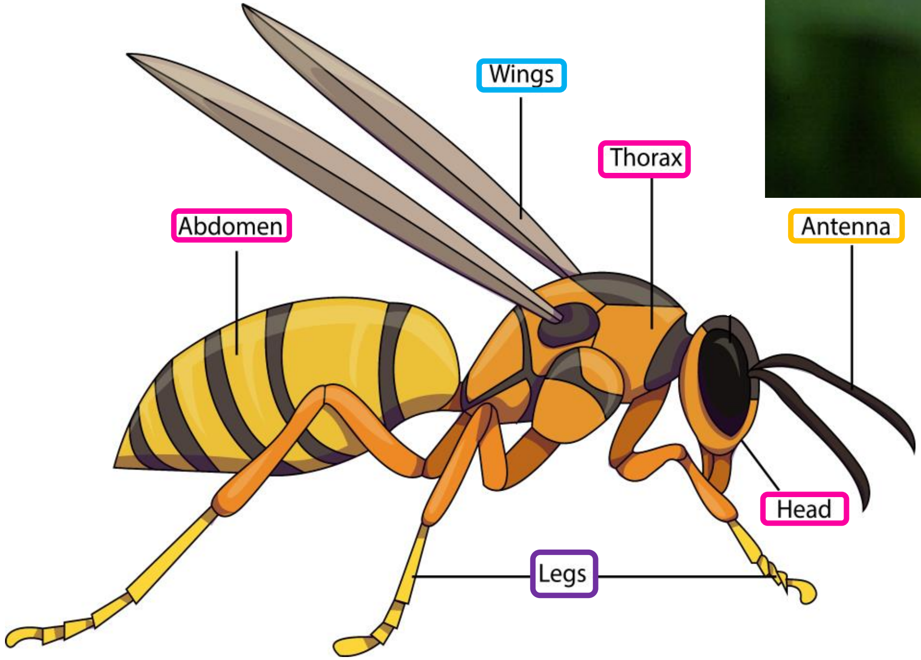
BUT an Arthropod **with** wing is an **insect**
(without exception)

Insecta

Birds, insects and bats are the only flying organisms

Insecta

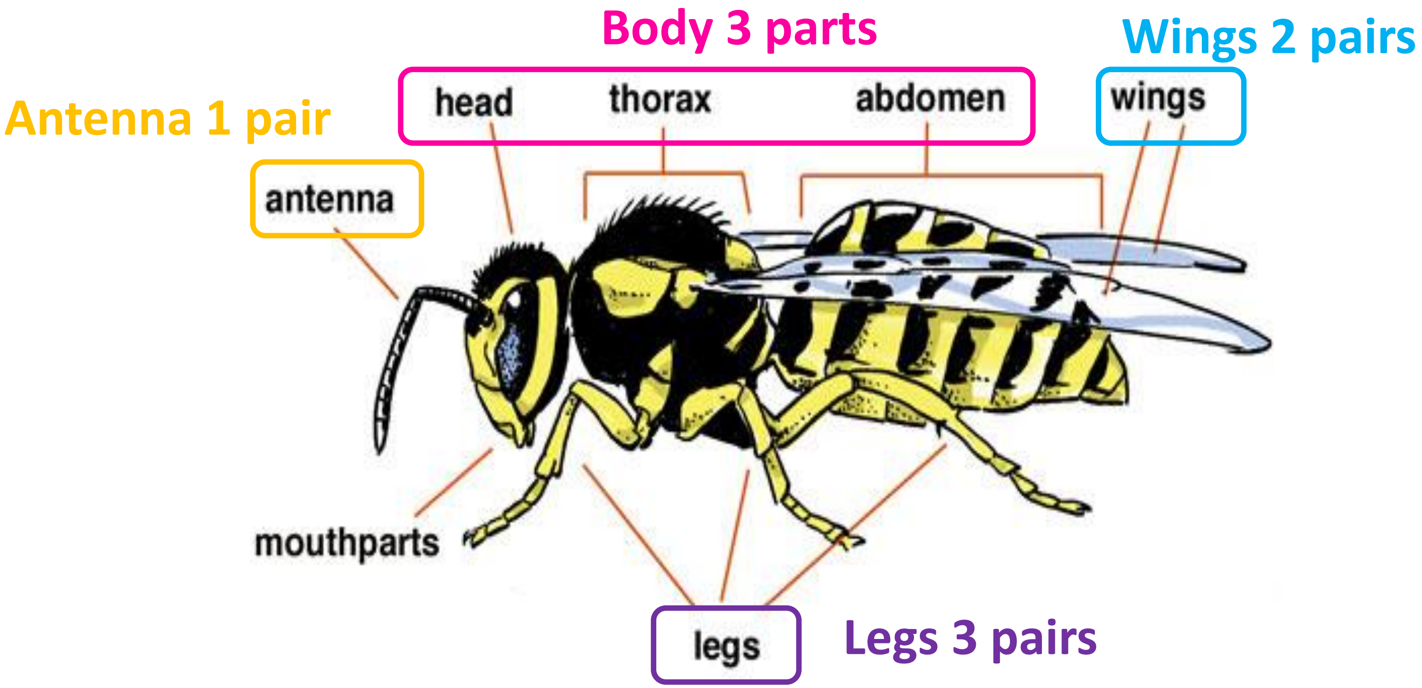
- Body in 3 parts: head, thorax, abdomen
- 1 pair of antenna
- 2 pairs of wings
- 3 pairs of legs



BUT an Arthropod **with** wing is an **insect**
(without exception)

1,300,000 described species

Summary : Insect – morphological criteria









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Insect development

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Sub Class Insecta

Insecta

- Apterygota
  *Adult – **no wing***

- Pterygota
  *Adult – **with wings***
  - *Hemimetabolous*

  - *Holometabolous*

Example of hemimetabolous

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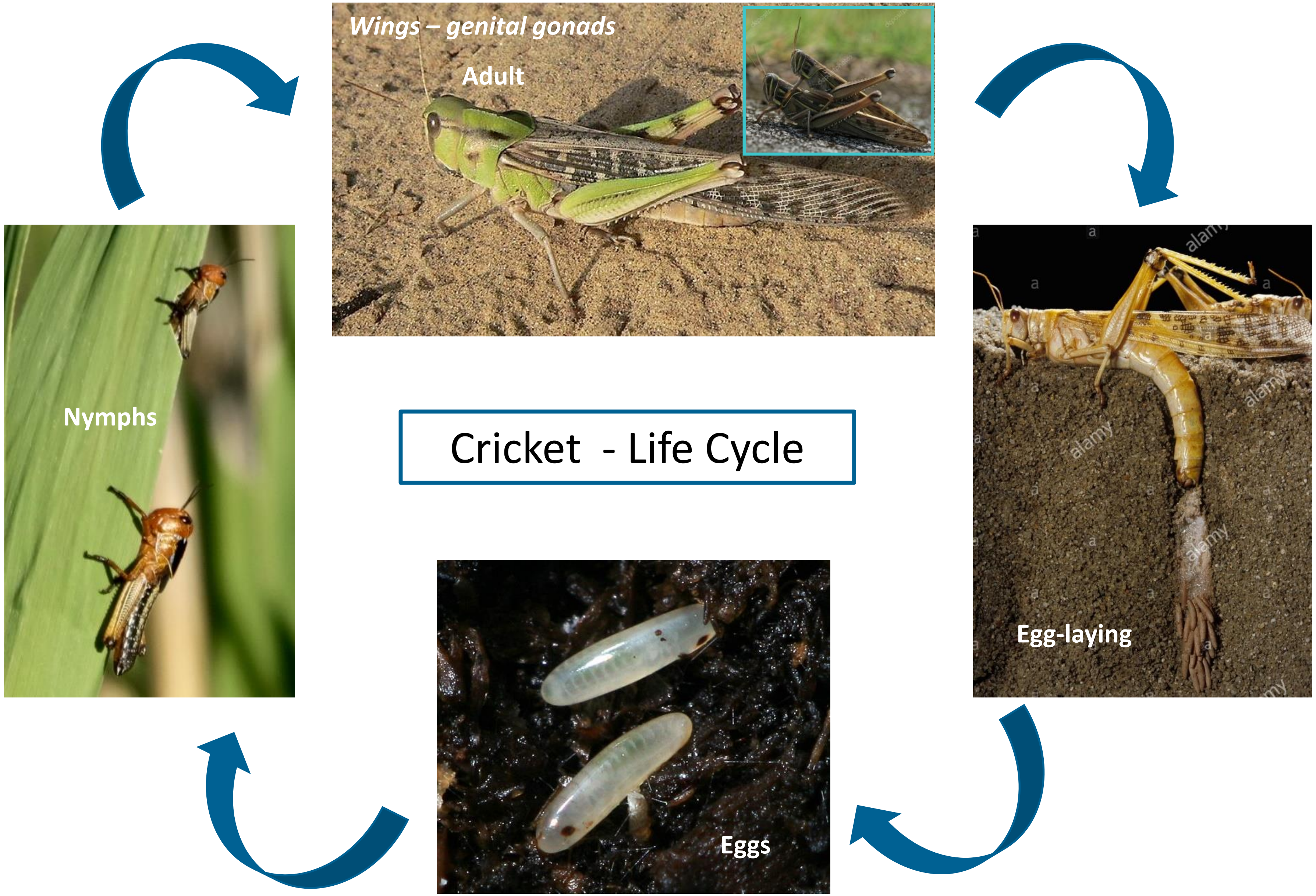
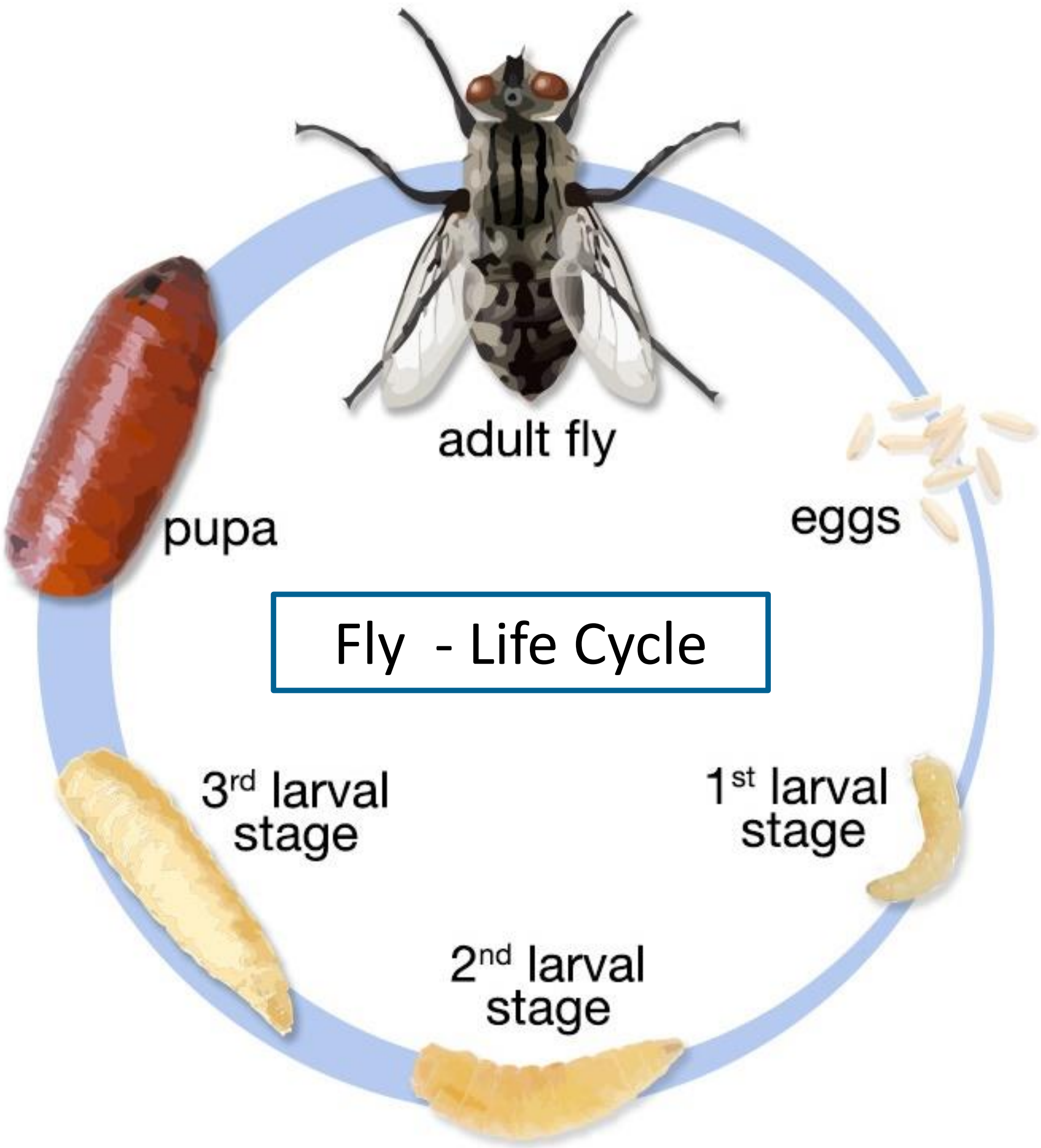


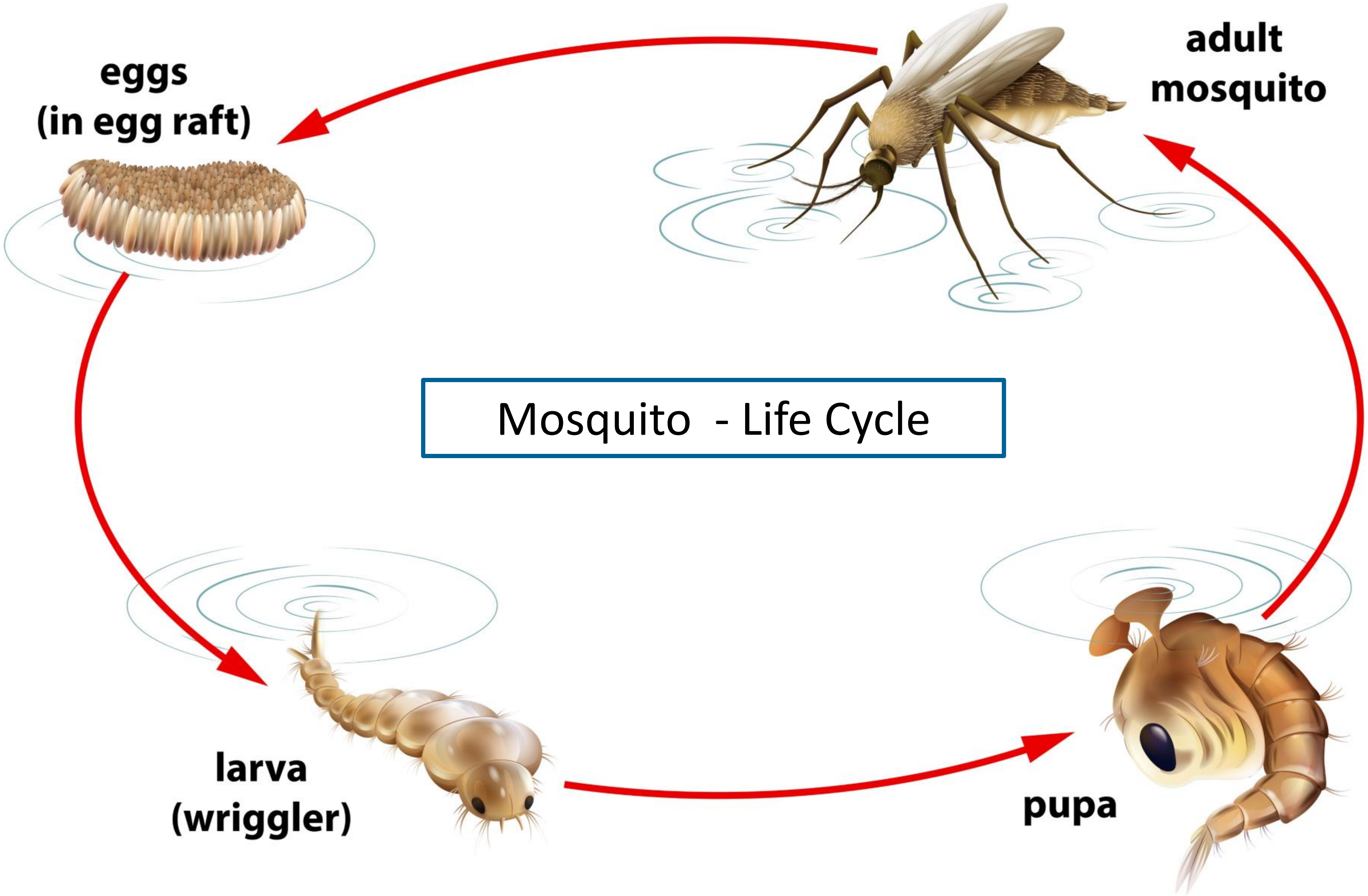
Example of holometabolous



https://cdn.domyown.com/images/content/fly_life_cycle.jpg

Butterfly - Life Cycle

Example of holometabolous



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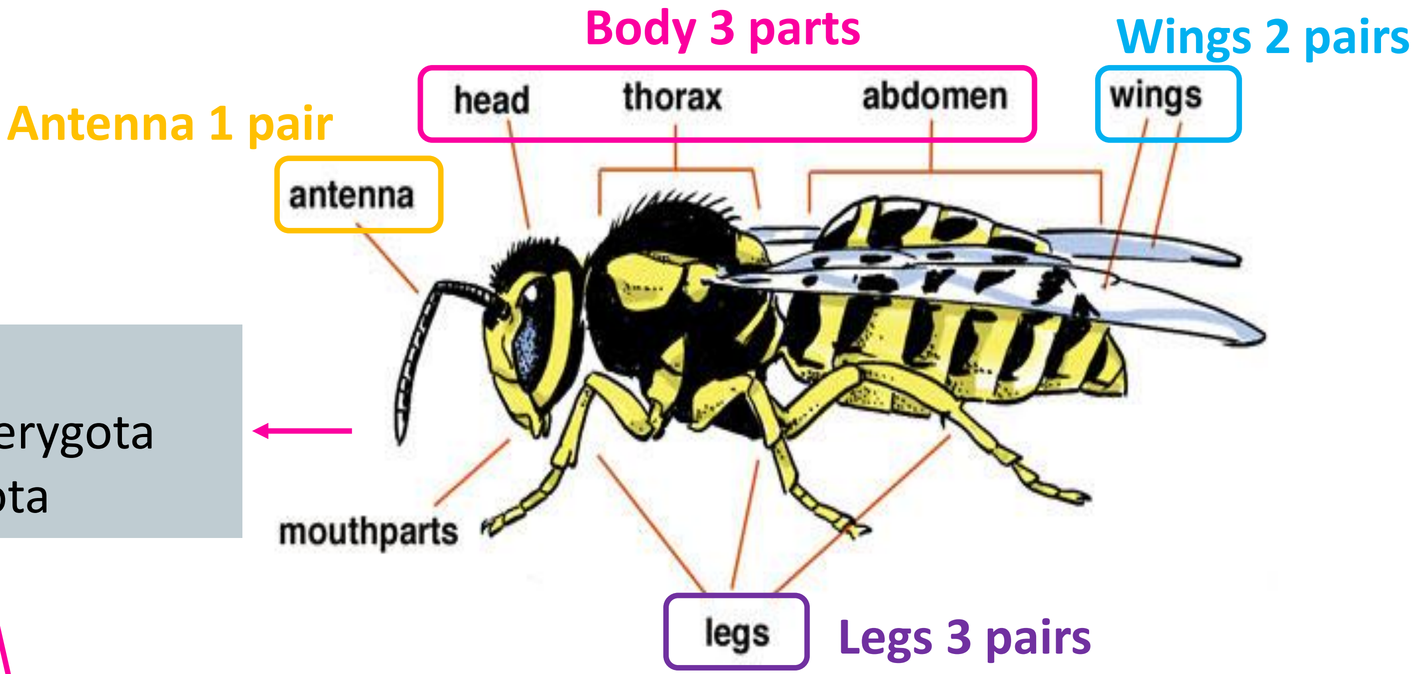

<u>Adult</u>

- Without wing: Apterygota
- With wing: Pterygota

<u>Development</u>

- Eggs – nymphs: Hemimetabolous
- Eggs – larvae – pupa: Holometabolous







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Sexual dimorphism

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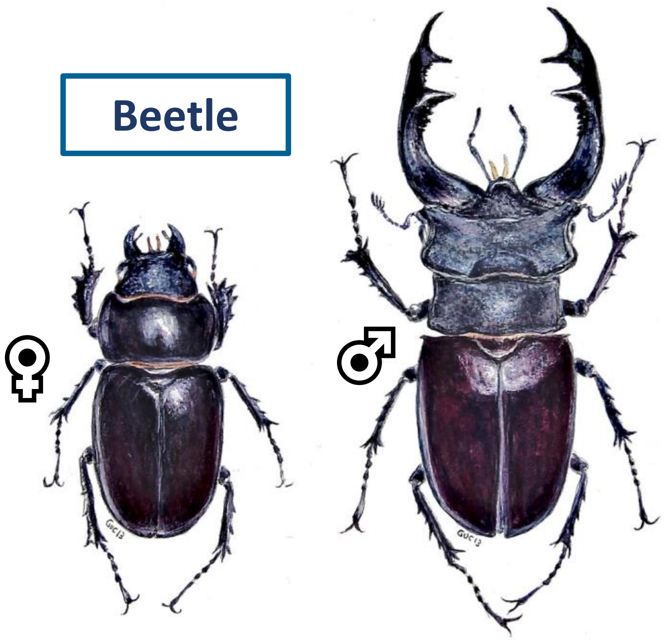
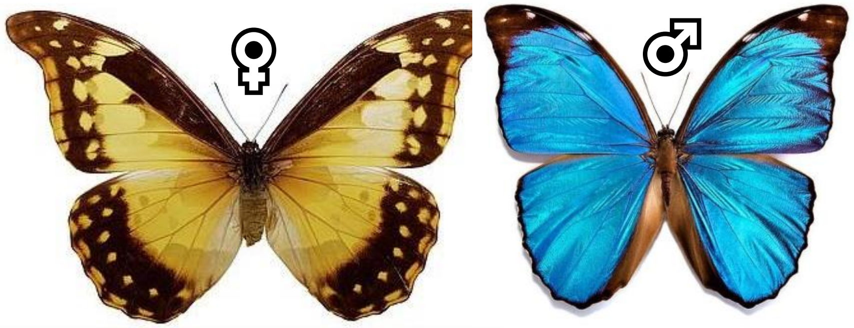
Sexual Dimorphism

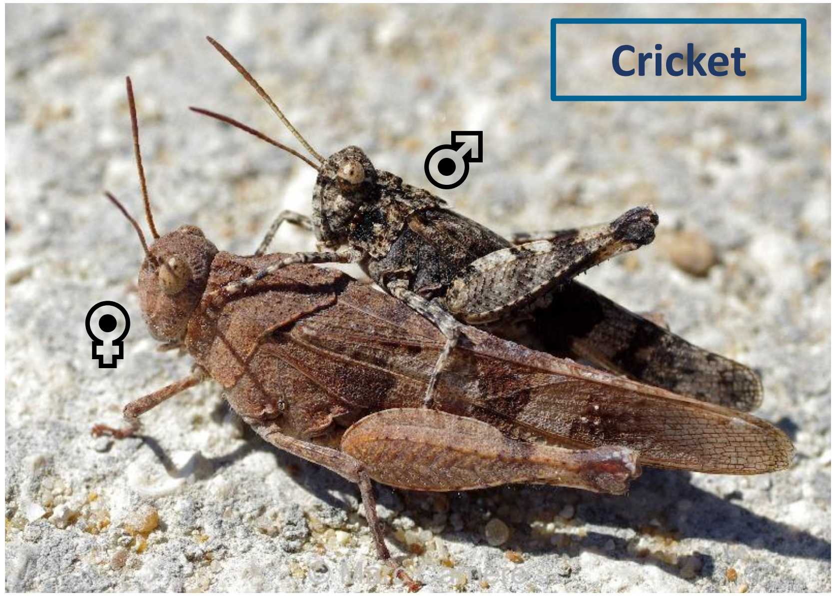
All **adult** insects are **male** or **female**

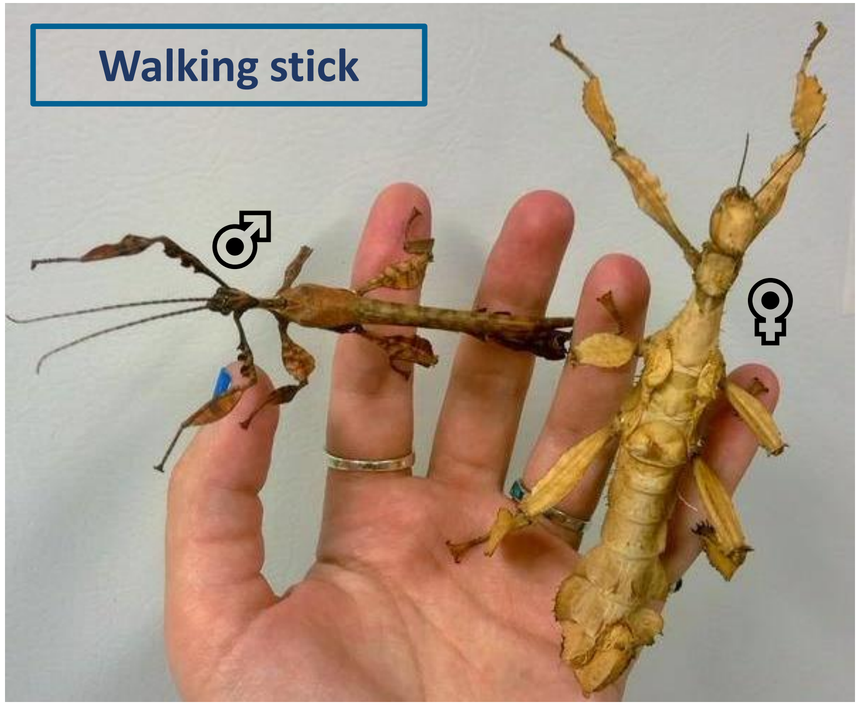
Beetle





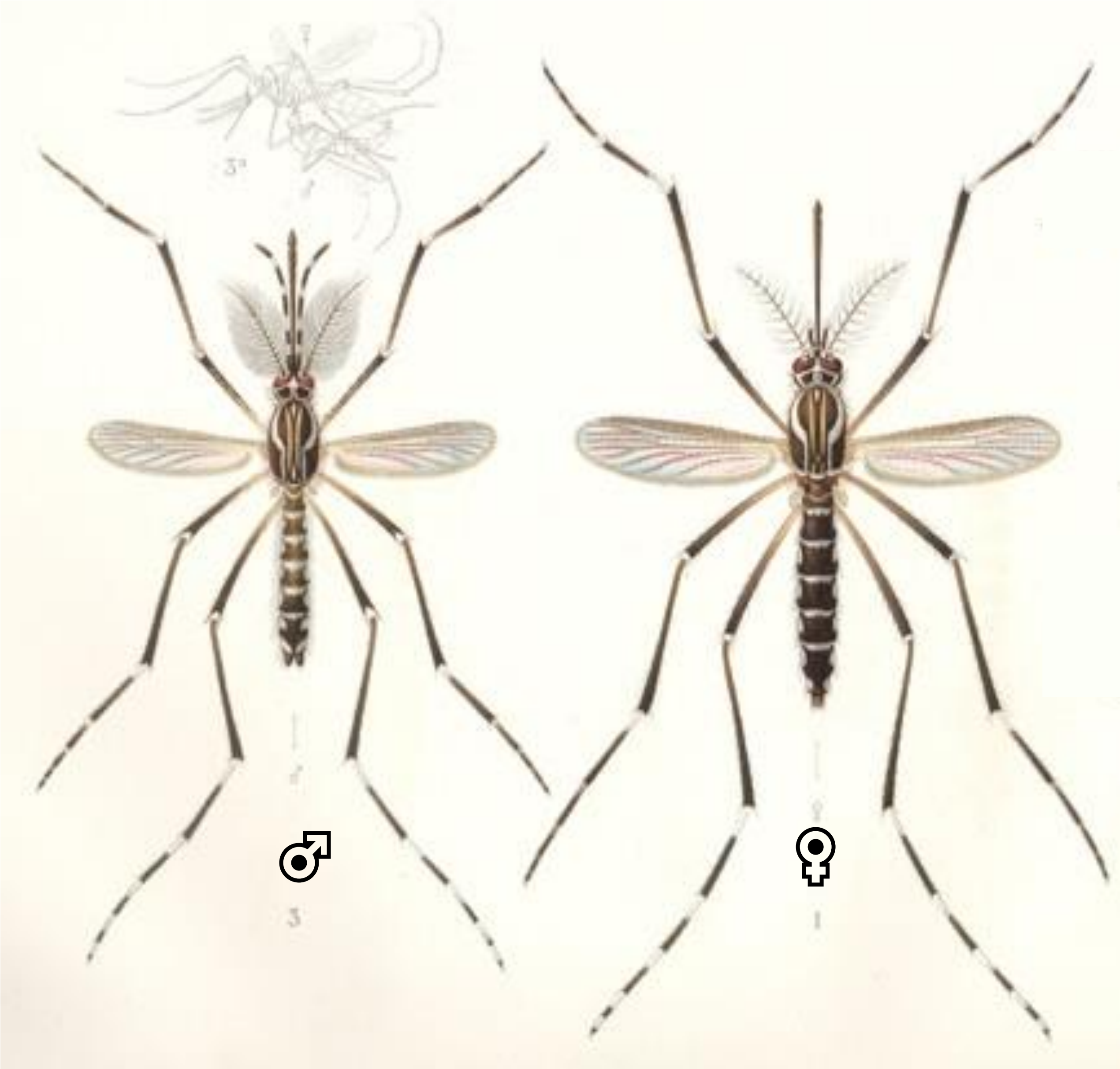
Blue morpho Butterfly





Sexual Dimorphism, Aedes aegypti

Five main differences



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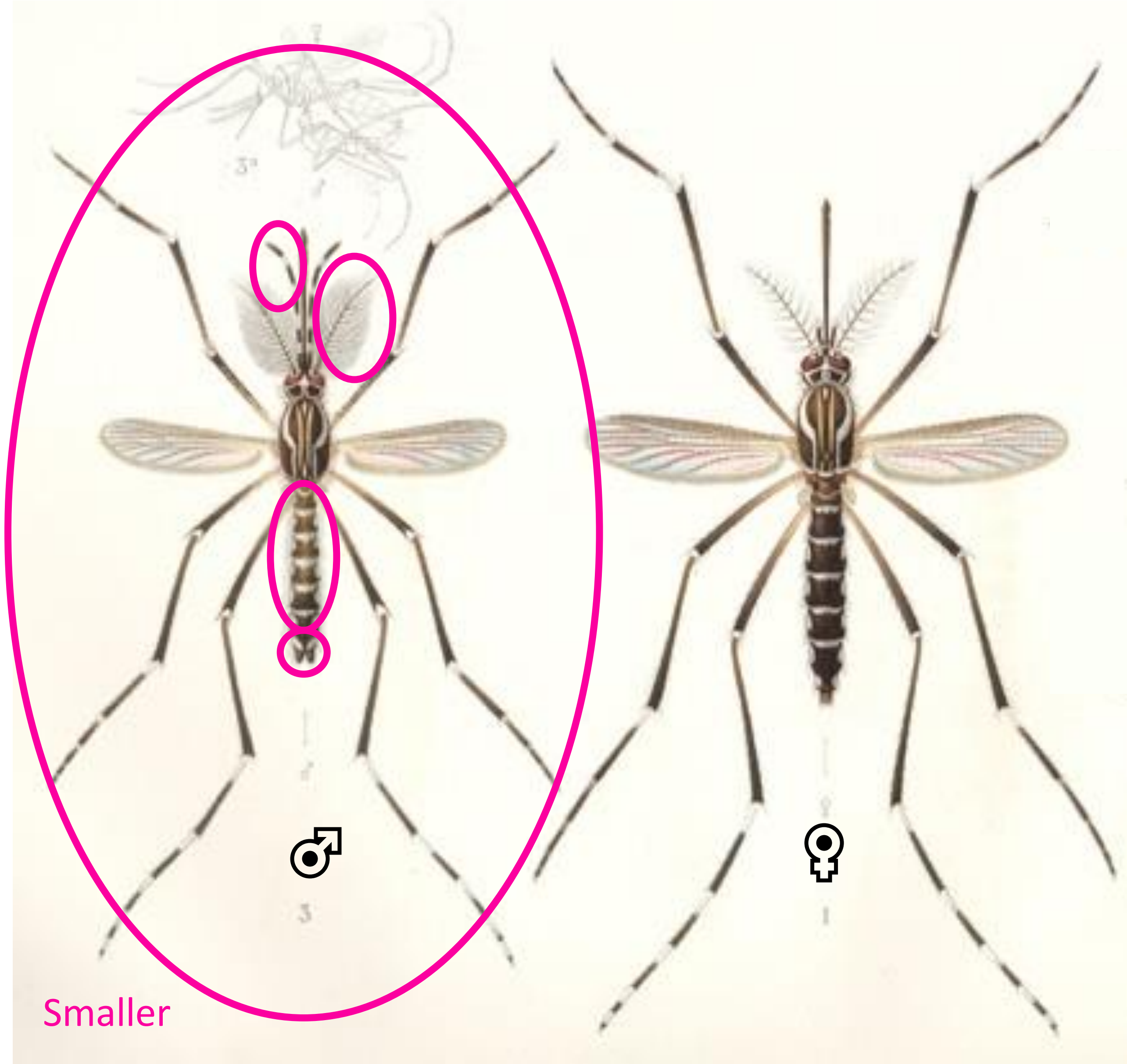
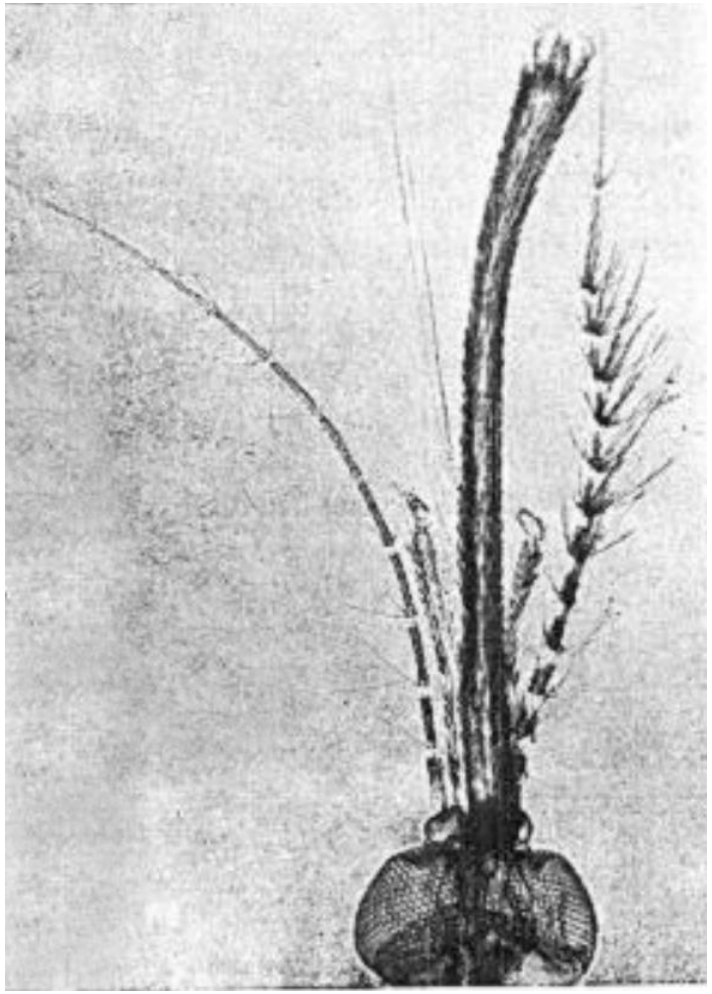


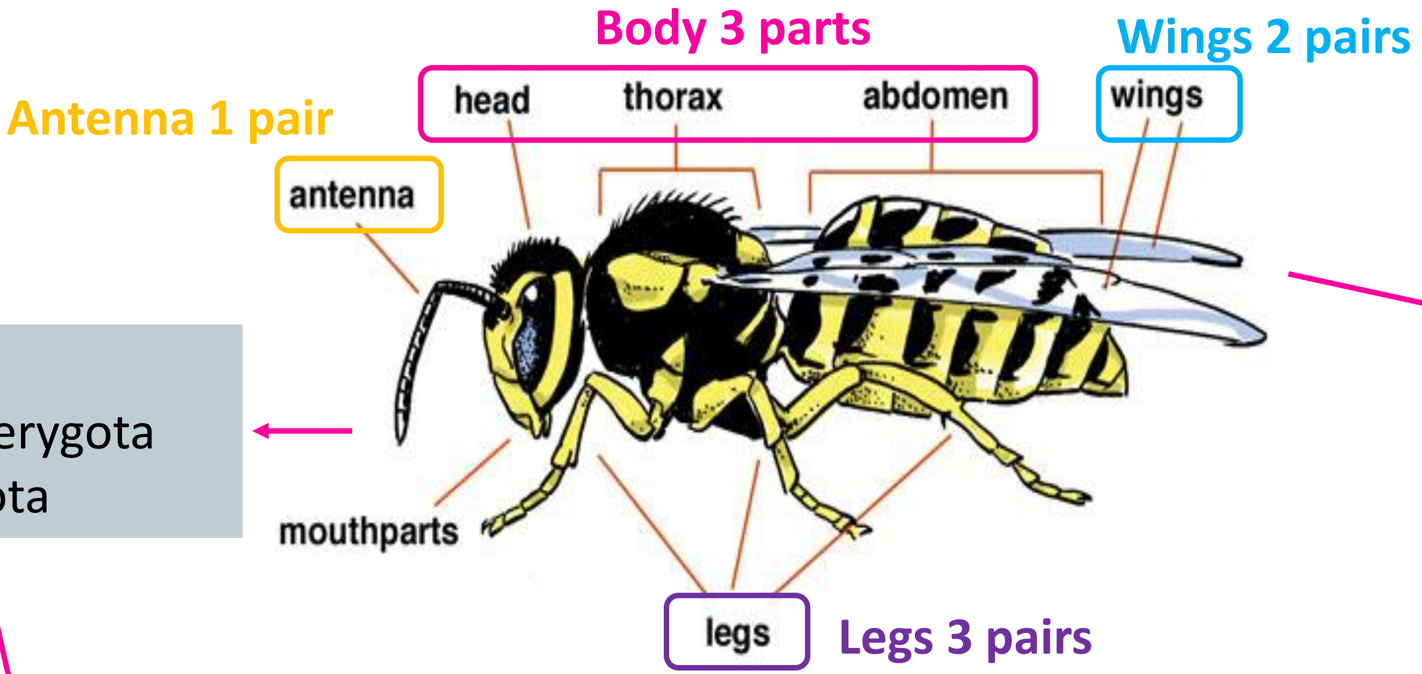
Sexual Dimorphism, exception: Gynandry

Organism which have both male and female characteristics



Very rare: <1/100,000 => *result from genetic determinism of sex*

Summary : Insect – morphological criteria



Sexual dimorphism

<u>Adult</u>
- Without wing: Apterygota
- With wing: Pterygota

<u>Development</u>
- Hemimetabolous: egg-juvenile stage-adult
- Holometabolous: egg-larvae-pupa-adult

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Senses

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Sense organs

Organ of smell

Organ of hearing

Organ of vision

Sense organs

Organ of smell

Antennas

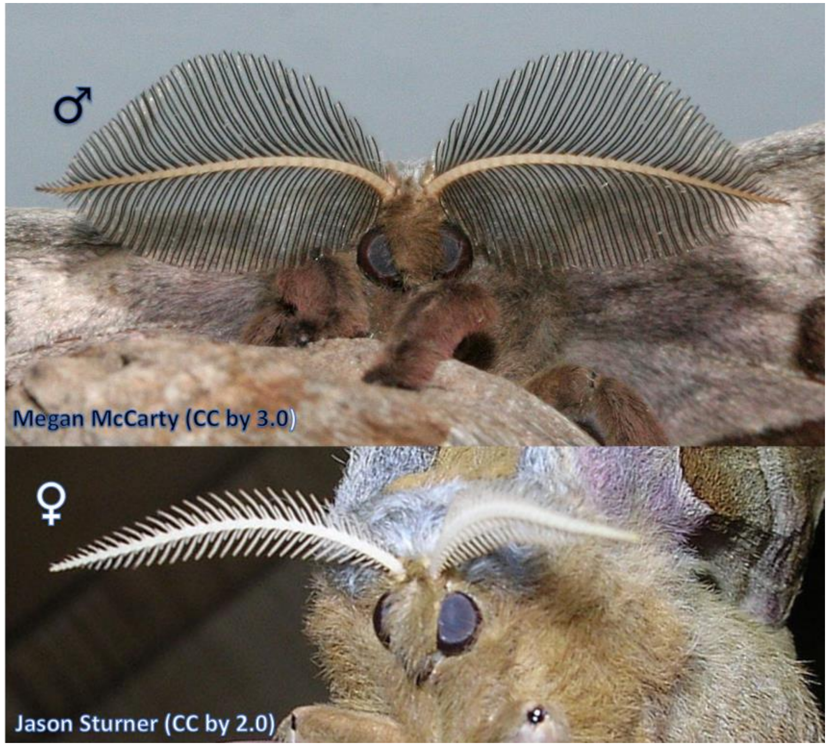
Organ of hearing

Organ of vision

Sense organs

Organ of smell

Antennas



Polyphemus Moth

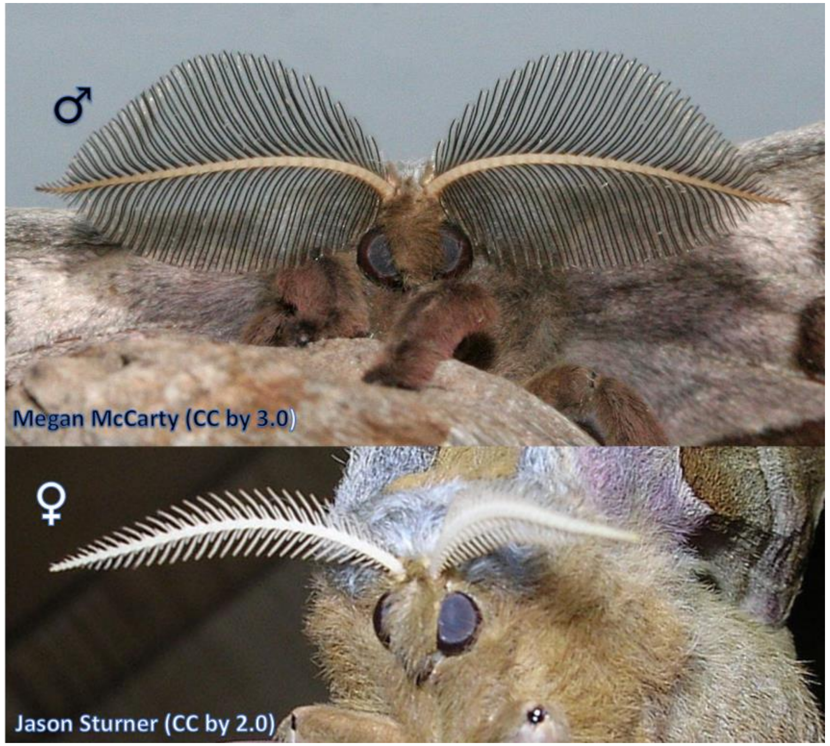
Organ of hearing

Organ of vision

Sense organs

Organ of smells

Antennas



Organ of hearing

Tympana

Organ of vision

Sense organs

Organ of smells

Antennas

Organ of hearing

Tympana

Organ of vision

Sense organs

Organ of smells

Antennas

Organ of hearing

Tympana

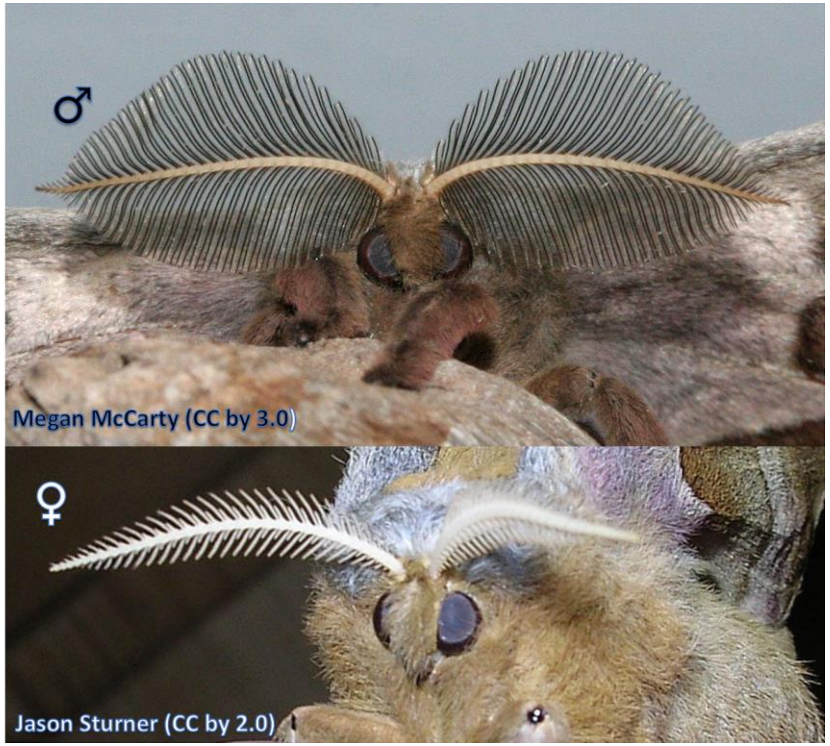
Organ of vision

Which location?

Sense organs

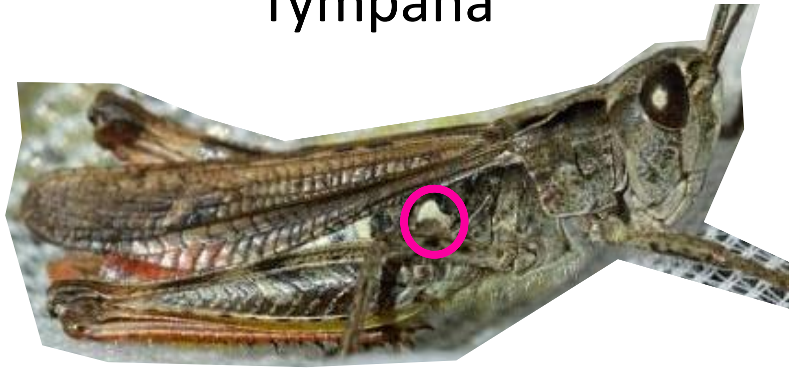
Organ of smells

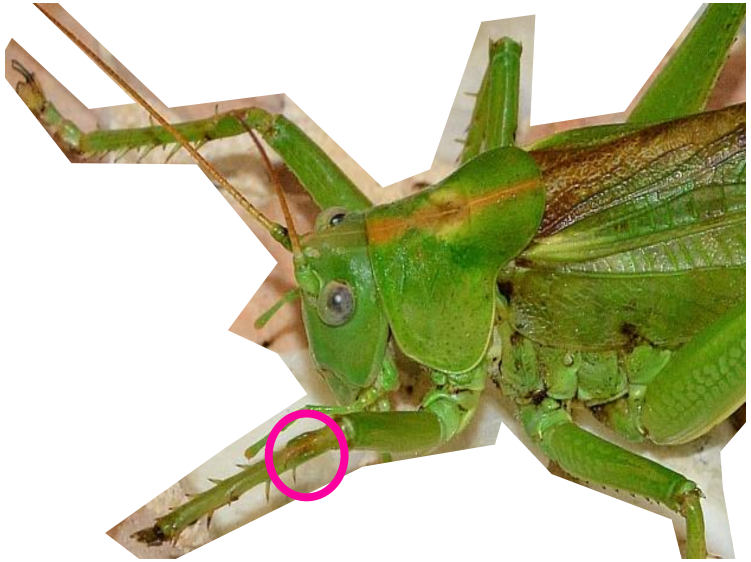
Antennas



Organ of hearing

Tympana





Organ of vision

Which location?

Sense organs

Example of sound emission

Which process?

Sense organs

Example of sound emission

Which process?

Stridulatory organs

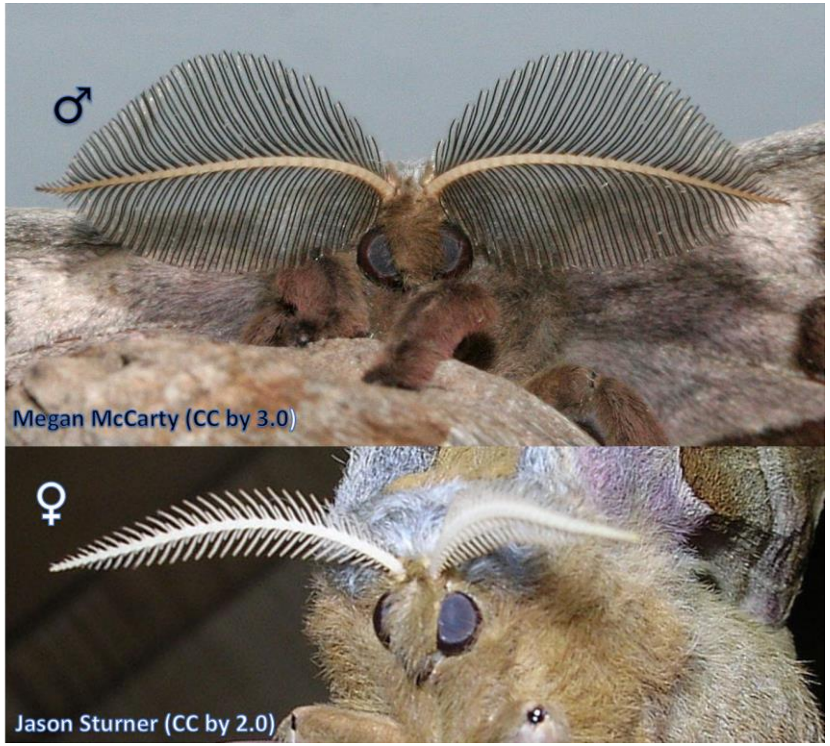
Femur rubbing the wing

Anterior wings rubbing against each other

Sense organs

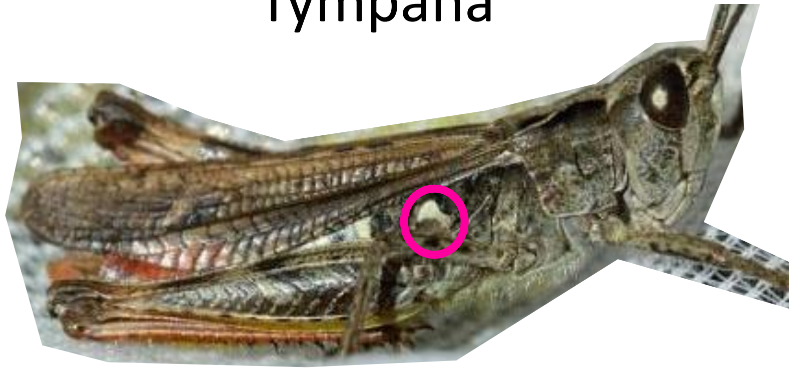
Organ of smells

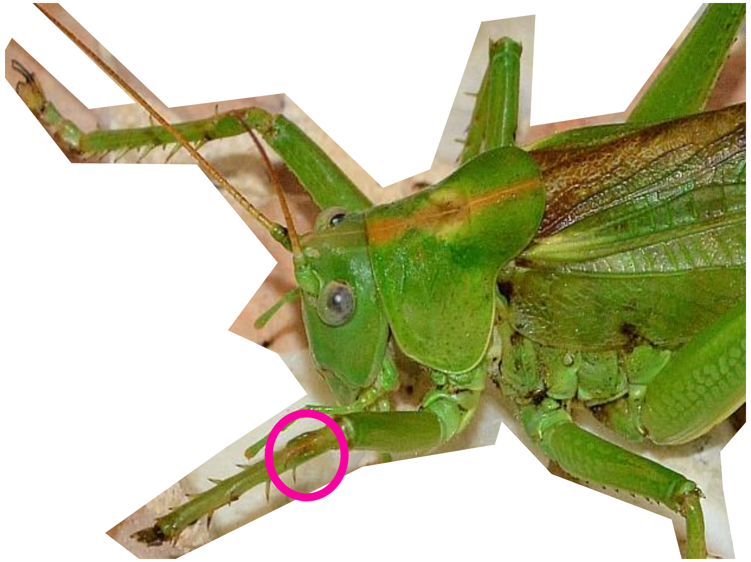
Antennas



Organ of hearing

Tympana





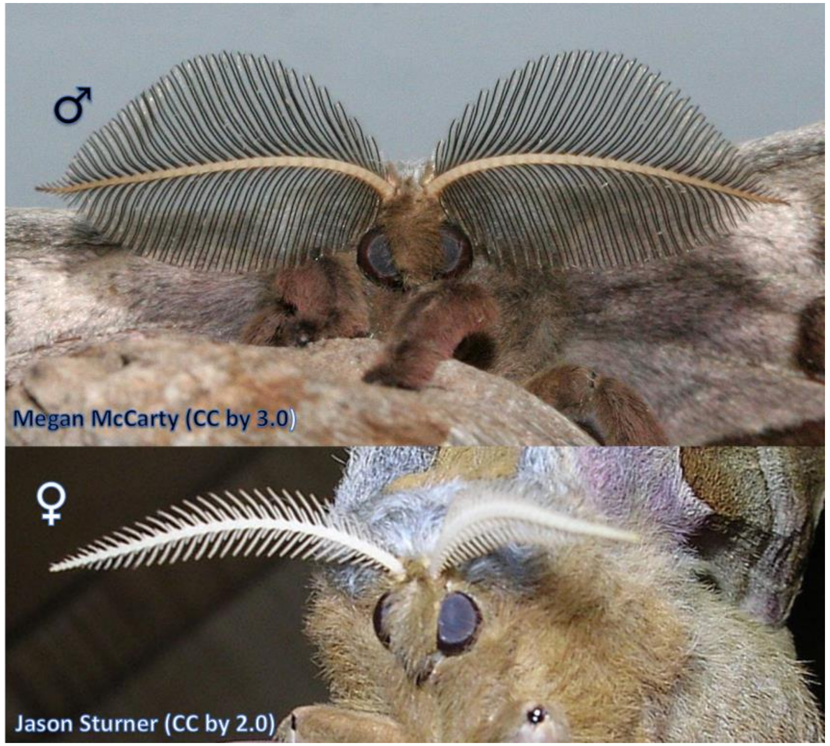
Organ of vision

Eyes

Sense organs

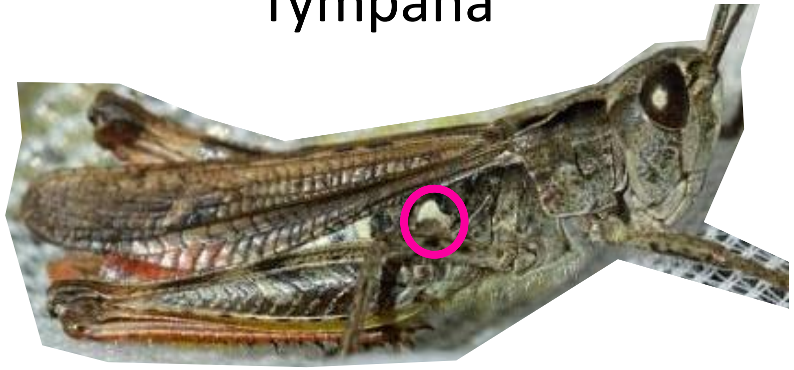
Organ of smells

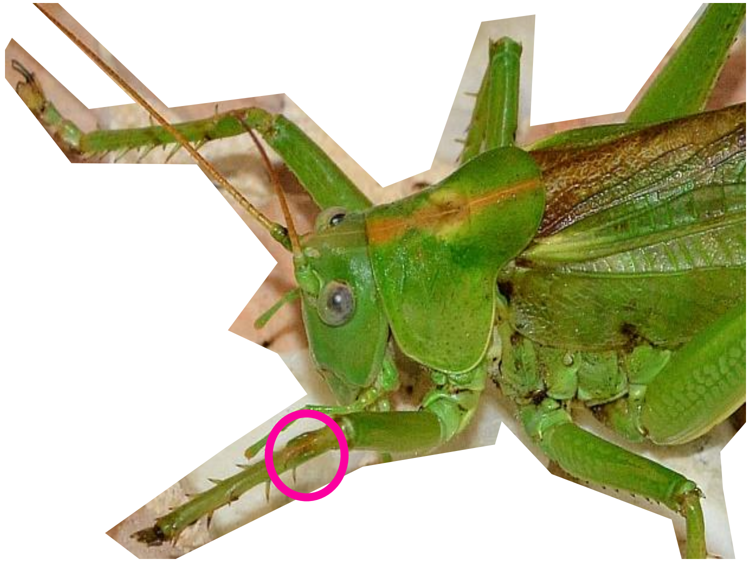
Antennas



Organ of hearing

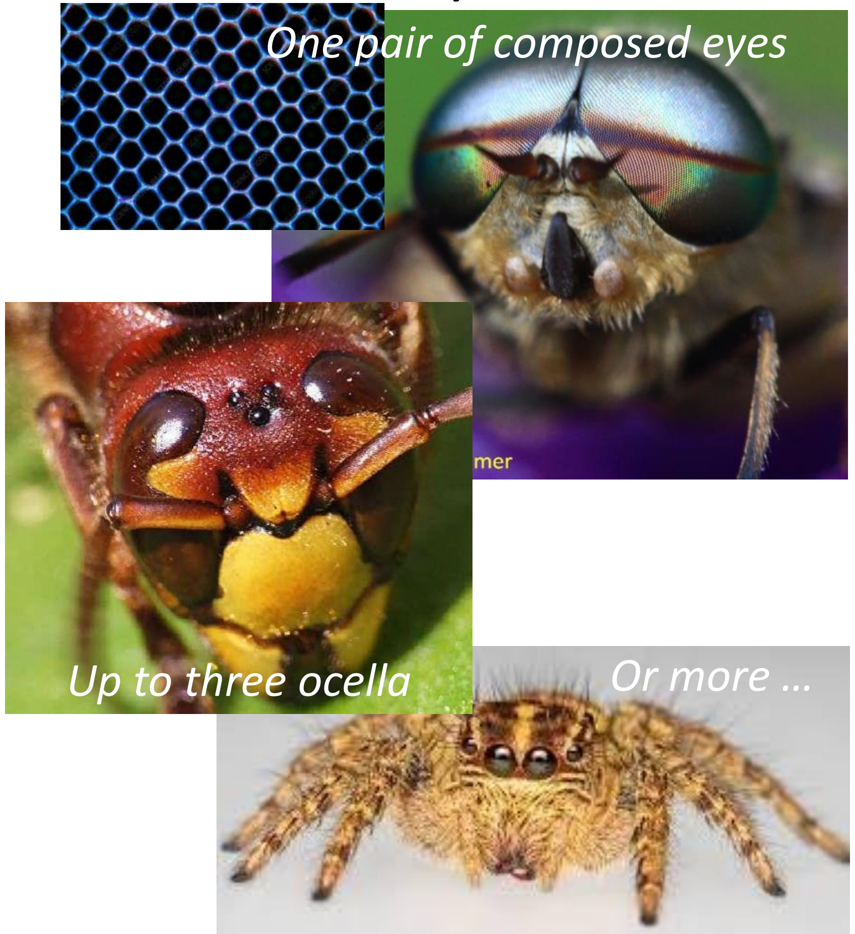
Tympana





Organ of vision

Eyes

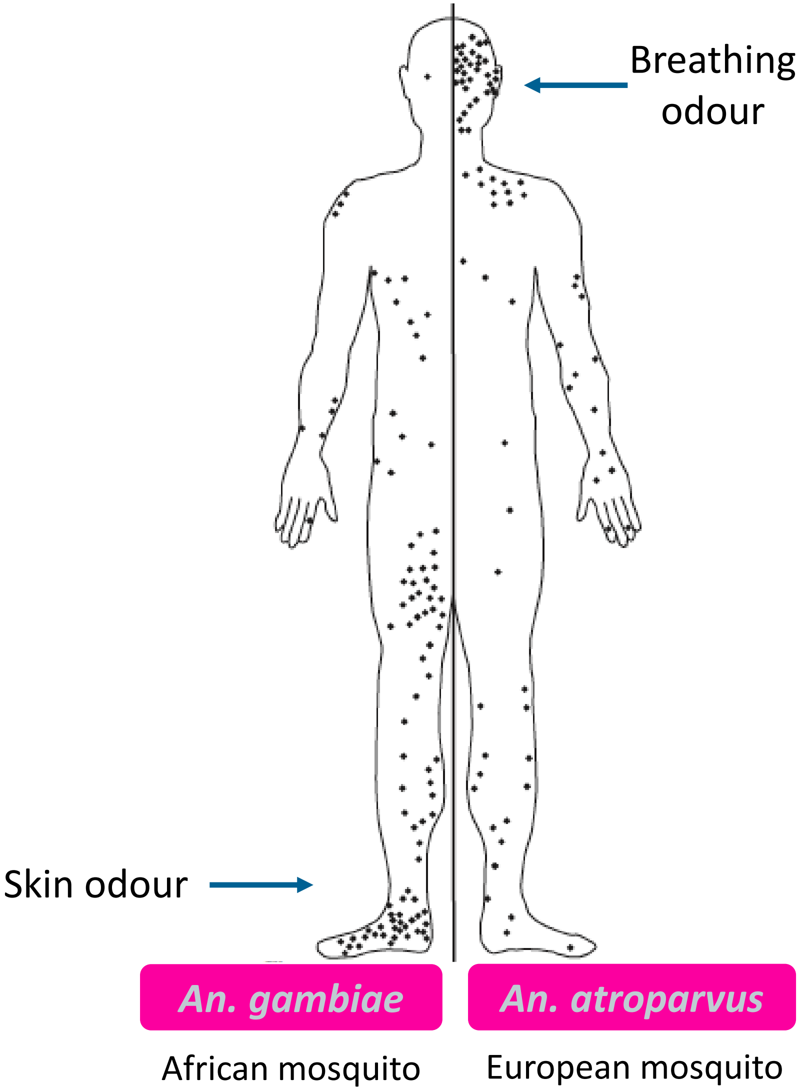


Mosquitoes sense organs

Orientation towards hosts

- Emission of volatile compounds – by the skin *(lactic acid, ammoniac etc. -> human skin)* / by the breath *(CO_2 and H_2O)*
- Heat – for mammals and birds *(warm-blooded animal)*
- Visual indications

Location of bites



Mosquitoes sense organs

Orientation towards hosts

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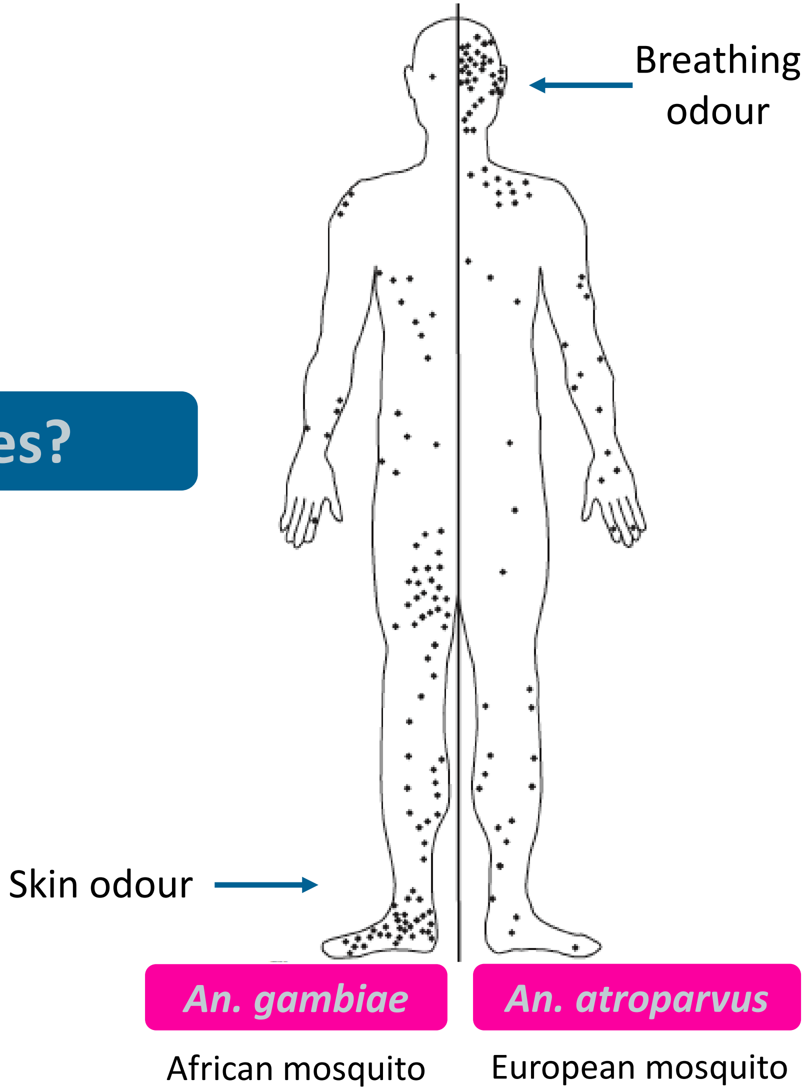
- Heat – for mammals and birds *(warm-blooded animal)*
- Visual indications

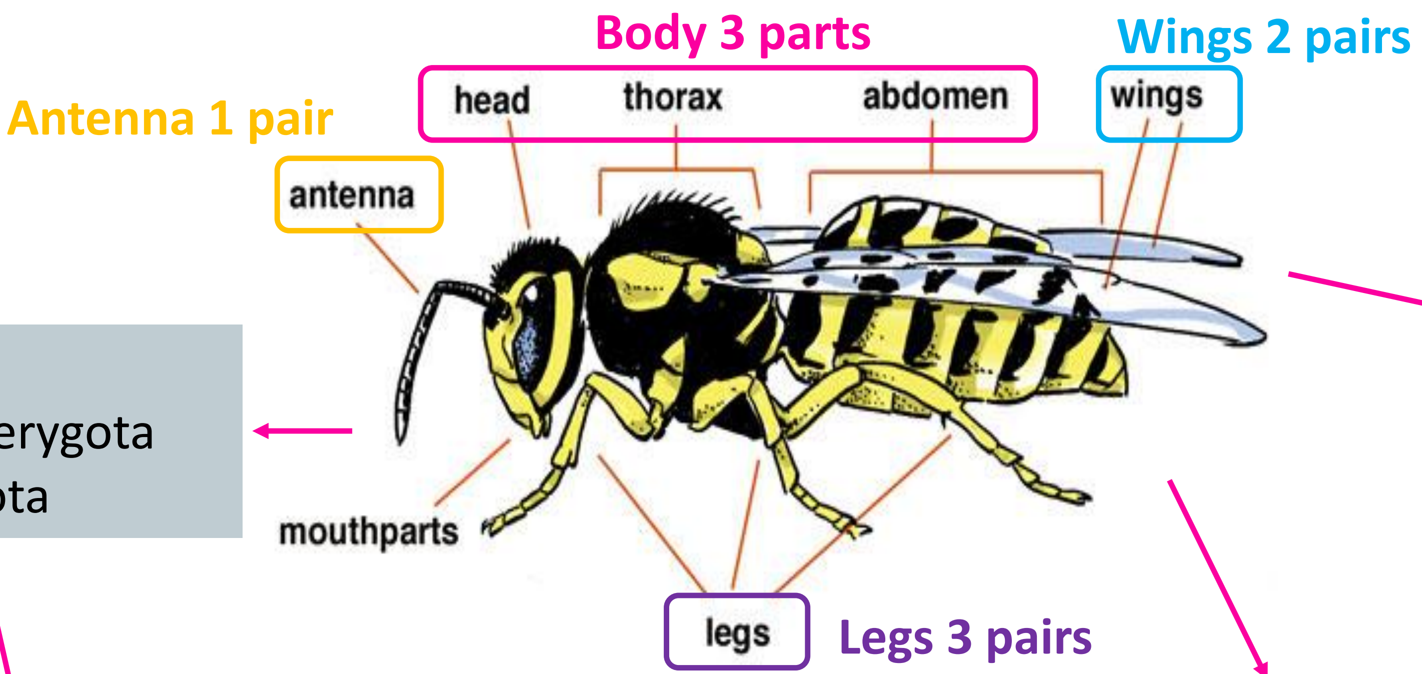
Why some people are more bitten than others by mosquitoes?

- First, is it true?
- Are there differences between mosquito species?
- Is there a real individual attractiveness for mosquitoes?

Location of bites



Summary : Insect – morphological criteria



Sexual dimorphism

<u>Adult</u>

- Without wing: Apterygota
- With wing: Pterygota

<u>Development</u>

- Hemimetabolous: egg-juvenile stage-adult
- Holometabolous: egg-larvae-pupa-adult

<u>Senses</u>

- Many organs
- Allow a lot of interactions with the environment

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A variety of entomologies in response to an enormous biodiversity

Entomologies

- Agricultural entomology
- Entomology of Museums
- Entomology of Conservation
- Entomology supports of other life sciences
- Forensic Entomology
- Nutritional Entomology
- **Medical & Veterinary Entomology**
- Military Entomology

Applications

- Crop Protection
- Taxonomy & Systematics
- Preservation of Biodiversity
- Genetics (ex: *Drosophila*), Physiology (ex:*Rhodnius*)
- Cadaver Dating
- Nutritional Intake
- **Human & Animal Health**
- Biological Weapons & Biosecurity

      

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Medical and Veterinary Entomology

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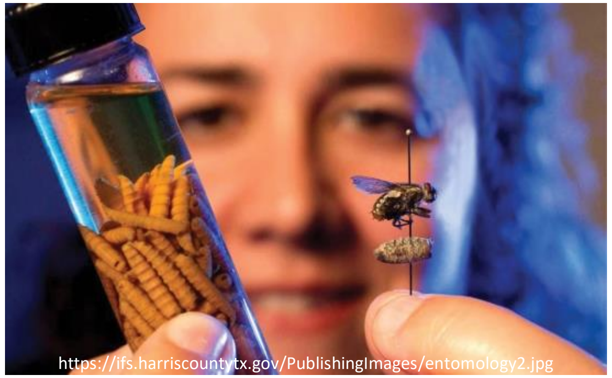
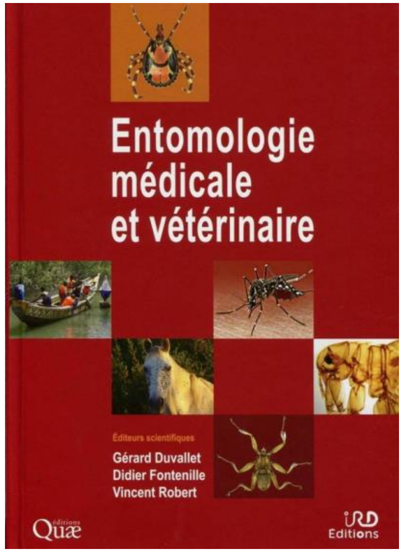
Definitions



- **Medical entomology:** science studying insects (by extension, Arthopods) of medical interest

Affect health of
- Human = **Public Health**
- Domestic animal *(livestock, pets, captive animals in zoos)* = **Animal Health**

Science at the interface between:
- **Arthropods (mainly insects and ticks)**
- **Health (Human and Animal)**



Medical Entomology

- **Arthropods of medical and veterinary interest belong mainly to:**

  - Insects
  - Acari (mites)
  - Ixodida (ticks)
  - Arachnida (scorpions, spiders)

} Arthropods but not insects

Scorpions: 1 million of Human are bitten per year, with 3000 deaths

Insecta Orders with Medical Importance

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- Insecta
  - Apterygota
    - *Adult – **no wing***
  - Pterygota
    - *Adult – **with wings***
    - *Hemimetabolous*
      - **Exopterygotes**
        - Ephemeroptera
        - Odonata
        - Plecoptera
        - Grylloblatodea
        - Orthoptera
        - Phasmida
        - Dermaptera
        - Embioptera
        - Dictyoptera
        - Isoptera
        - Zoraptera
        - Psocoptera
        - Mallophaga – Chewing lice
        - Phtiraptera – Sucking lice
        - Hemiptera – True bugs
        - Thysanoptera
    - *Holometabolous*
      - **Endopterygotes**
        - Nevroptera
        - Coleoptera - Beetles
        - Strepsiptera
        - Mecoptera
        - Siphonaptera - Fleas
        - **Diptera – Mosquitoes / Black flies / Phlebotomes / Midges**
        - Lepidoptera – Moths / Butterflies
        - Hymenoptera – Ants / Wasps / Bees
        - Tricoptera

Insecta Orders with Medical Importance

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Medical Importance

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      - **Hymenoptera – Ants / Wasps / Bees**
      - Tricoptera










Classification based on the pathogenic role

1/ Arthropods that cause a nuisance

2/ Arthropods that carry or host infectious agents

Classification based on the pathogenic role

1/ Arthropods that cause a nuisance

a. Parasite
b. Venomous
c. Urticant, blistering, allergenic
d. Blood depriving
e. Harmful, damaging

2/ Arthropods that carry <u>or</u> host infectious agents

a. Carrier (uncertain dissemination)
b. Intermediary hosts (obligatory parasitism)
c. Vectors (active transmission to vertebrates)

Arthropods that cause nuisance – Parasite

Parasites of the body of Vertebrates, at least at one stage

Mite (Acaria) = Agent of scabies

Mite *Sarcoptes scabiei*

Males are not parasites

Inseminated **females** become **endoparasites**

They first penetrate perpendicularly in the skin, then burrow galleries in epidermis, where **they lay eggs**

An estimated 300 million cases of scabies occur each year

Arthropods that cause nuisance – Venomous / Poisonous

Venomous = venom

Injection of **venom by bites** through abdominal sting (scorpions, wasps, bees …)

Scorpion

Bee

Poisonous = poison

Injection of **digestive saliva** by bites : spider, centipedes, true bugs …

Centipede

Belostoma

In case of bites by wasps or bees, 3 types of reaction are possible:

1- a **local reaction** with few consequences

2- a **toxic reaction** linked to the number of bites (dose effect of venom)

3- an **allergic reaction**, eventually due to a single bite after previous exposure to allergens

Arthropods that cause nuisance – Urticant

The **contact** with some insects (scales, setae…) can lead to **itching, urticaria, oedema, conjunctivitis, severe allergenic reactions**…

Urticant Moth

Hylesia metabus

Moth dermatitis occurs in South America (French Guyana, Brazil, Argentina, Peru) and Africa (Gabon, RCA)

The disease is due to **urticant scales of adult moths, passively dispersed during the flight**

Urticant Caterpillar

Pine processionary (*Thaumetopoea pityocampa*)

Arthropods that cause nuisance – *Blood depriving*

Blood spoliation due to Arthropods may **lead to severe anaemia** in Vertebrates

Simulides

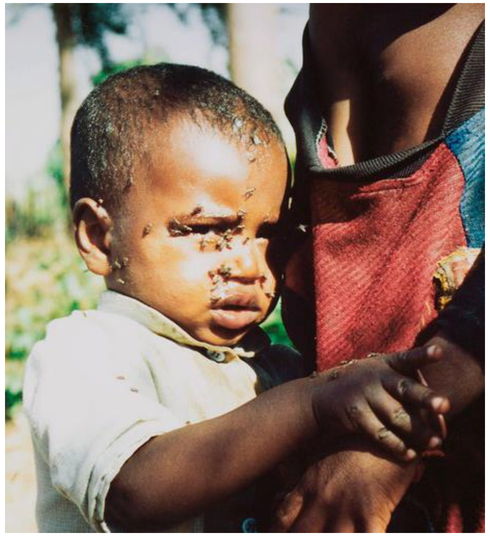
Example: black flies (larvae in running water), mosquitoes in Canada…

Ticks

Example: ticks on Bovids

Arthropods that cause nuisance – ***Harmful / Damaging***

In case of **huge densities**, nuisance forbid some activities in specific areas.



<u>Example</u>: mosquitoes in Northern lands and in some tropical islands, biting midges (*Ceratopogonidae*) on certain beeches…

Arthropods that carry/host infectious agents – *Carrier*

Arthropods **carry and move** various pathogenic agents

That allows a **hazardous dissemination** of the infectious agent

Example: cockroaches, flies, ants, and every Arthropods in link with Human

Arthropods that carry/host infectious agents – Intermediary Hosts

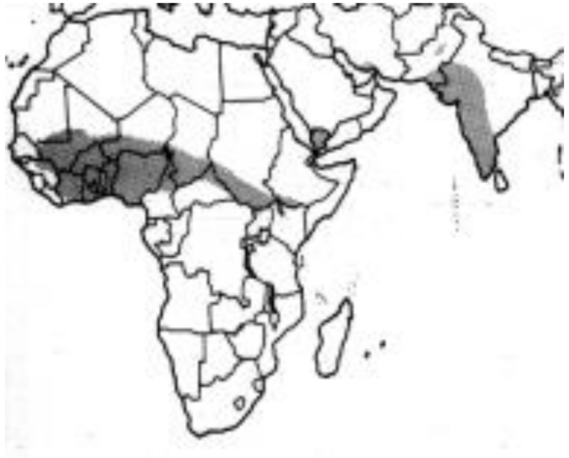
In case of **complex life cycles** (with several hosts), the parasite **must obligatory infect an intermediary host** before to infect the definitive host.

The intermediary is **often an Insecta** (Coleoptera, Diptera, Hymenoptera) and a **Crustacea**.

Dracunculosis = Guinea-worm disease

Adult female filaria

Crustacea Copepod, obligatory intermediary host



Geographical repartition

Arthropods that carry/host infectious agents – *Vectors*

A vector always exhibits a **host-oriented behaviour** that **favours the transmission** of pathogens.

- Most of the time, the Arthropod is mandatory in the pathogen life cycle
- The **vectors dominate all the medical arthropodology**

Vectorial transmission is not the rule, but rather an exception





Hay *et al.* 2010; recognise **41 species of Anopheles** as major vectors of *Plasmodium* (on ± 450 anopheline species)

Example of Bubonic Plague – Europe – 14th Century

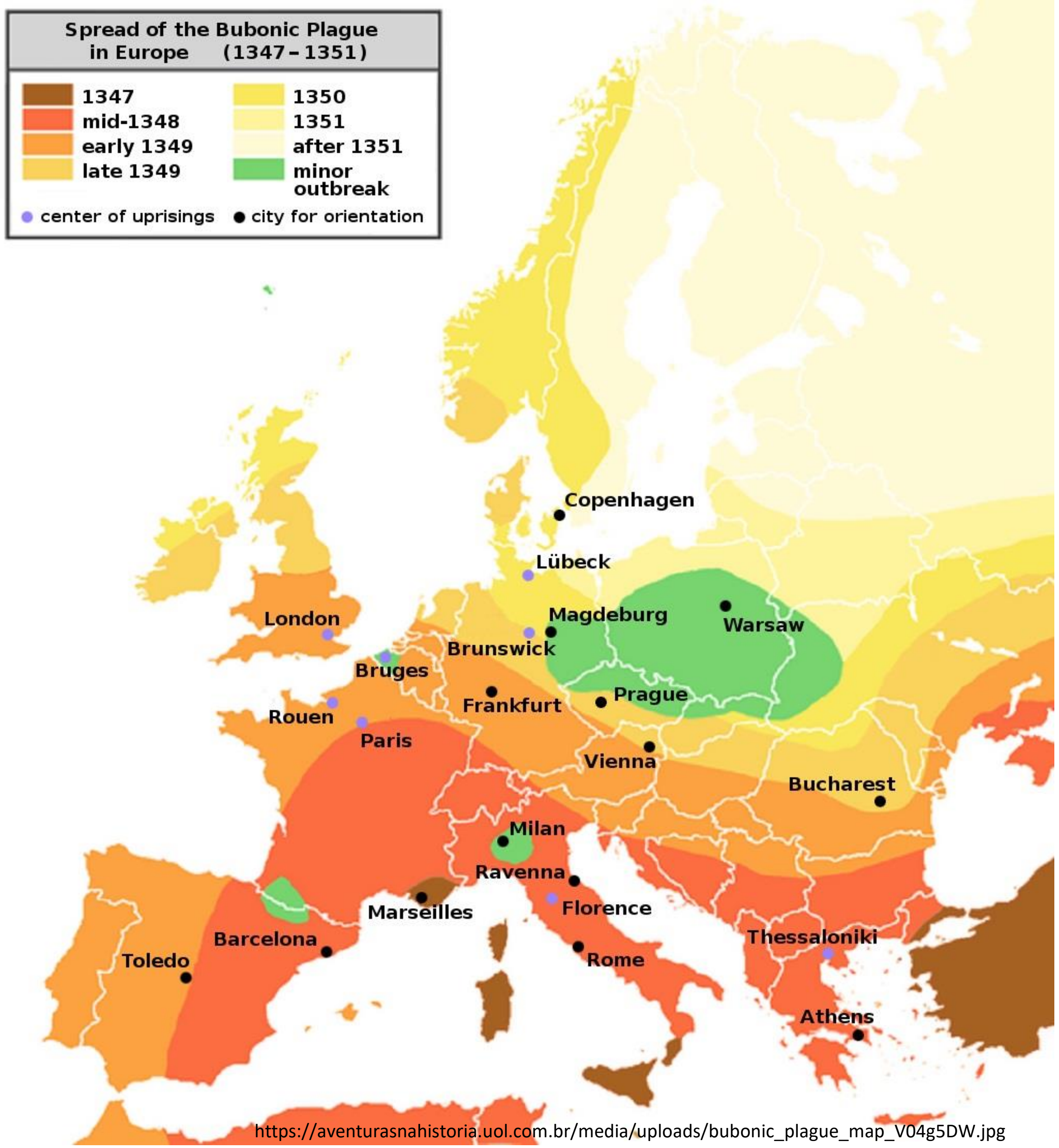
Importance of vectors

The **Black Death**, also known as the **Great Plague**, was one of the **most devastating pandemics in human histo**ry, resulting in the deaths of an estimated 75 to 200 million people in Eurasia and peaking in **Europe from 1347 to 1351**.

- Human **mortality rate was 30%** overall in Europe; 60 to 100% in infected populations.
- The bacillus ***Yersinia pestis*** have originated in Central Asia. Then from **Mediterranean ports**. Then, as a wave, from South to North of Europe.
- Epidemics run between rats and the rat fleas *Xenopsilla cheopis*. **Humans were infected by flea bites after the rats died**.

Poor knowledge of the epidemics at that time:

- no vector identified (➔ no vector control)
- no pathogenic agent identified (➔ no treatment such as antibiotics)
- but knowledge of the implication of the rat, sick people and corpse



https://aventurasnahistoria.uol.com.br/media/uploads/bubonic_plague_map_V04g5DW.jpg

Summary

Medical & Veterinary Entomology

Arthropods science for medical interest

<u>Infectious agents host</u>

Carrier / Intermediary Host / Vectors

<u>Nuisance</u>

Parasite / Venomous / Urticant / Blood depriving / Harmful







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Vector Definition

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Vectors = Two Definitions

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Large Definition

Stricto sensu Definition of Arthropod Vector

Vectors = Two Definitions

Large Definition

Any organism **involved in the transmission** of an **infectious agent**

Any organism:

- *carriers of pathogens*
- *intermediary hosts without active behaviour (example: mollusc)*

- *leeches (vector of fish parasites)*

- *dogs (vector of rabies)*

- *rats (reservoir of Leptospira)*

This definition is accepted by WHO

Stricto sensu Definition of Arthropod Vector

Vectors = Two Definitions

Large Definition

Any organism **involved in the transmission** of an **infectious agent**

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- *carriers of pathogens*
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- *dogs (vector of rabies)*

- *rats (reservoir of Leptospira)*

This definition is accepted by WHO

Stricto sensu Definition of Arthropod Vector

A **hematophagous** Arthropod that facilitates the **active transmission of an infectious agent**, from vertebrate to vertebrate

Hematophagous Arthropod: the blood feeding Arthropods encompass a large (but not the totality) of blood-feeding animals.

Active transmission: the Arthropod, through its host-oriented behaviour, establishes a contact between vertebrates (infected and not infected).

Infectious agent: not necessarily pathogen.

Vertebrate: any terrestrial tetrapod reptiles, amphibians, birds, mammals (including Human).

Vector-borne Pathogens

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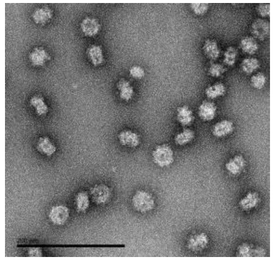
Virus:

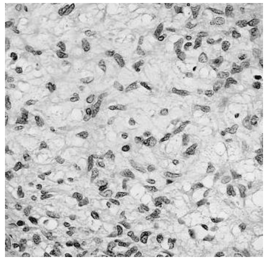
Bacteria:

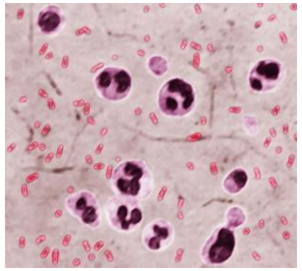
Protozoa:

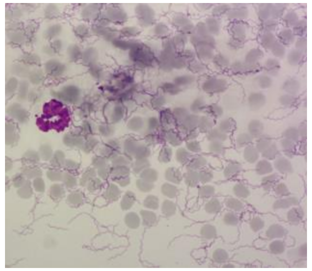
Parasitic worms (Helminths):

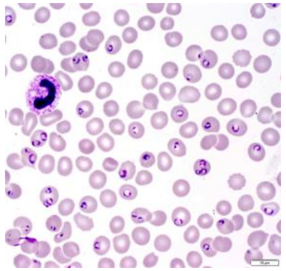
Vector-borne Pathogens

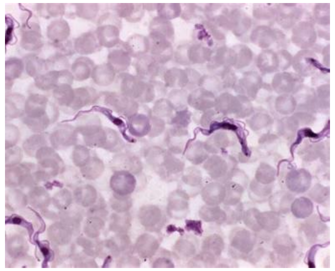

dengue virus


myxoma virus

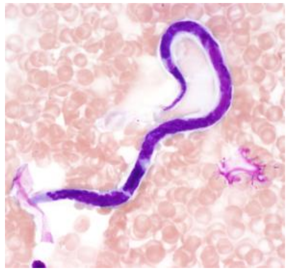

Yersinia sp.


Borrelia sp.


Plasmodium sp.


Trypanosoma sp.


Wuchereria sp.


Loa loa

Virus: arbovirus (~ 500 listed of which >100 are pathogenic for Human), and other virus (non-arboviruses) such as *myxoma* virus and plant virus

Vectors : various insects and ticks

Bacteria: *Yersinia* (plague), *Borrelia* (recurrent fevers), *Rickettsia* (typhus, spotty fever…)

Vectors: lice, fleas, various Acaria

Protozoa: *Plasmodium* (malaria), *Trypanosoma* (Chagas disease, sleeping sickness), *Leishmania* (leishmaniasis)

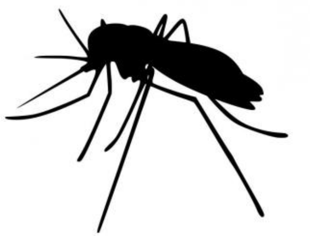
Vectors: various Diptera

Parasitic worms (Helminths): *Wuchereria bancrofti* (Bancroft filaria), *Loa loa* (filariasis), *Onchocerca volvulus* (onchocerciasis)

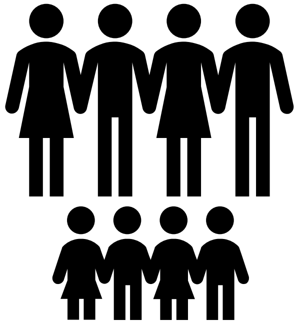
Vectors: various Diptera

The Vectorial Triad

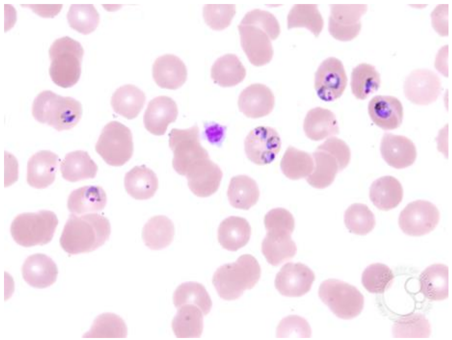
<u>*Example*</u>*:*
Anopheles gambiae / Plasmodium falciparum



Vector
(definitive host)



Vertebrate
(intermediary host)



Infectious agent
(pathogen)

- *Most of the time, vector is mandatory in the pathogen life cycle*
- *Vectors exhibit a host-oriented behaviour that favours the transmissions of pathogens*

The most important Arthropod vectors in medical entomology

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Insecta

Vectors belong to 4 orders

- Diptera (Culicidae, Phlebotominae, Simuliidae, Ceratopogonidae, Tabanidae, Muscidae (*Glossina*))

- Hemiptera (*Triatoma*…)

- Siphonaptera (fleas)

- Anoplura (lice)

Acaria (Ticks)

- Hard Ticks

- Soft Ticks

Examples of Human diseases and Vectors associated

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Human Diseases	*Dedicated Vectors*
Dengue	*Aedes* mosquitoes
Rift Valley fever	*Aedes & Culex* mosquitoes
Chikungunya fever	*Aedes* mosquitoes
West Nile fever	*Culex* mosquitoes
Malaria	*Anopheles* mosquitoes
Tick encephalitis	*Ixodes* ticks
Lyme disease (Borreliosis)	*Ixodes* ticks
Tick hemorrhagic fever	*Hyalomma* ticks
Epidemic typhus	Sucking lice
Rickettsiasis	Fleas & Ticks
(Bubonic) Pest	Fleas
Onchocerciasis	Simulidae
Loasis, Calabar swellings	Chrysops
Bancroftian filariasis	Mosquitoes
Trypanosomosis	Tsetse flies
Chagas disease	Triatomes
Leishmaniasis	Phlebotomine sand Flies

Summary

Medical & Veterinary Entomology

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<u>Infectious agents host</u>
Carrier / Intermediary Host / **Vectors**

<u>Nuisance</u>
Parasite / Venomous / Urticant / Blood depriving / Harmful

Involve in **infectious agents** transmission

Virus / Bacteria / Protozoan / Parasite

<u>Arthropods</u>

- Active transmission
- **Hematophagous**







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Hematophagy in Insects

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Definitions

- **Hematophagy = ingestion of blood**

<u>Hematophagy can be</u>

- **<u>Mandatory</u>** = **Almost exclusive source of nutriments – at all life stage**
  (example: ticks and lices)

- **<u>Optional</u>** = **Female only, for eggs production but not for surviving (never male and immature stages)**
  (example: mosquitoes)

The Blood

- **Specificity of vertebrates**

  (vs. haemolymph in invertebrates – Arthropods)

- **Interest = rich in nutriment and water / ordinary sterile / very digest**
- **Constraint = difficult and dangerous to reach**

Blood Ingestion Methods

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Solenophagy

- **By catheterisation** = **favours ingestion of blood pathogens**
  (example: mosquitoes)

Telmophagy

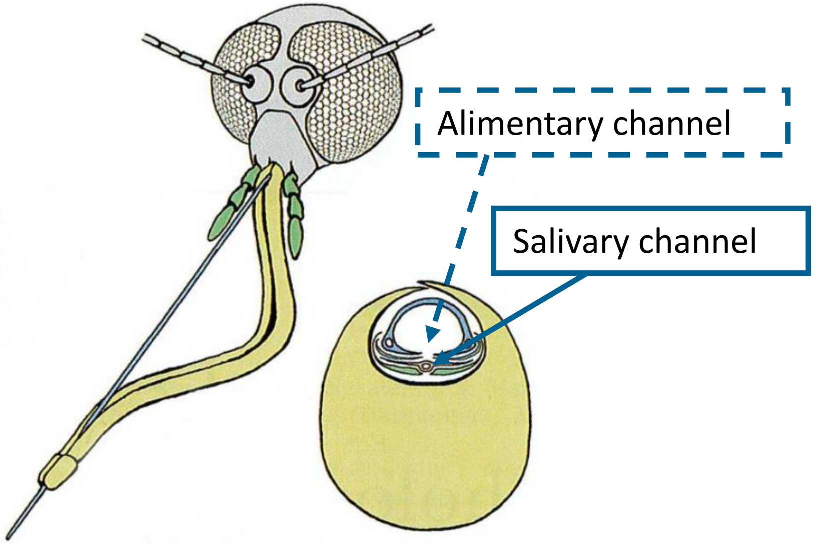
- **By broken skin** = **favours ingestion of blood AND lymphatic pathogens**
  (example: sandfly, black fly)

Blood Ingestion Methods

Solenophagy

- **<u>By catheterisation</u> = favours ingestion of blood pathogens**
  (example: mosquitoes)

Proboscis – female mosquito



Telmophagy

- **<u>By broken skin</u> = favours ingestion of blood AND lymphatic pathogens**
  (example: sandfly, black fly)

Blood Ingestion Methods

Solenophagy

- **By catheterisation** = **favours ingestion of blood pathogens**
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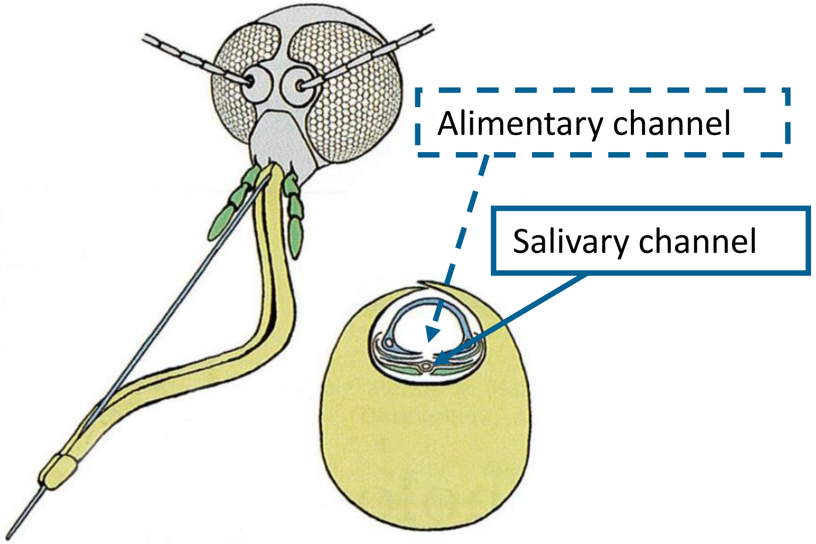
Proboscis – female mosquito



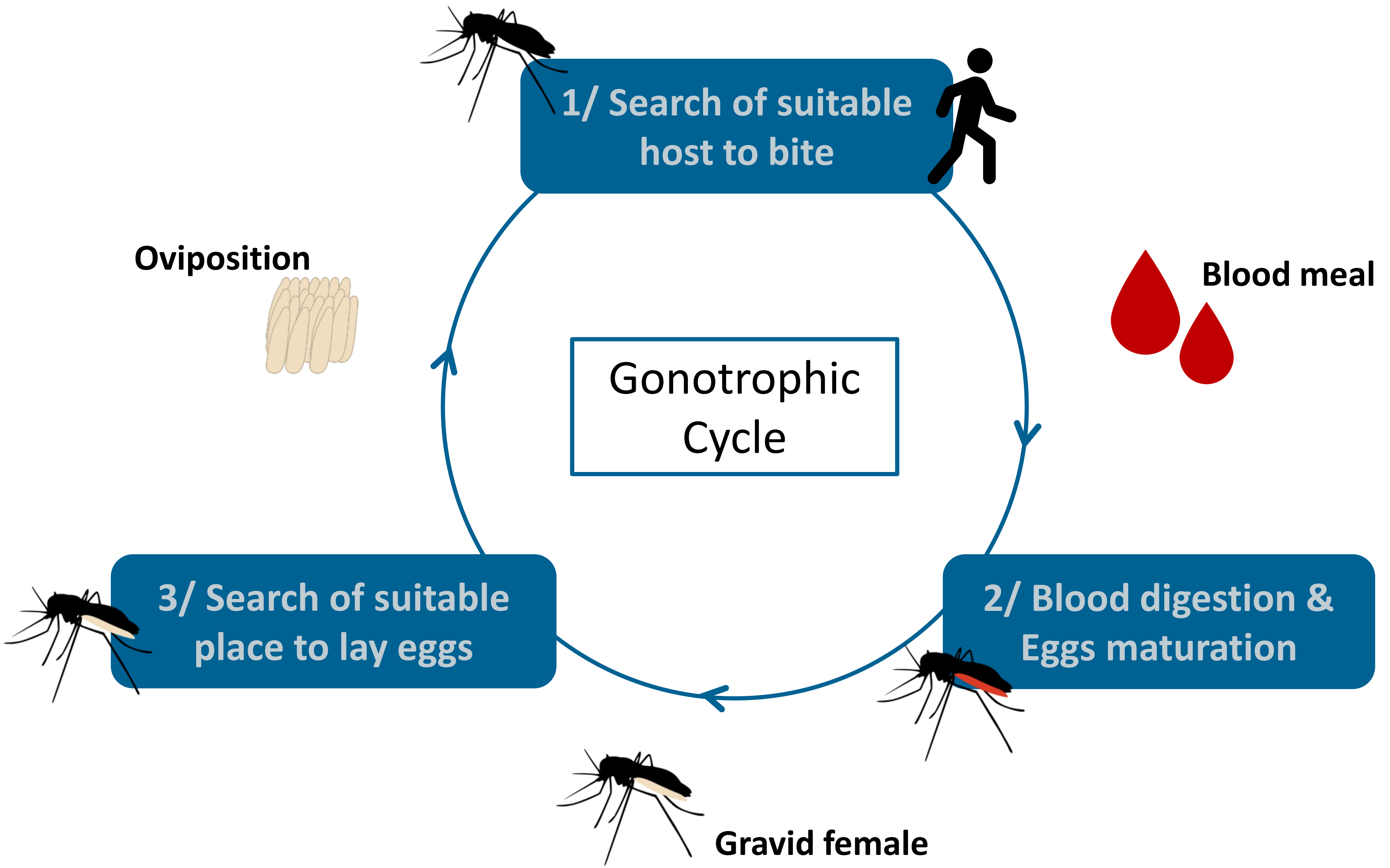
The bite of female mosquito

Two steps

- **Probing**= Localisation of blood vessel
- **Feeding** = Blood intake

- **The saliva** is **injected** at the extremity of the proboscis
- Its injection is **continuous** during the whole probing **and** feeding

Gonotrophic Cycle (3 phases)



- *Cycle requires 2 to 4 days*
- *Mosquito female completes 3 to 7 cycles during her lifetime*

Hematophagy in animal kingdom

- In Arthropods *(Insecta + Acaria)* = **14,600 hematophagous species**





- Estimates of the number of arthropod species vary **between 1 million and 10 millions**
- More **than 1.2%** of Arthropod species are **hematophagous**

Hematophagy in animal kingdom

- **Annelids Hirudinae** = Leeches

- **Arthropods** = Insect and Acaria
  - Anopluran
  - Diptera (Culicidae, Simulidae, Phlebotominae, Ceratopogonidae, Glossinidae)
  - Hemiptera (Reduviidae)
  - Ixodidae (Argasidae)
  - Siphonaptera

- **Parasitic worms**
  - Cestodes (Taenia)
  - Nematodes (Hookworm)
  - Trematodes (Schistosoma)

- **Fish Petrozontidae** = Lamprey (38 species)

- **Birds** = Galapagos birds (2 species)
  - Thraupidae (Darwin's finches - Geospiza difficilis)
  - Mimidae (Nesomimus macdonaldi)

- **Mammal Desmodontidae** = Vampire bats (3 species)





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Parasite / Venomous / Urticant / Blood depriving / Harmful

Involve in **infectious agents** transmission

Virus / Bacteria / Protozoan / Parasite

<u>Arthropods</u>

- Active transmission
- **Hematophagous**

<u>Blood Meals</u>

- Mandatory or Optional
- Solenophagy or Telmophagy

<u>Mosquitoes example</u>

- Mandatory for adult female
- Solenophagy => proboscis
- Bite in 2 steps => probing & feeding
- Saliva essential

Table of contents

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Example of vector:
Aedes **mosquito and arbovirus**

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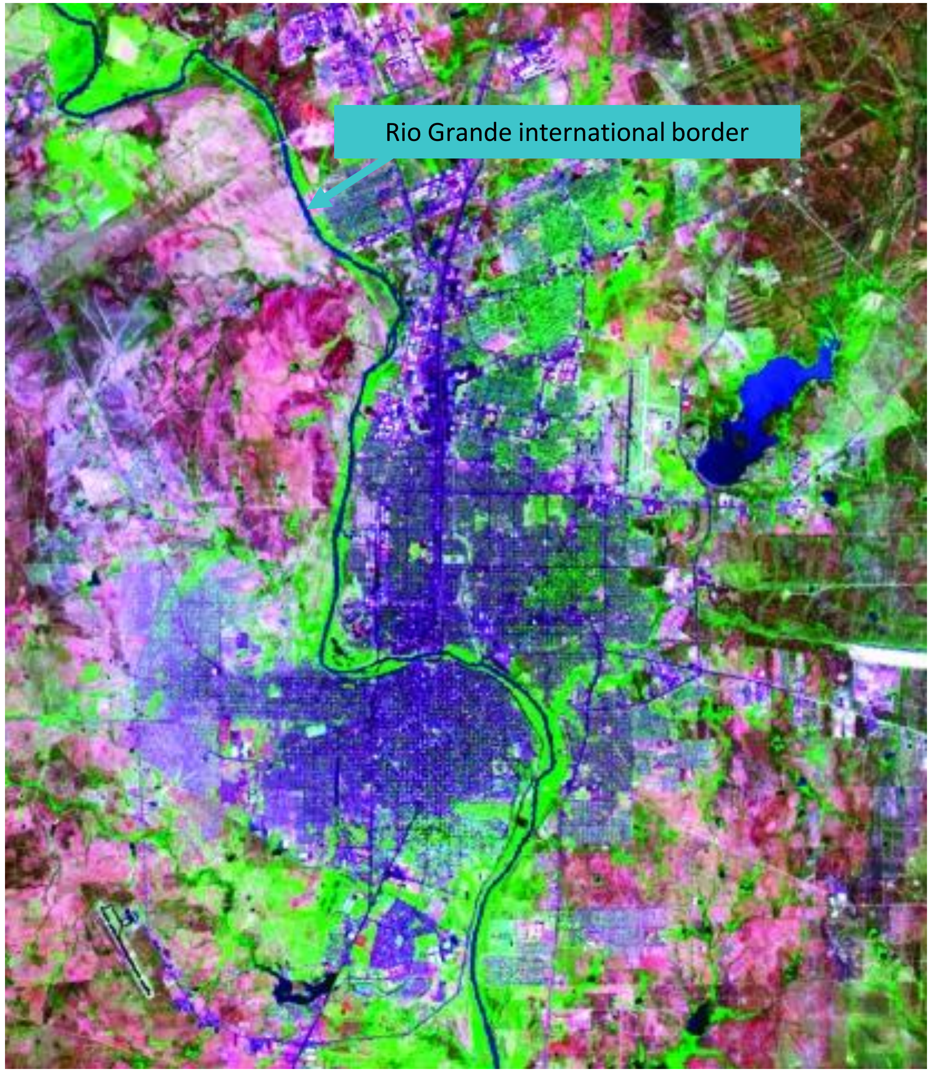
Importance of Human-Vector Contact

Reiter P. *et al.* 2003 – **Texas lifestyle limits transmission of dengue virus.** *Emerging Infectious Diseases, 2003, 9(1): 86-89.*

Boarding states of Mexico

- **62,514 suspected dengue cases [1980-1999]**



Whole Texas

- **48 dengue cases [1980-1999]**

Importance of Human-Vector Contact

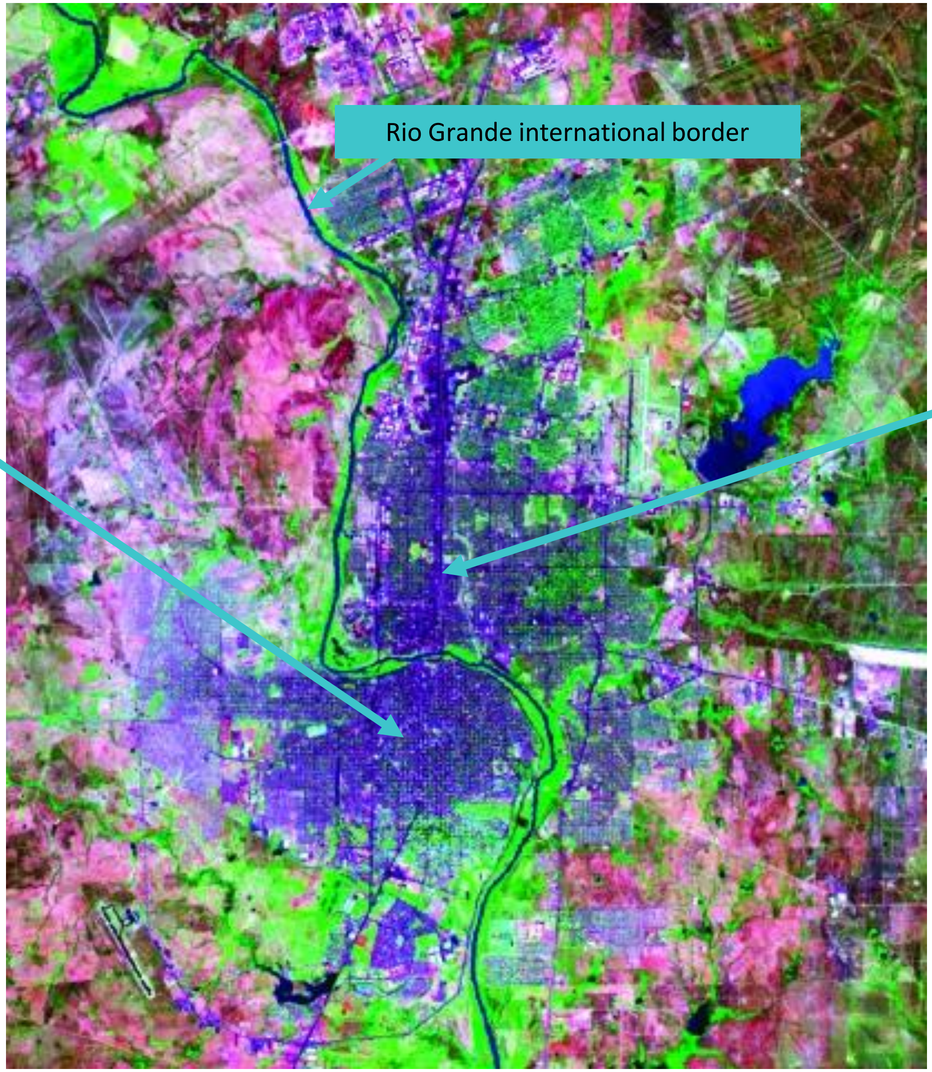
Reiter P. *et al.* 2003 – **Texas lifestyle limits transmission of dengue virus.** *Emerging Infectious Diseases, 2003, 9(1): 86-89.*

Boarding states of Mexico

- **62,514 suspected dengue cases [1980-1999]**

Nuevo Laredo, Mexico

Aedes aegypti density	High
Anti-dengue IgM prevalence	16 %
Habitat	**Windows** and **doors** are left **open**, particularly at **day-time**



Whole Texas

- **48 dengue cases [1980-1999]**

Laredo, Texas

Aedes aegypti density	High
Anti-dengue IgM prevalence	< 1 %
Habitat	**Air-conditioning**, window screens

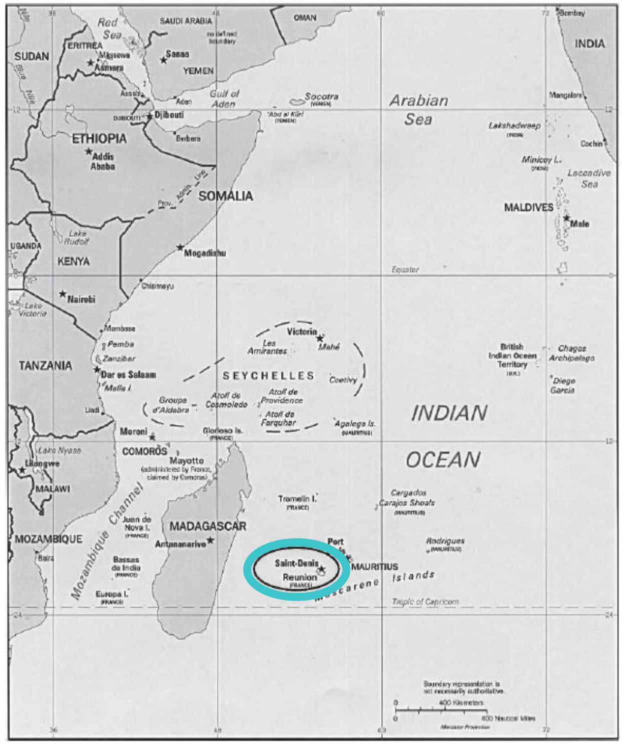
Importance of Vector-Pathogen Relationship

Example of Aedes–Virus Relationships

La Réunion Island

Up to 2005, no chikungunya cases

- Very few *Ae. aegypti*, good vector
- A lot of *Ae. albopictus*, poor vector



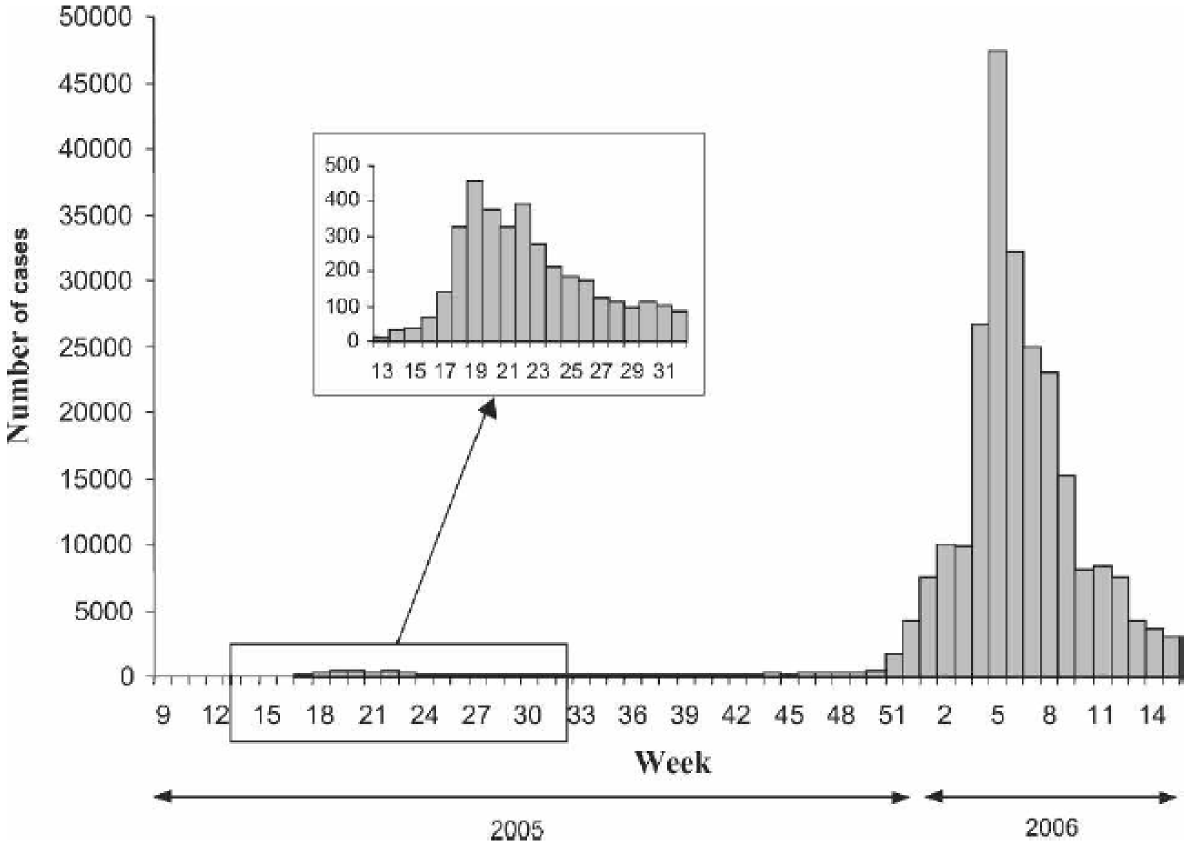


FIGURE 2. Number of weekly incident cases of chikungunya, Réunion Island, March 28, 2005–April 16, 2006 (n = 244,000). *Reported by the active case-finding system between weeks 9 and 50 of 2005 and estimated from the sentinel physician network between week 51 of 2005 and week 15 of 2006.

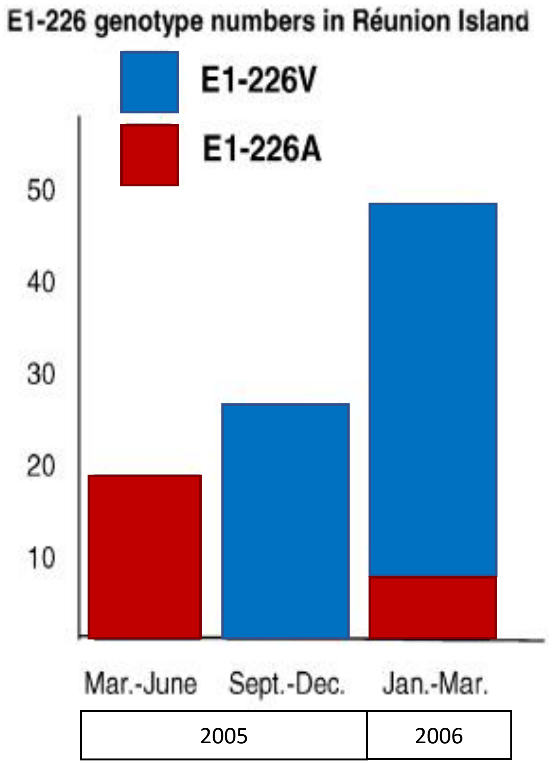
Importance of Vector-Pathogen Relationship

Example of Aedes–Virus Relationships

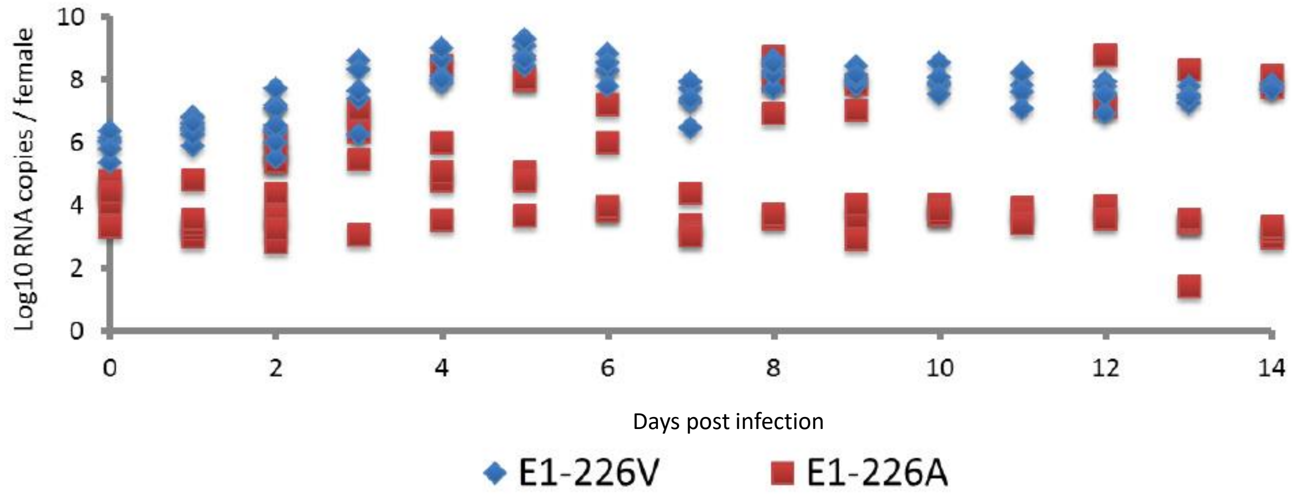
La Réunion Island

One single amino acid change from alanine to valine at position 226 of **CHIKV E1 glycoprotein** (E1-A226V)

- **Increases transmission by *Ae. albopictus*** (but not by *Ae. aegypti*)



Enhanced replication in *Aedes albopictus*



Vazeille *et al.* PLoS One (2007)

Illustrate the fitness of vector-parasite relationships

Importance of Vertical Transmission

Danis-Lozano *et al.* 2019 - **Vertical transmission of dengue virus in *Aedes aegypti* and its role in the epidemiological persistence of dengue in Central and Southern Mexico.** *Trop Med Int Health 2019, 24: 1311-1319*

Example from infected female to her progeny

METHODS: Vertical transmission of **DENV** was monitored in Mexico states in which DEN is endemo-epidemic.

Aedes eggs were collected in ovitraps, then adults were reared under laboratory conditions and their heads were used to infect C6/36 cells.

RESULTS: 54 of 713 (**7.8%**) of ***Ae. aegypti* adult pools tested positive**.

A minimum infection rate of 2.52 per 1000 mosquitoes was estimated for *Ae. aegypti*.

DENV-1, DENV-2 and DENV-3 serotypes were detected even during interepidemic periods.

Summary

<u>Paramount for arboviruses circulation</u>

- Importance of Human-Vector contact
- Importance of Vector-Pathogen relationship

Transmission and Dispersion

Vertical transmission = virus conservation in interepidemic periods

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Example of vector:
Anopheles mosquito and malaria

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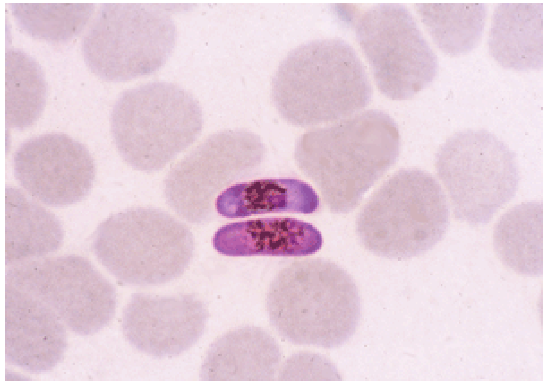
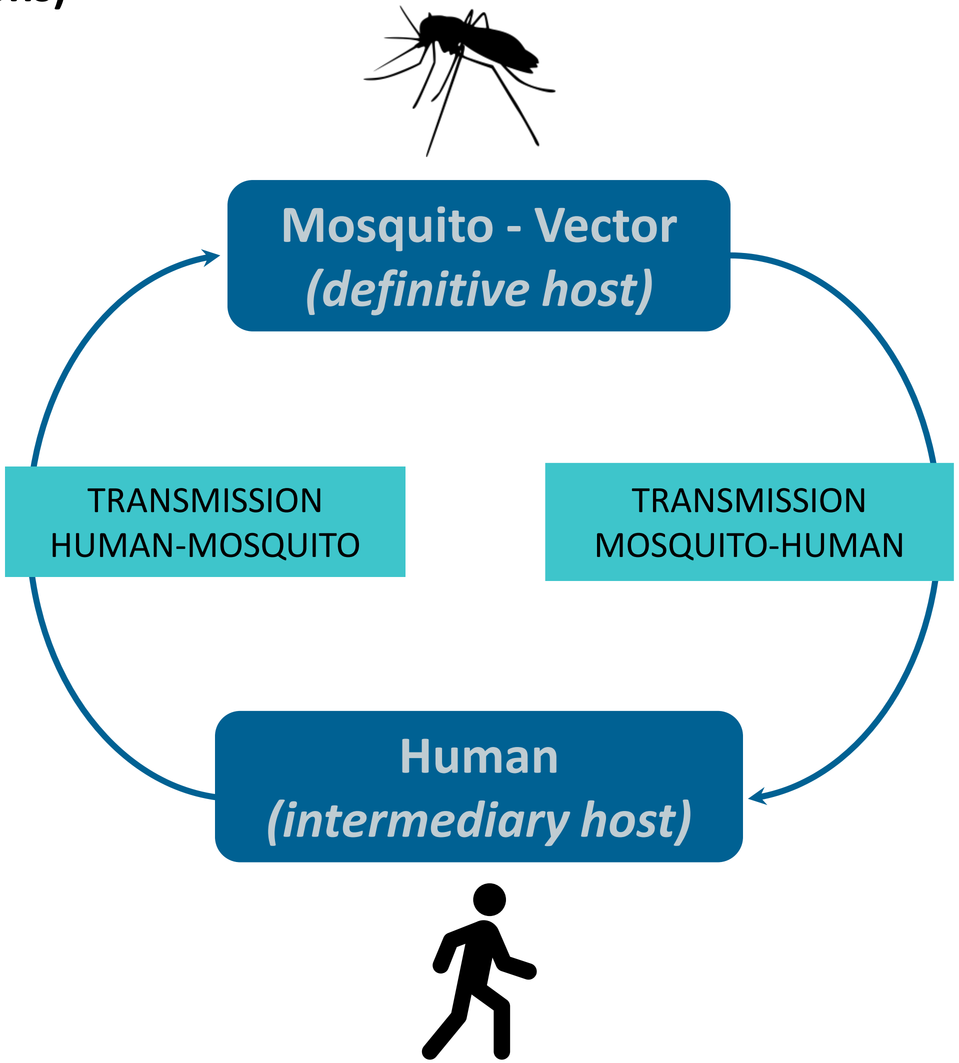
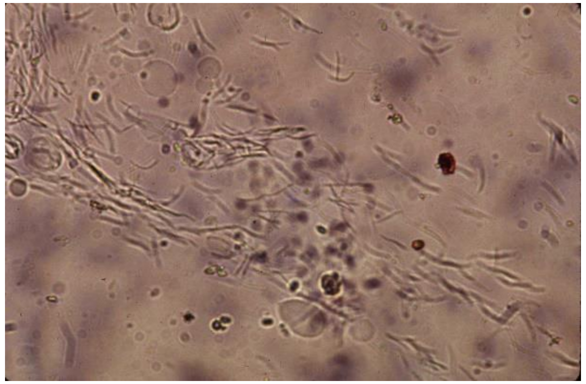
The transmission of Plasmodium

(in fact, there are two transmissions)



Gametocytes in the peripheral blood of the Human





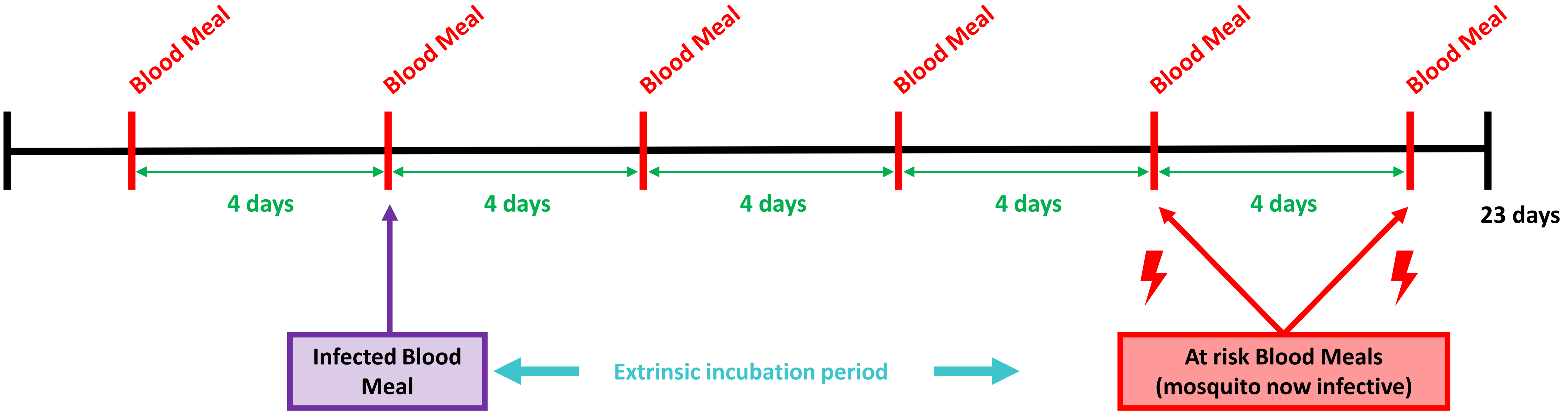
Sporozoites in the salivary glands of the mosquito

Be always precise with the transmission you address.

Numerical example of Plasmodium *transmission*

Longevity: **23 days** Gonotrophic cycle : **4 days**

Extrinsic period: **10 days** First bloodmeal at **2 days**



Summary

Transmission and Dispersion

<u>Paramount for arboviruses circulation</u>

- Importance of Human-Vector contact
- Importance of Vector-Pathogen relationship

Vertical transmission = virus conservation in interepidemic periods

<u>Malaria – two types of transmission</u>

- Human-Mosquito
- Mosquito-Human

Most of the time – Malaria transmission = Mosquito => Human transmission

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Entomological Inoculation Rate (EIR)

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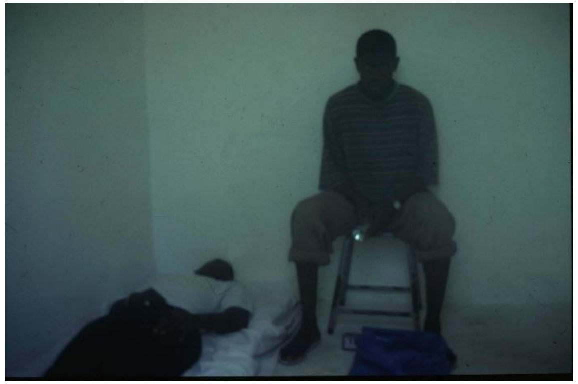
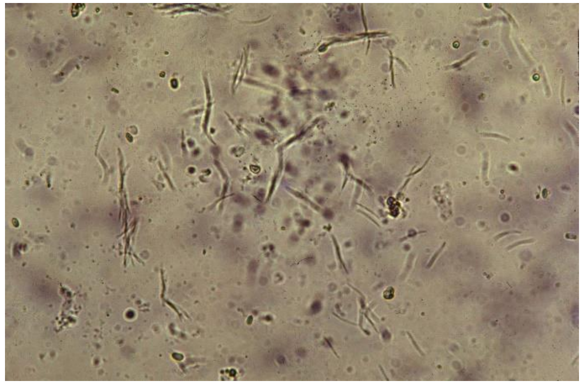
Definitions

- **EIR: E**ntomological **I**noculation **R**ate



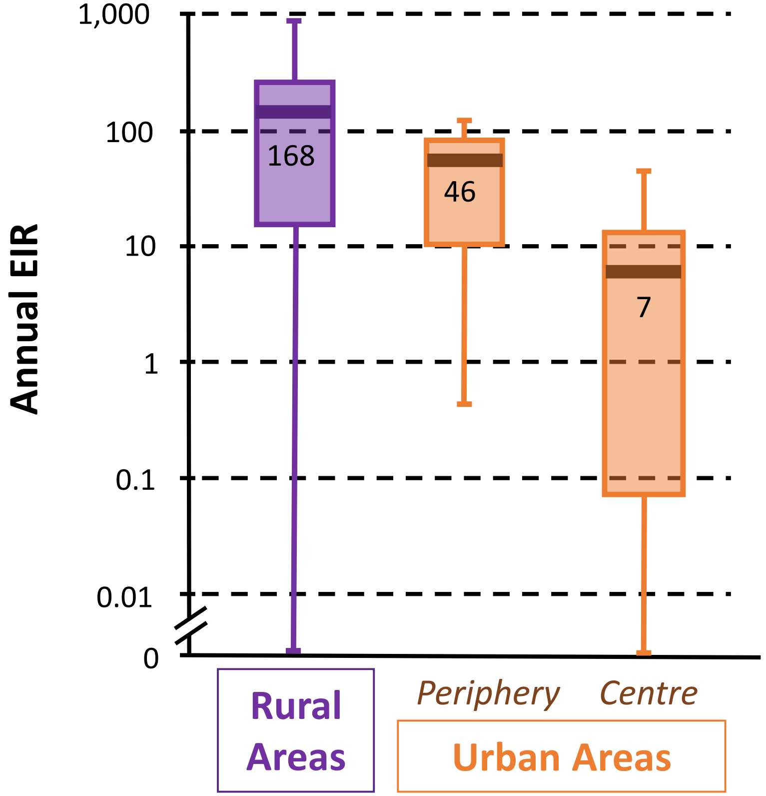
EIR = ma x s

- ma = **biting rate**
- s = **sporozoite index**

Unit = Number of bites of infected anopheline mosquito per length of time (night, month, year, life)

Importance of global changes (urbanisation)

Box plot showing the mean annual EIR, expressed in number of infected anophelines per man per year



Robert *et al.* 2003. **Malaria transmission in urban sub-Saharan Africa.**

Examples EIR Calculation

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Example 1

High endemic area (a village in Central Africa end of 20th century)

- **50 bites** of anopheles per man in one night
- **2** of them have sporozoites in their salivary gland

EIR = ??

- ma = **biting rate**
- s = **sporozoite index**

Examples EIR Calculation

Example 1

High endemic area (a village in Central Africa end of 20th century)

- **50 bites** of anopheles per man in one night
- **2** of them have sporozoites in their salivary gland

EIR = 50 x 2/50 = 2

- ma = **biting rate**
- s = **sporozoite index**

EIR = 2 bites of infected mosquito/man/night

Examples EIR Calculation

Example 2

Low endemic area (a village in Savanna Africa, dry season)

- **9 bites** of anopheles per man in 31 nights (1-31 January)
- **2 of 458** mosquitoes have sporozoites in their salivary gland

EIR = ??

- ma = **biting rate**
- s = **sporozoite index**

Examples EIR Calculation

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Example 2

Low endemic area (a village in Savanna Africa, dry season)

- **9 bites** of anopheles per man in 31 nights (1-31 January)
- **2 of 458** mosquitoes have sporozoites in their salivary gland

EIR = 9/31 x 2/458 = 0.29 x 0.0044 = 0.00127

- ma = **biting rate**
- s = **sporozoite index**

EIR = 0.001 bites of infected mosquito/man/night, and so 0.04/month

In other terms, 4% of villagers receive 1 infected bite in the month

Summary

Transmission and Dispersion

<u>Paramount for arboviruses circulation</u>

- Importance of Human-Vector contact
- Importance of Vector-Pathogen relationship

Vertical transmission = virus conservation in interepidemic periods

<u>Malaria – two types of transmission</u>

- Human-Mosquito
- Mosquito-Human

Most of the time – Malaria transmission = Mosquito => Human transmission

<u>Entomological Inoculation Rate (EIR)</u>

- Proxy of "malaria transmission"
- Closely related to the endemicity level







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Population Size & Density in Entomology

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Definitions

- **Population size:** Absolute number

➢ on May 18, 2022, there are 600,450,732 cats on the earth surface

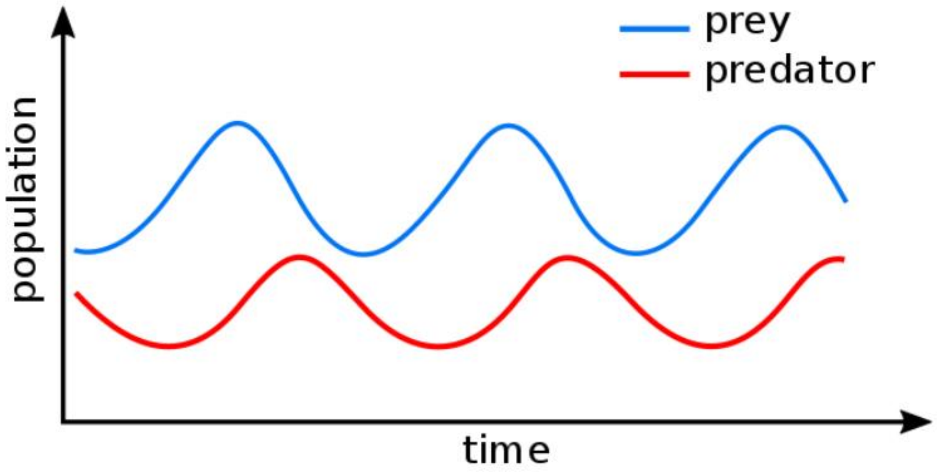
- **Population density:** Relative number (regarding a surface/a host)

➢ there are 3.4 biting female mosquitoes per night and per unprotected human in the town of Podgorica

Type of Regulations

Prey - Predator

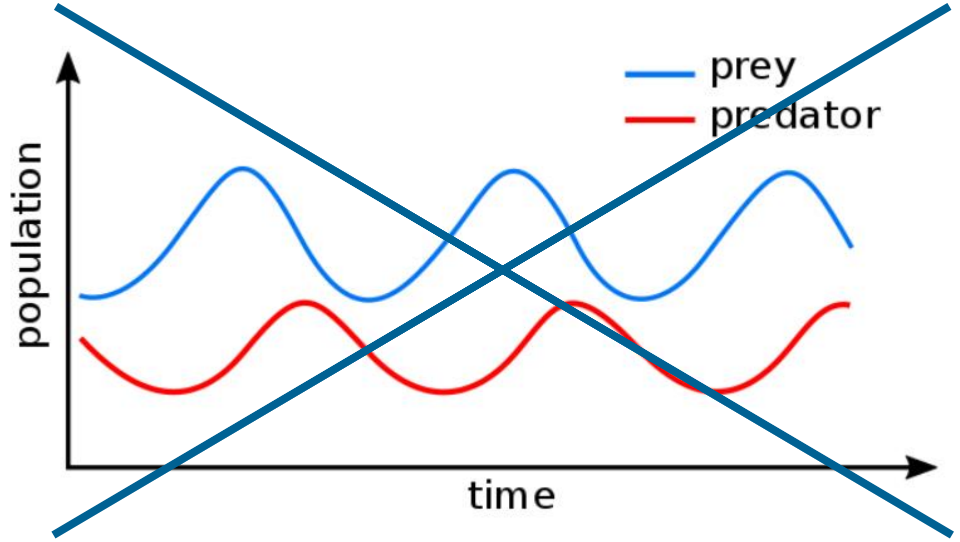
- **Sinusoidal regulation between prey and predators**



Type of Regulations

Prey - Predator

➢ **Sinusoidal regulation between prey and predators**



Type of Regulations

Prey - Predator

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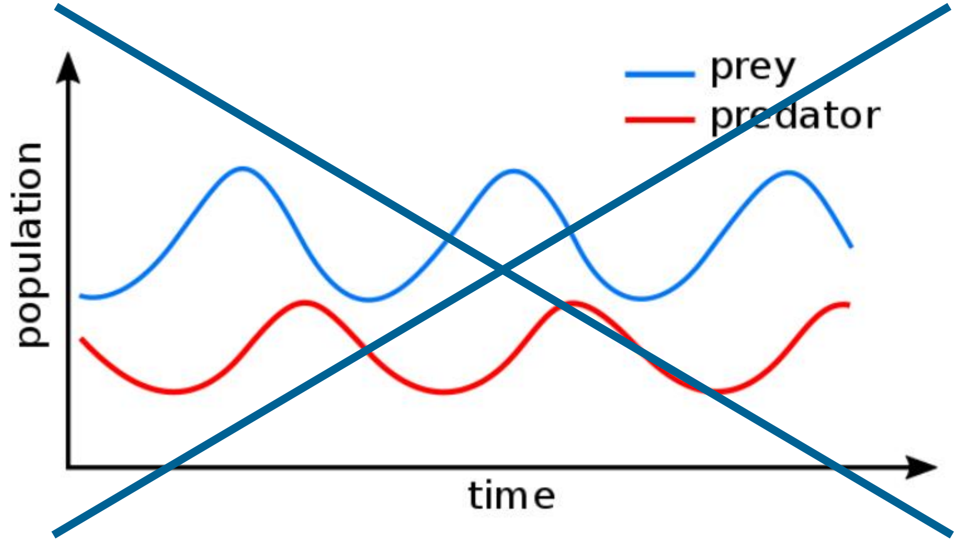
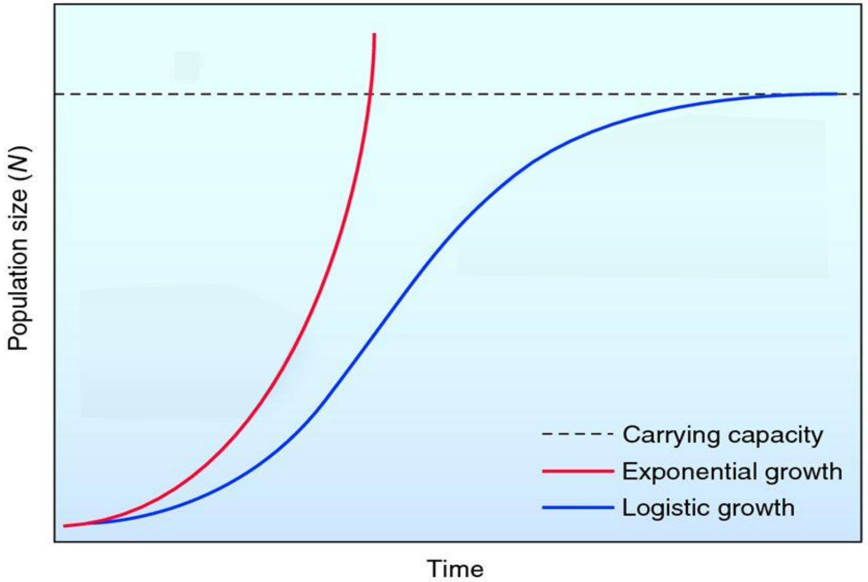


Exponential - Logistic

- **Short generation length of time**
- ***High progeny***
- ***High rate of development success***

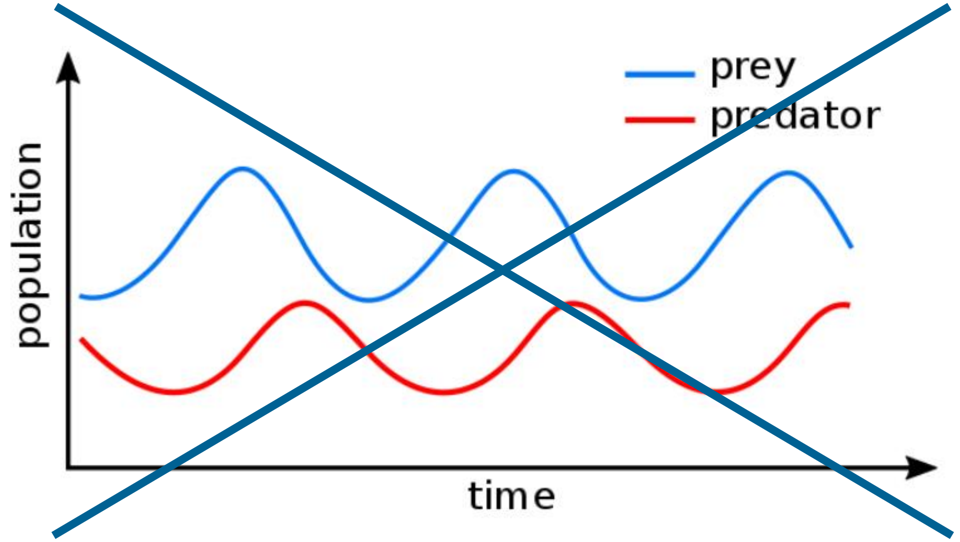


Type of Regulations

Example of mosquitoes

Prey - Predator

- **Sinusoidal regulation between prey and predators**



Population dynamic proceeds by outbreaks

Exponential - Logistic

- **Short generation length of time**

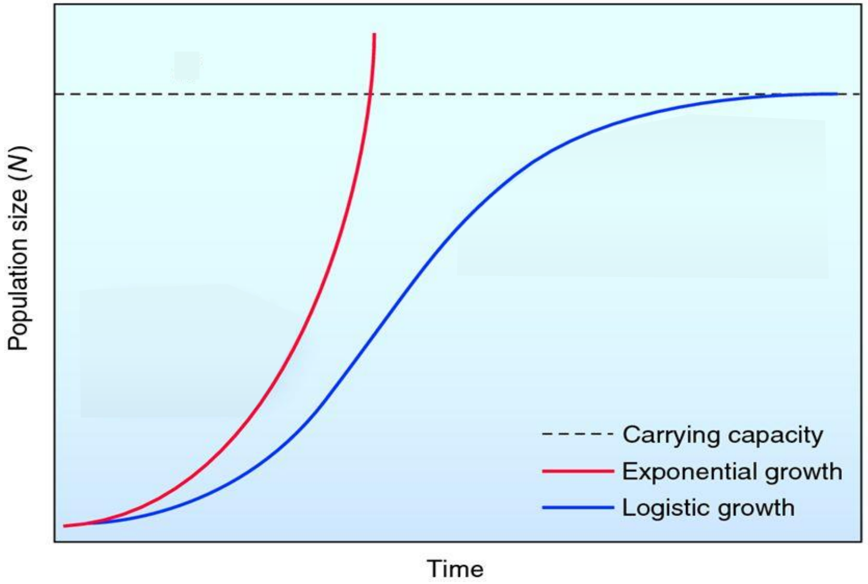
  15 days

- ***High progeny***

  2,000 eggs/female

- ***High rate of development success***

  Few predators, adults and immatures are not competitors



Type of Regulations

Example of Grasshopper Migratory Locust



- **Solitary phase**

in well localised areas

↓

When conditions are favourable during several generations

- **Gregarious phase**

in response to high population density; under hormonal regulation

↓

- *Lighter*
- *Longer wings*
- *Smaller offspring*
- *Gregarious behaviour*

- **Departure without return**

Africa, Asia, New Zealand – formerly Europe
10 to 130 km/day – up to 80 millions individuals/km^2

Type of Regulations

Example of infrequent regulation – Tsetse fly

- 7 pupa/female
- very small progeny

Population dynamic is much more stable

Summary

Transmission and Dispersion

<u>Paramount for arboviruses circulation</u>

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- Importance of Vector-Pathogen relationship

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- Human-Mosquito
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Most of the time – Malaria transmission = Mosquito => Human transmission

<u>Entomological Inoculation Rate (EIR)</u>

- Proxy of "malaria transmission"
- Closely related to the endemicity level

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Natural Dispersion of Insects

Institut de Recherche pour le Développement
FRANCE
French National Research Institute for Sustainable Development

Definitions

- **Dispersion:** Process by which individuals or populations colonise or recolonise a territory

  - **Natural Dispersion:** May occur through walking and/or flying

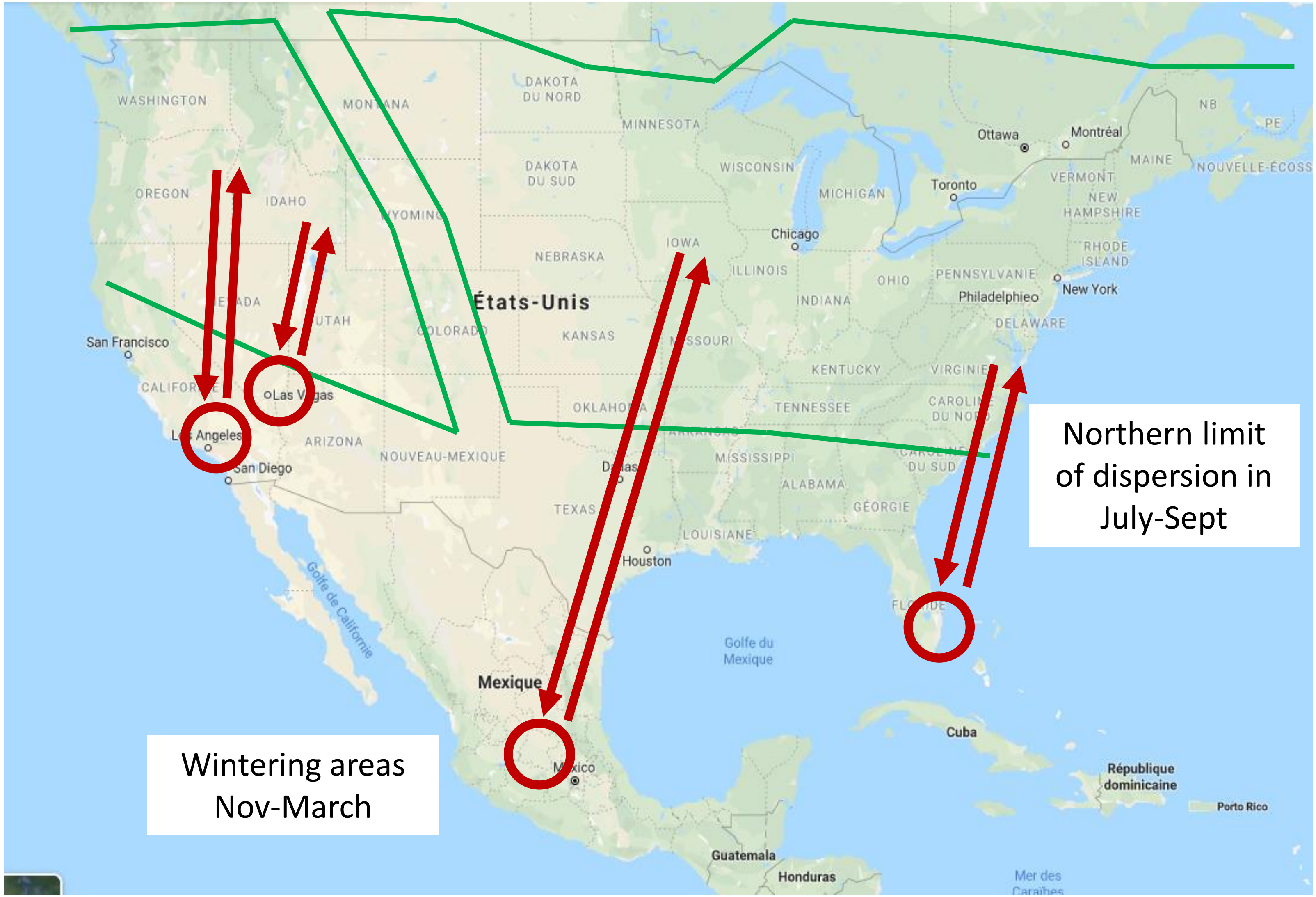
Most of species disperse few (some km)

But some exceptions exist,
with true migration process (return within departure area)

Natural Dispersion of Insects

Example of Monarchus *butterfly*

In North America

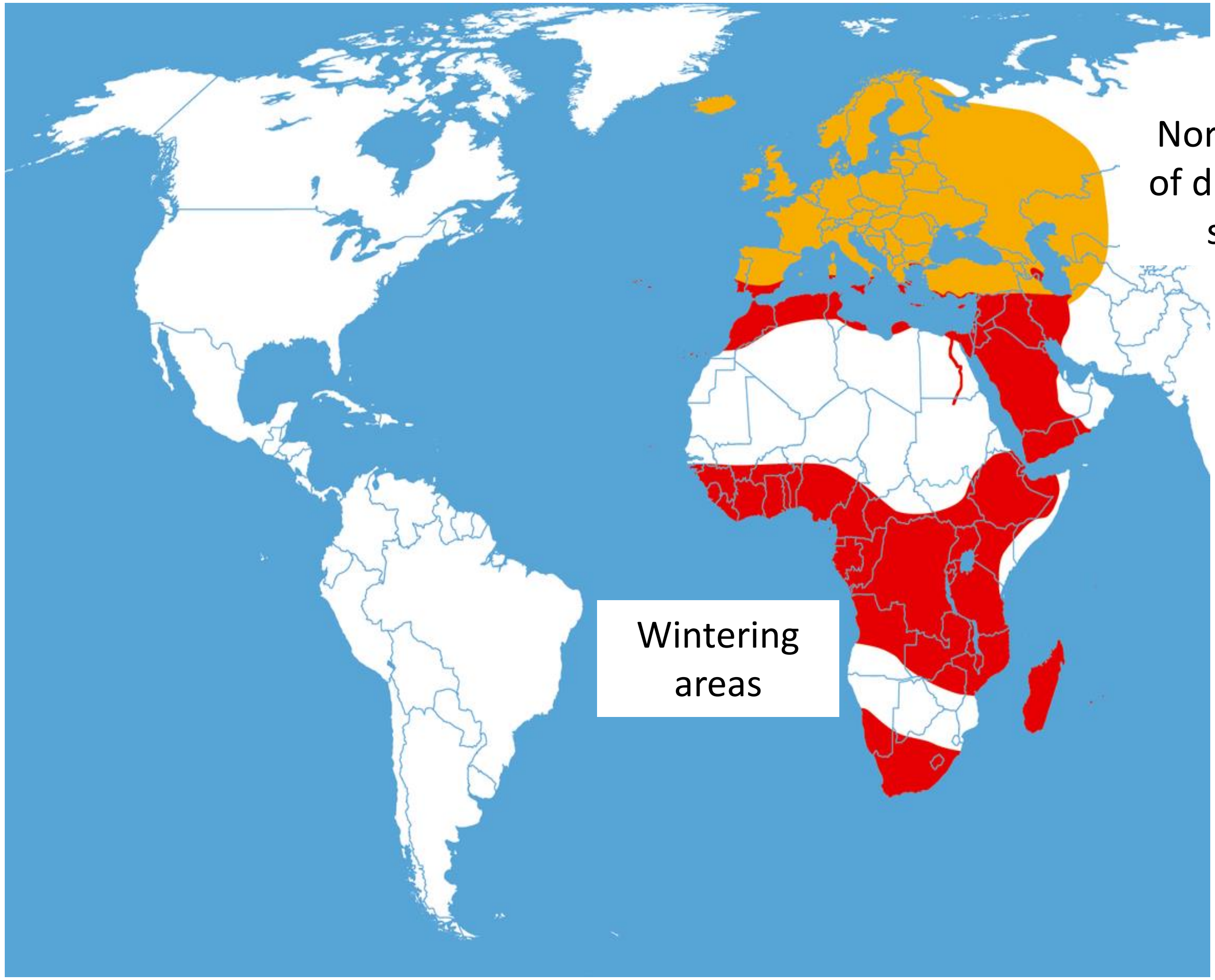


4/5 generations per year

Natural Dispersion of Insects

Example of Monarchus _moth_

Between Africa & Europe



Northern limit of dispersion in summer

2 generations per year April-Aug

Summary

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- Small range of dispersion
- For mosquitoes from 100m to 10km

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Entomological Inoculation Rate (EIR)

- Proxy of "malaria transmission"
- Closely related to the endemicity level







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Human Assisted Dispersion of Insects

Dr Florence FOURNET
mls.entomo@ird.fr

Institut de Recherche pour le Développement
FRANCE
French National Research Institute for Sustainable Development

Definitions

- **Dispersion:** Process by which individuals or populations colonise or recolonise a territory

  - **Human assisted Dispersion:** May occur through plane, boat and/or car

Between two localities on earth, the distance-time may always be lower than 48 hours.

Huge increase of trade and mobility in the last centuries

Importance of the global changes (traffic)

Air traffic

Maritime traffic

Examples of transports due to Human traffic

- ***Anopheles arabiensis*** from Africa to Brazil
- ***Anopheles gambiae*** from Madagascar to Mauritius
- ***Tunga penetrans*** from Tropical America to Africa, then to Madagascar
- Many cases of 'airport malaria'
- ***Aedes aegypti*** all over the world
- ***Aedes albopictus*** now in the 5 continents

Example of Human assisted Dispersion – Asian Tiger Mosquito

Aedes albopictus

Example of Human assisted Dispersion – Asian Tiger Mosquito

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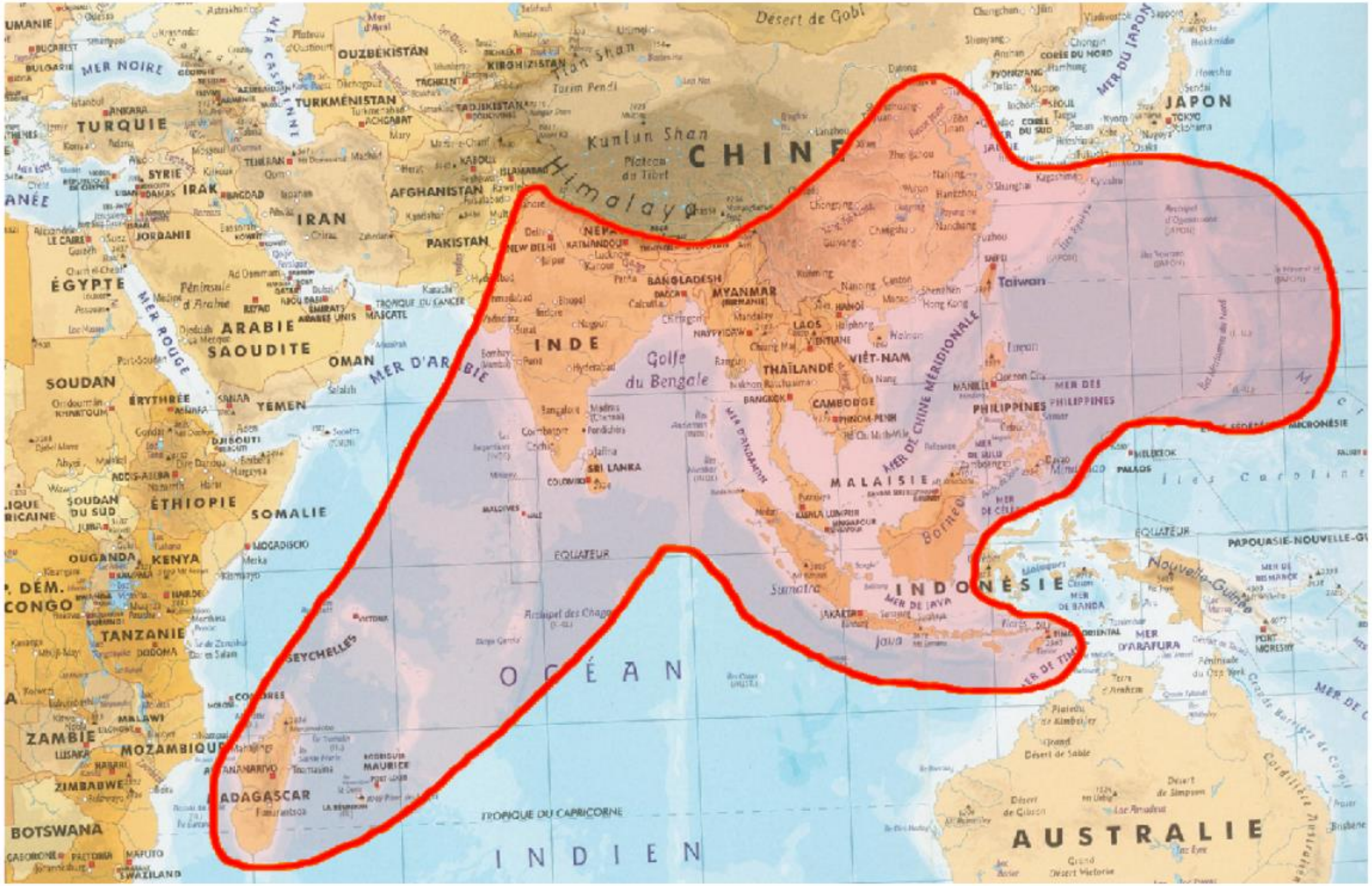
Distribution area of *Aedes albopictus* around 1900



Rhodain F 1996 - **Problèmes posés par l'expansion d'Aedes albopictus**. *Bull Soc Path Ex, 1996, 89, 137-141*

Example of Human assisted Dispersion – Asian Tiger Mosquito

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Mechanisms of dispersion

- ***A passive transportation due to globalisation***

Example of Human assisted Dispersion – Asian Tiger Mosquito

Mechanisms of dispersion

- ***A passive transportation due to globalisation***

Intercontinental trades of tires – mainly by boats

- Eggs are resistant to desiccation

Example of Human assisted Dispersion – Asian Tiger Mosquito

Mechanisms of dispersion

- ***A passive transportation due to globalisation***

Intercontinental trades of tires – mainly by boats

- Eggs are resistant to desiccation

Intercontinental dissemination – short distance – mainly by cars and/or trucks

- Adults – spontaneously enter in cars

In great contrast with the natural dispersion
(about 150 m per adult female)

- Eggs too

Signalisation of construction site

Example of Human assisted Dispersion – Asian Tiger Mosquito

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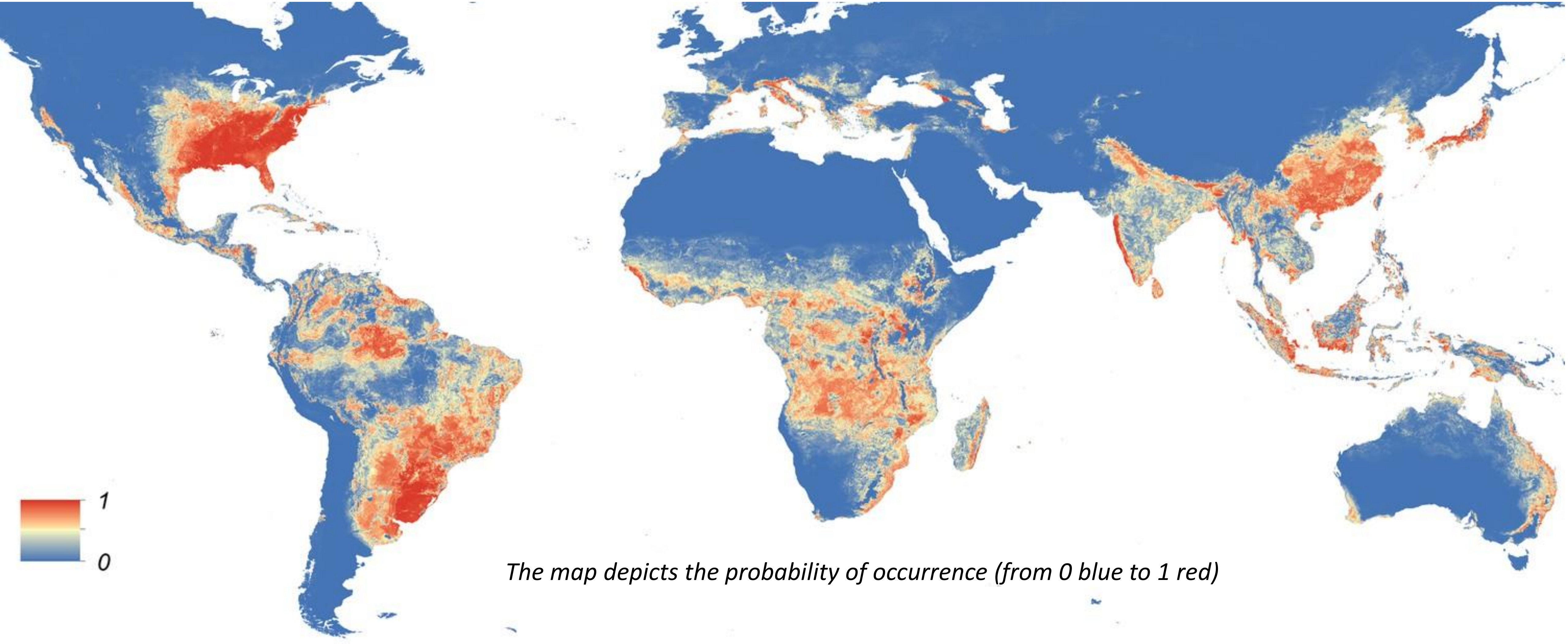
Kraemer *et al.* 2015 – **The global distribution of the arbovirus vectors *Aedes aegypti* and *Aedes albopictus***. *Elife 2015 June 30:4. doi: 10.7554 eLife.08347*

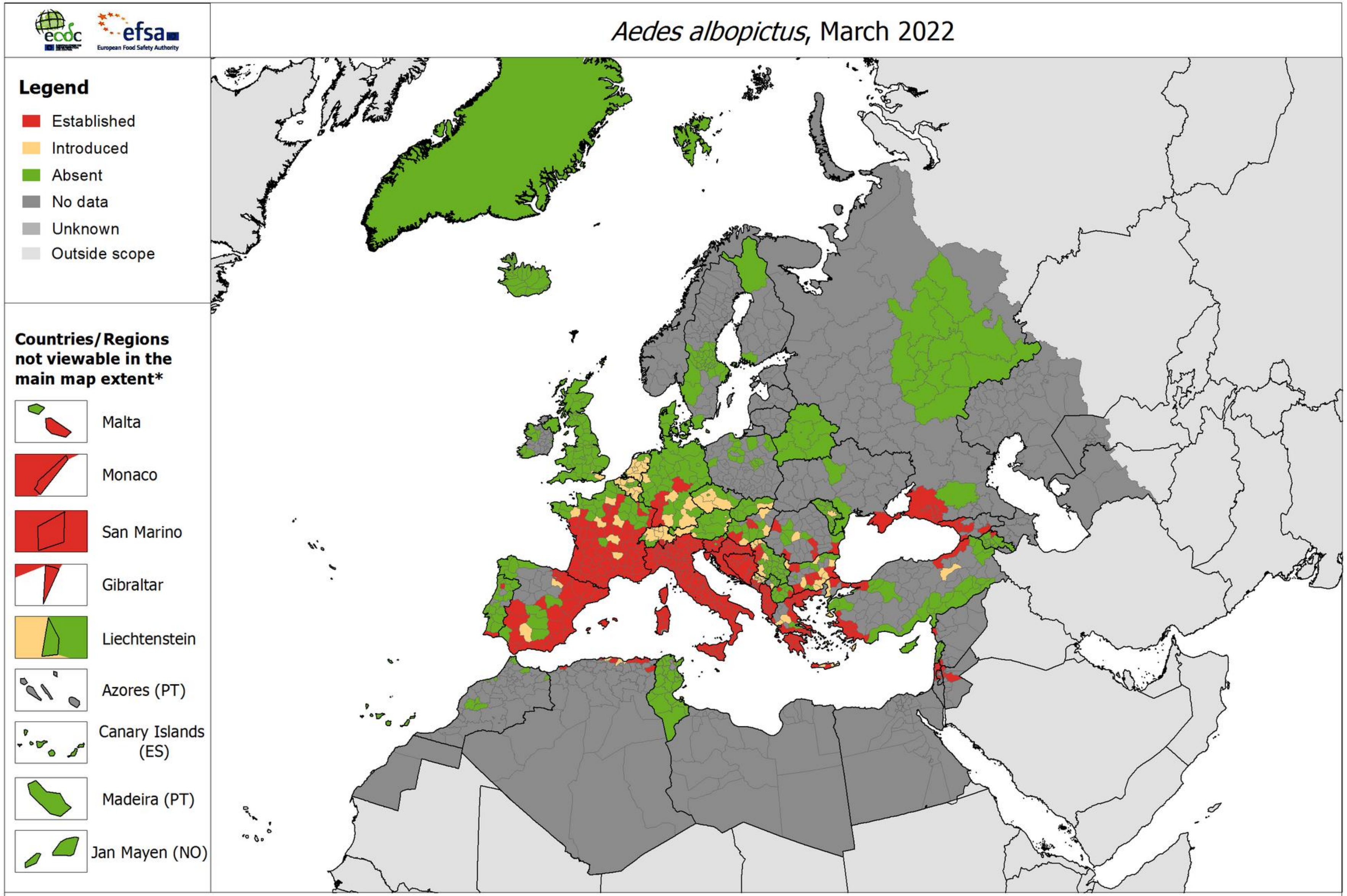
Global map of the predicted distribution of *Aedes albopictus*



The map depicts the probability of occurrence (from 0 blue to 1 red)

Example of Human assisted Dispersion – *Asian Tiger Mosquito*

***Aedes albopictus* –**
Distribution Map from
European Center for Disease
prevention and Control (ECDC)
– March 2022



ECDC and EFSA, map produced on 8 Mar 2022. Data presented in this map are collected by the VectorNet project. Maps are validated by external experts prior to publication. Please note that the depicted data do not reflect the official views of the countries.
* Countries/Regions are displayed at different scales to facilitate their visualisation.The boundaries and names shown on this map do not imply official endorsement or acceptance by the European Union.Administrative boundaries © EuroGeographics, UNFAO.

Example of Human assisted Dispersion – *Asian Tiger Mosquito*

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***Aedes albopictus* –** Distribution Map – around French departments in Metropolitan France

2004

Aedes albopictus presence

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Example of Human assisted Dispersion – *Asian Tiger Mosquito*

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2006

Aedes albopictus presence

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Example of Human assisted Dispersion – *Asian Tiger Mosquito*

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2007

Aedes albopictus presence

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Example of Human assisted Dispersion – Asian Tiger Mosquito

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2010

Aedes albopictus presence

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Example of Human assisted Dispersion – Asian Tiger Mosquito

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2011

Aedes albopictus presence

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Example of Human assisted Dispersion – *Asian Tiger Mosquito*

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2012

Aedes albopictus presence

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Example of Human assisted Dispersion – *Asian Tiger Mosquito*

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2013

Aedes albopictus presence

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Example of Human assisted Dispersion – Asian Tiger Mosquito

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2014

Aedes albopictus presence

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Example of Human assisted Dispersion – *Asian Tiger Mosquito*

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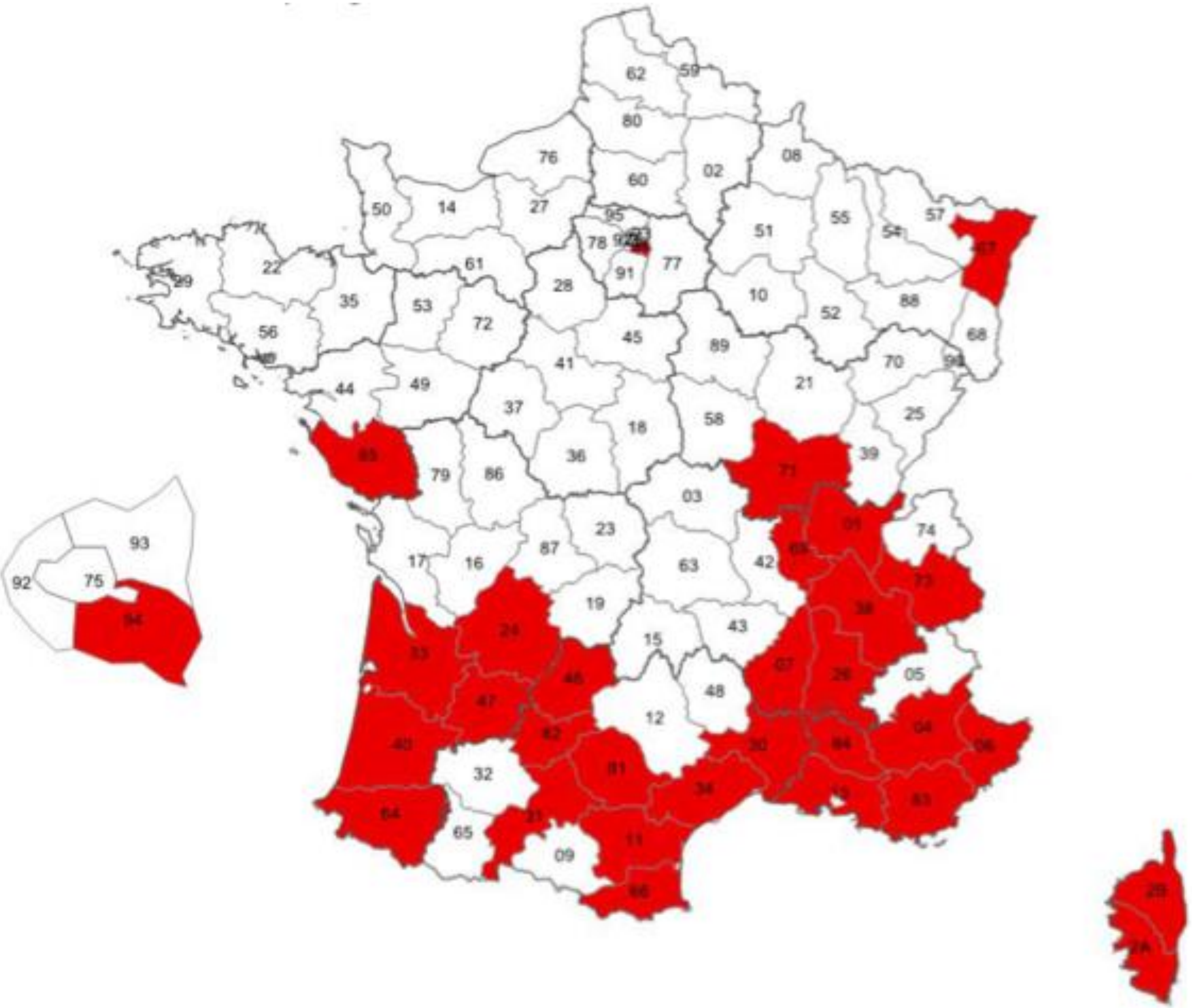
2015



Aedes albopictus presence

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Example of Human assisted Dispersion – Asian Tiger Mosquito

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2016

Aedes albopictus presence

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Example of Human assisted Dispersion – *Asian Tiger Mosquito*

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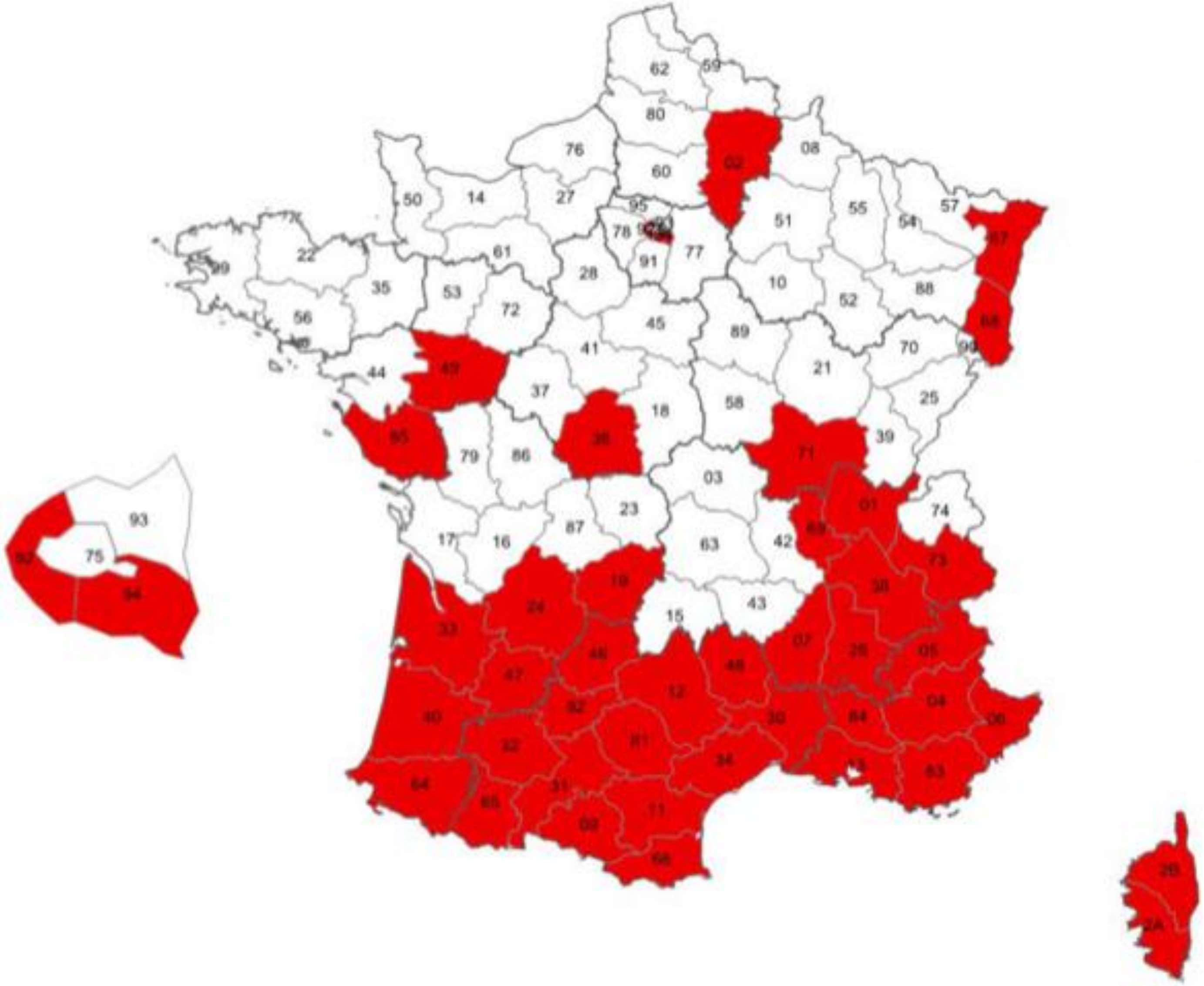
2017



Aedes albopictus presence

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Example of Human assisted Dispersion – Asian Tiger Mosquito

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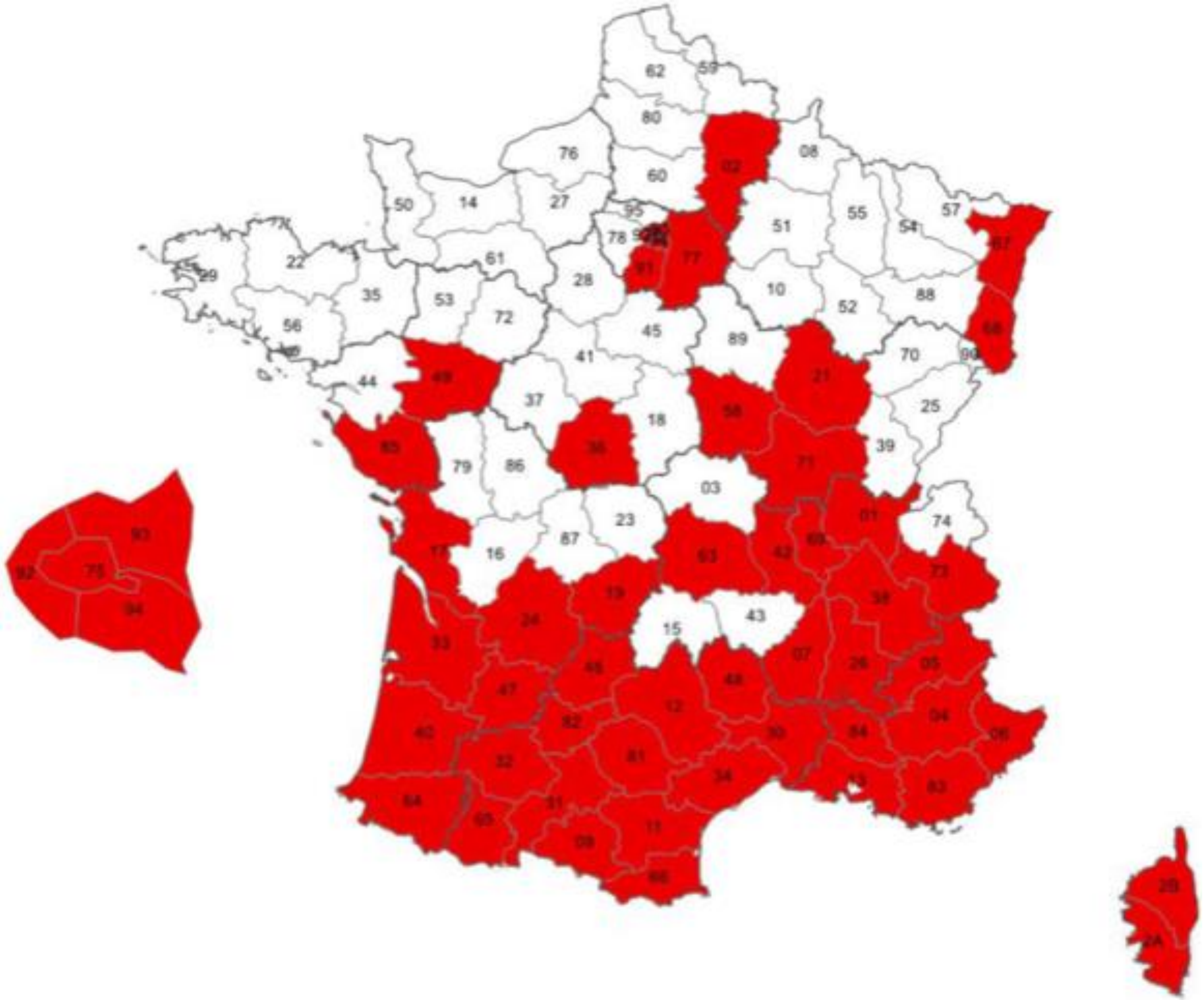
2018



Aedes albopictus presence

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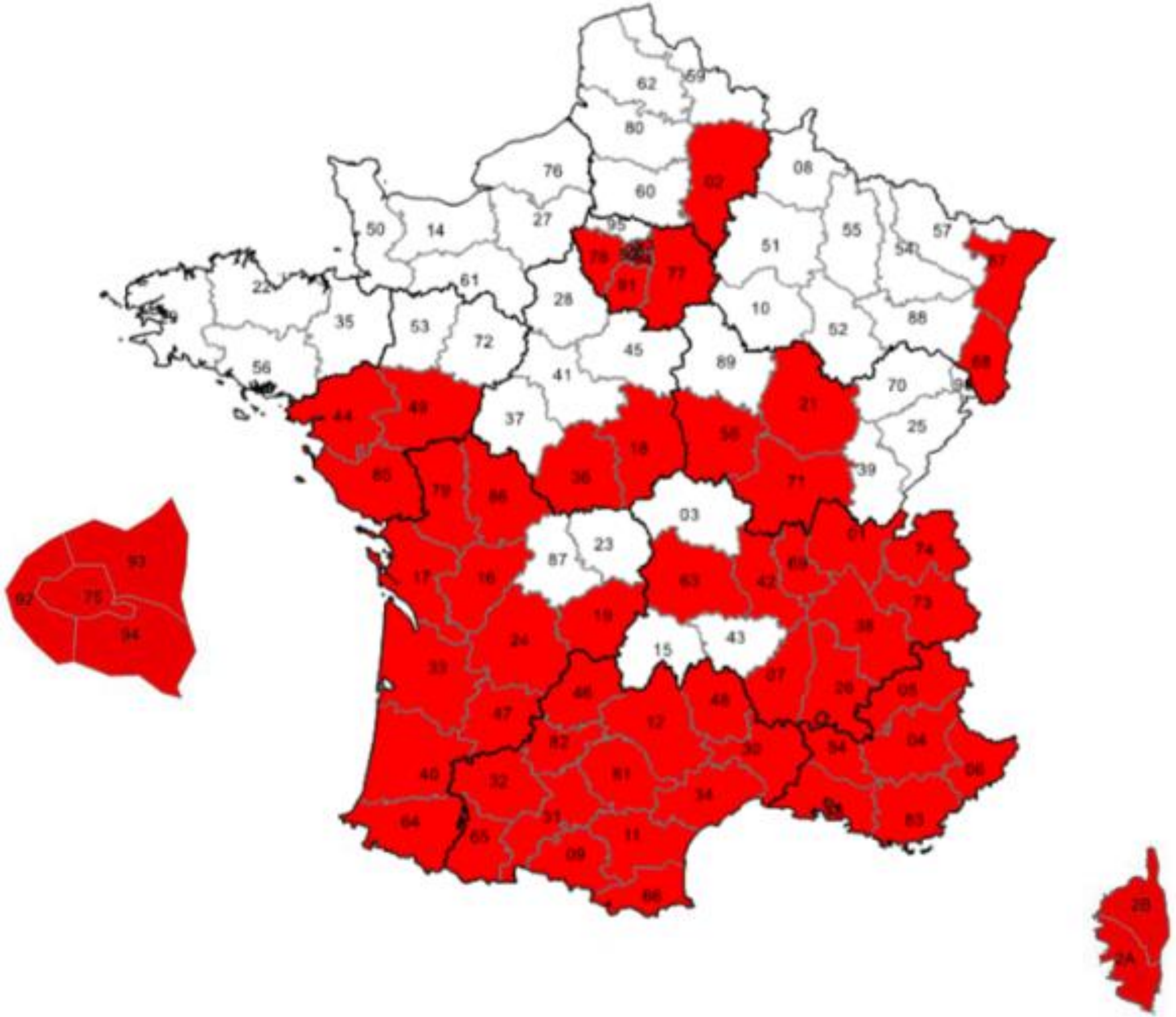
2019



Aedes albopictus presence

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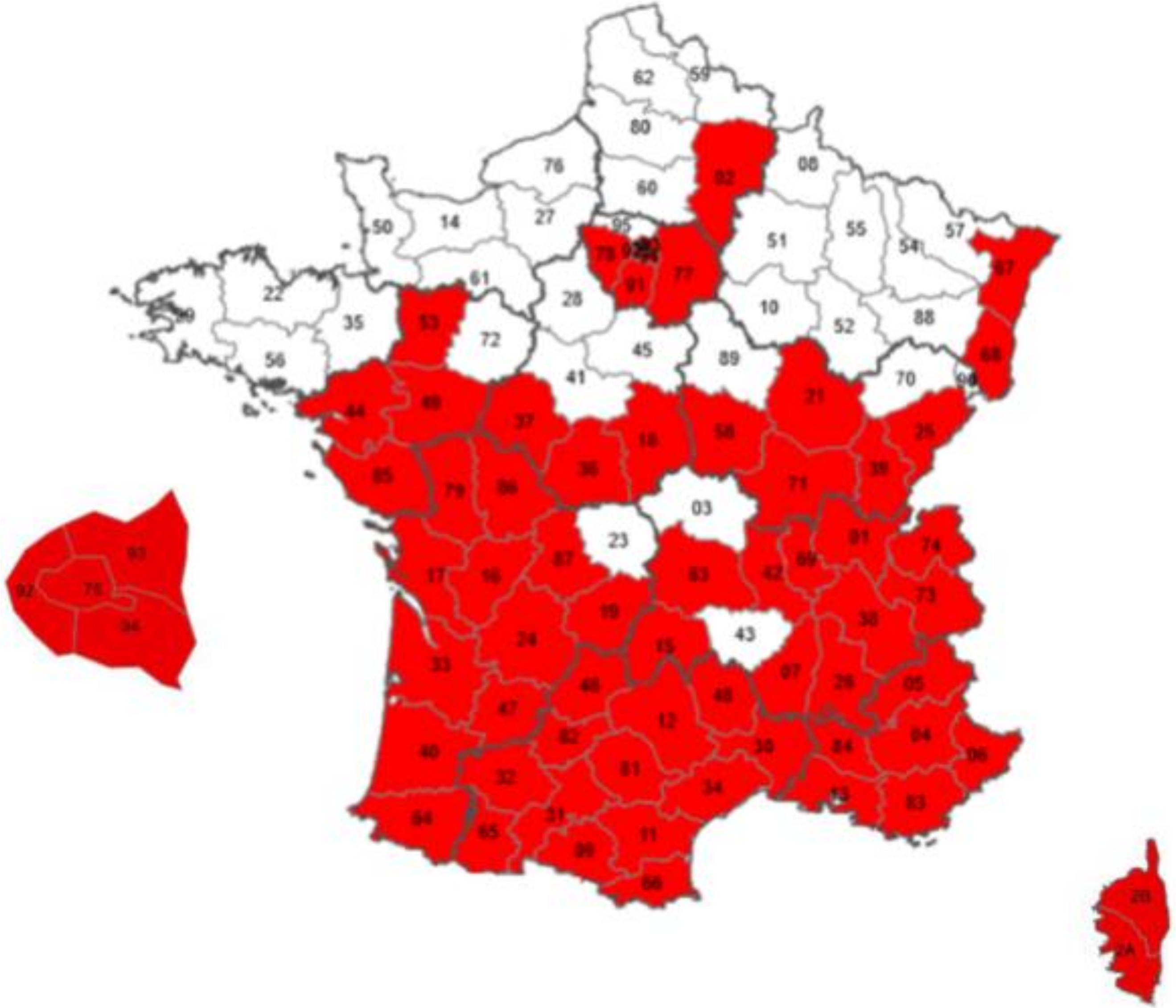
2020



Aedes albopictus presence

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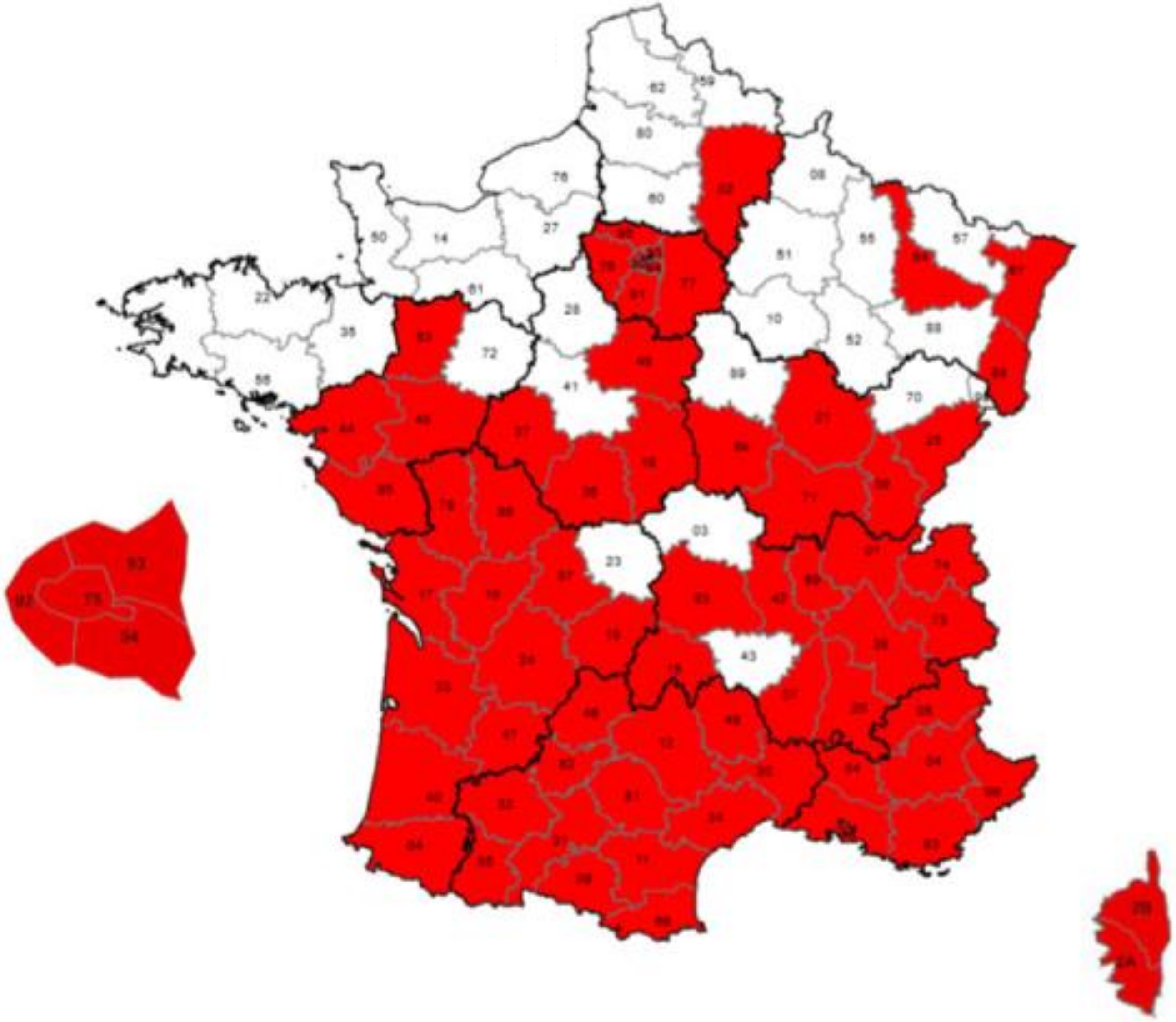
2021



Aedes albopictus presence

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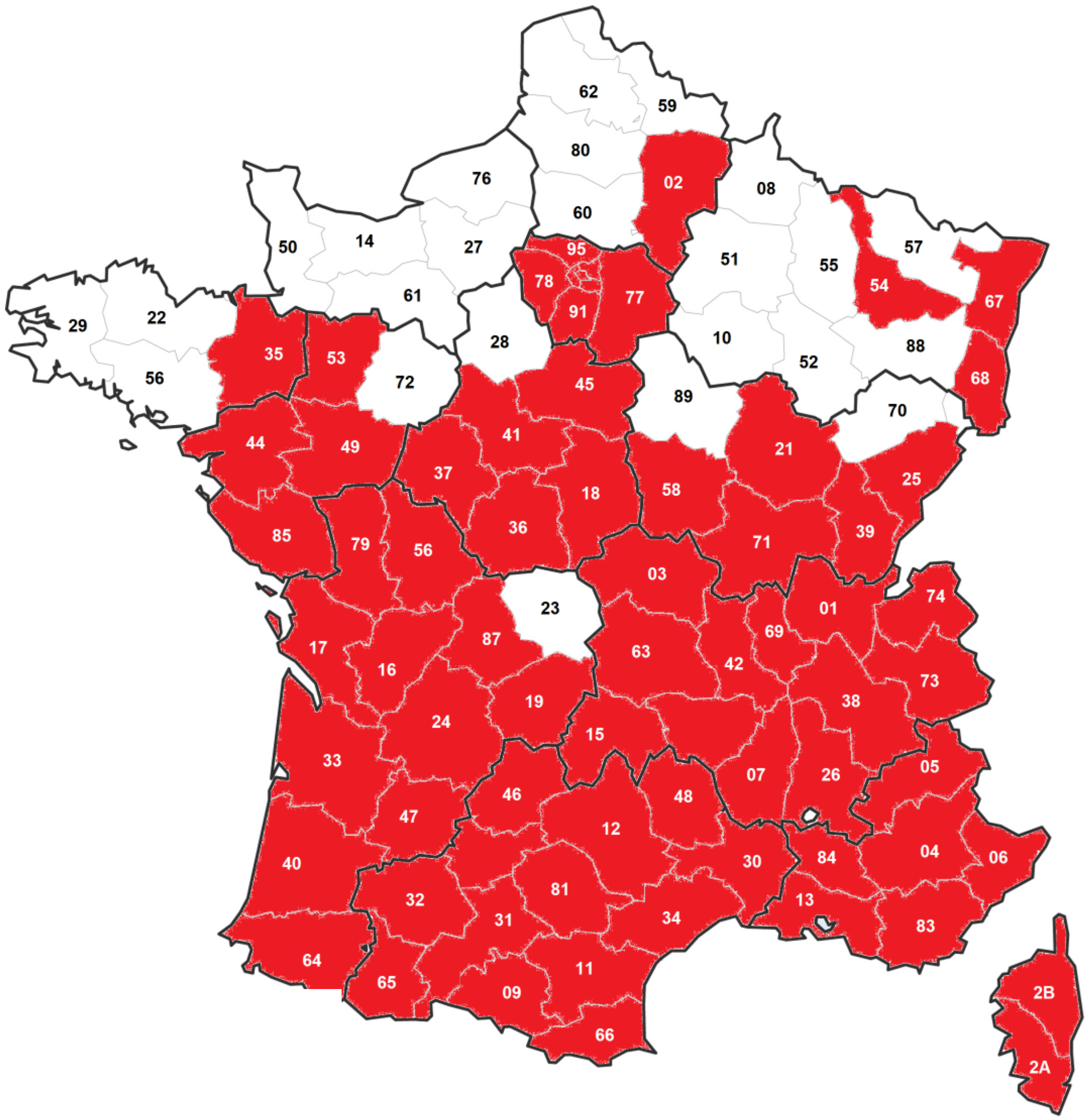
2022



■ *Aedes albopictus* presence

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Natural dispersion

- Small range of dispersion
- For mosquitoes from 100m to 10km

Assisted dispersion

- Invasive species – closely related to human environment
- Dispersion quite unlimited
- Huge consequences in terms of nuisance and Public Health

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Observation of mosquitoes

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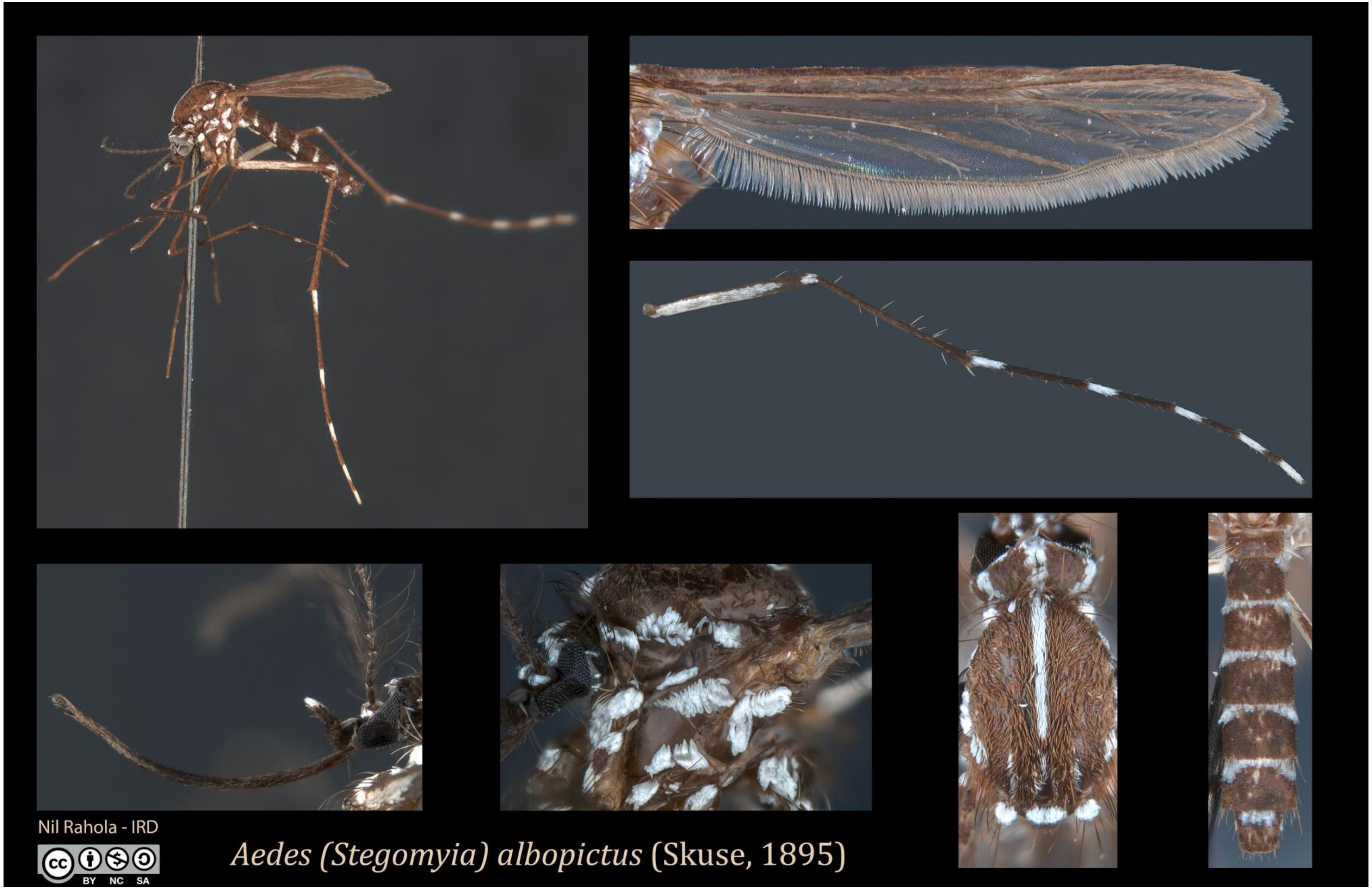
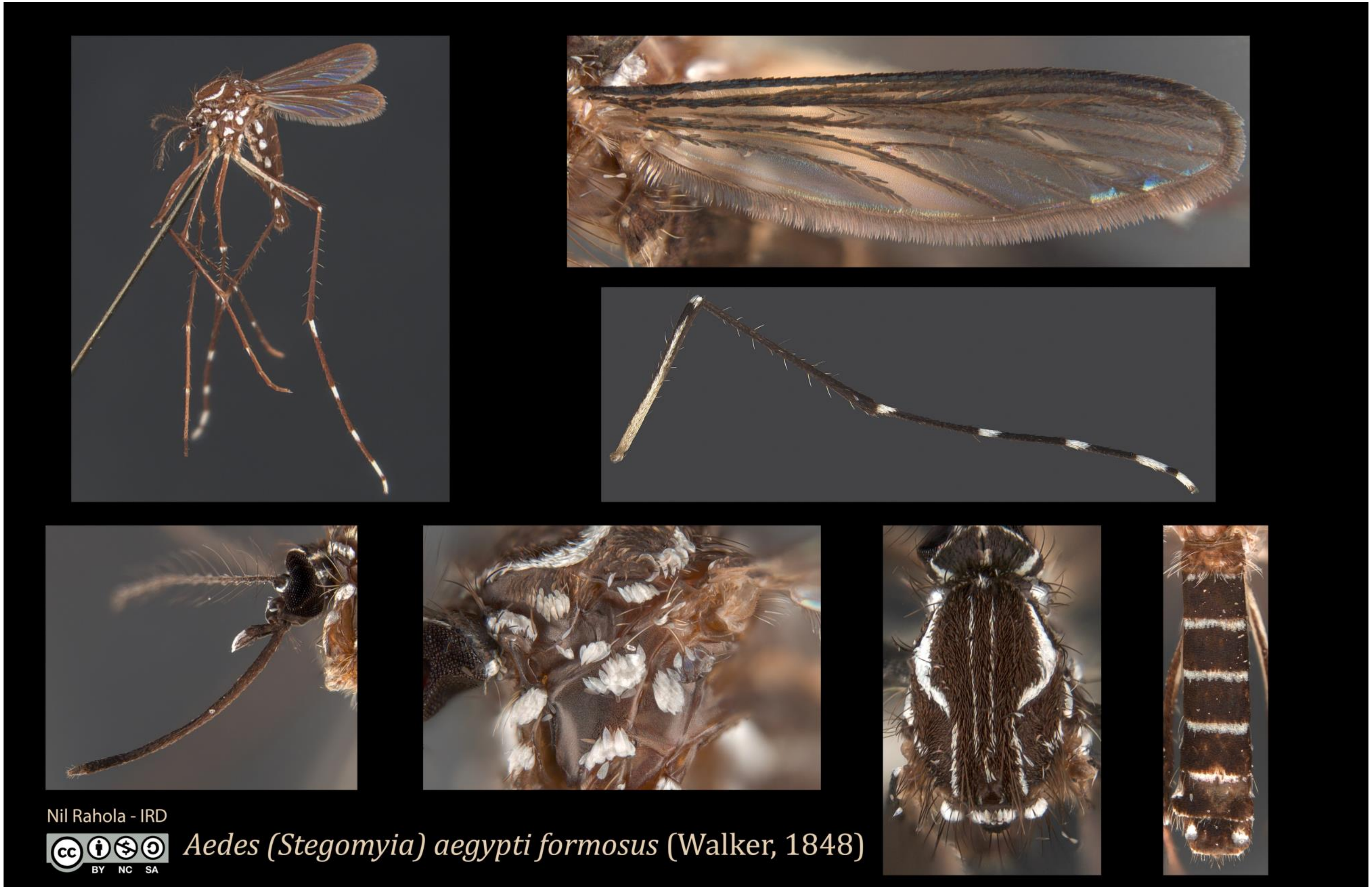
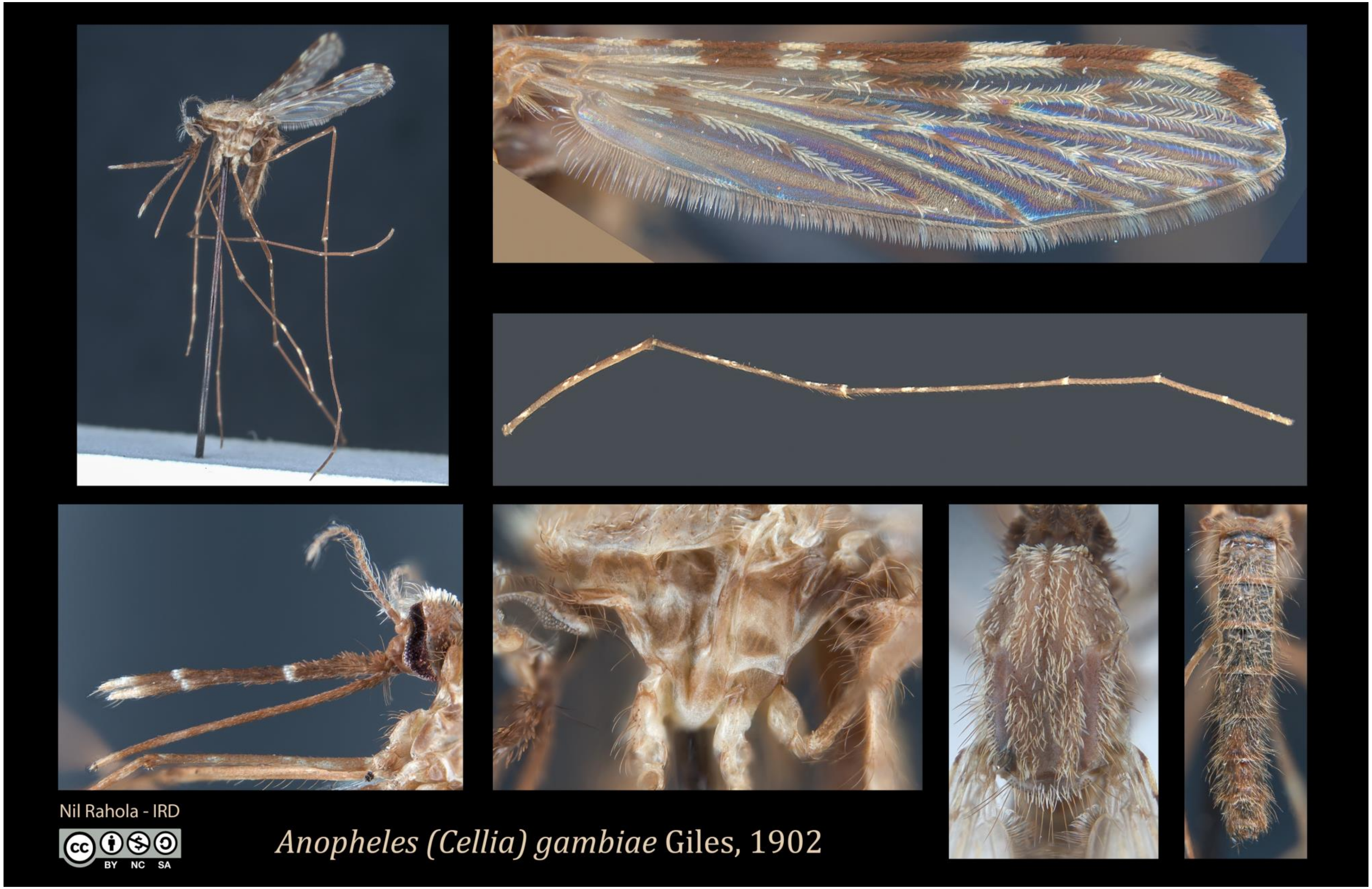
Aedes albopictus



Aedes aegypti

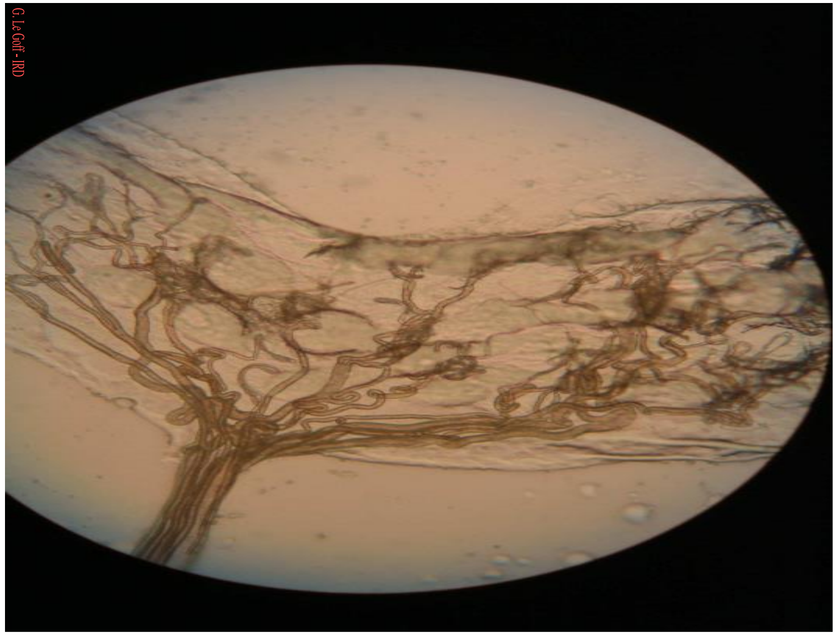


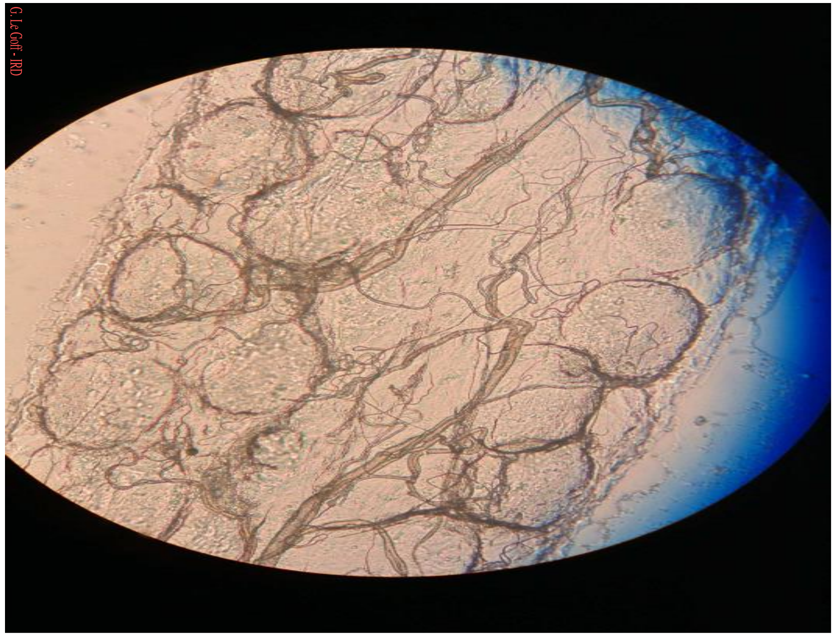
Anopheles gambiae



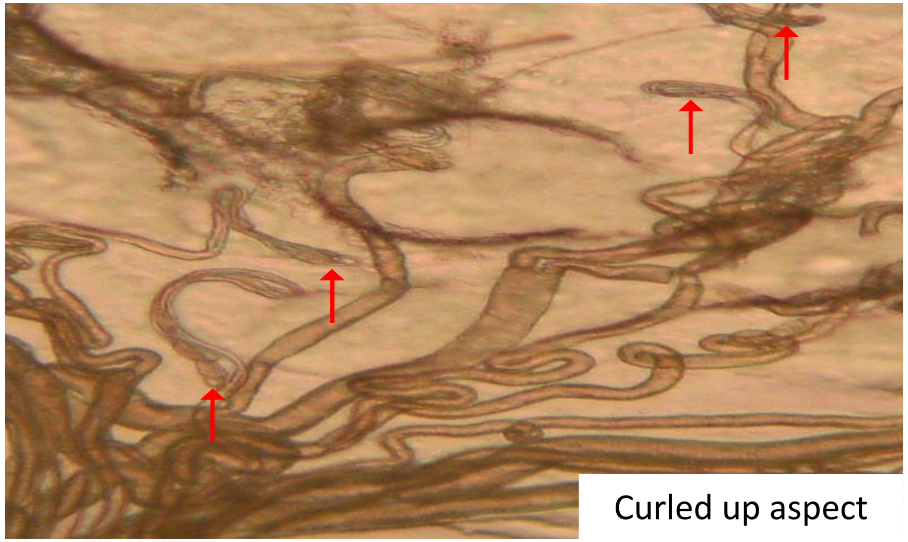
Culex pipiens

Mosquito Ovaries

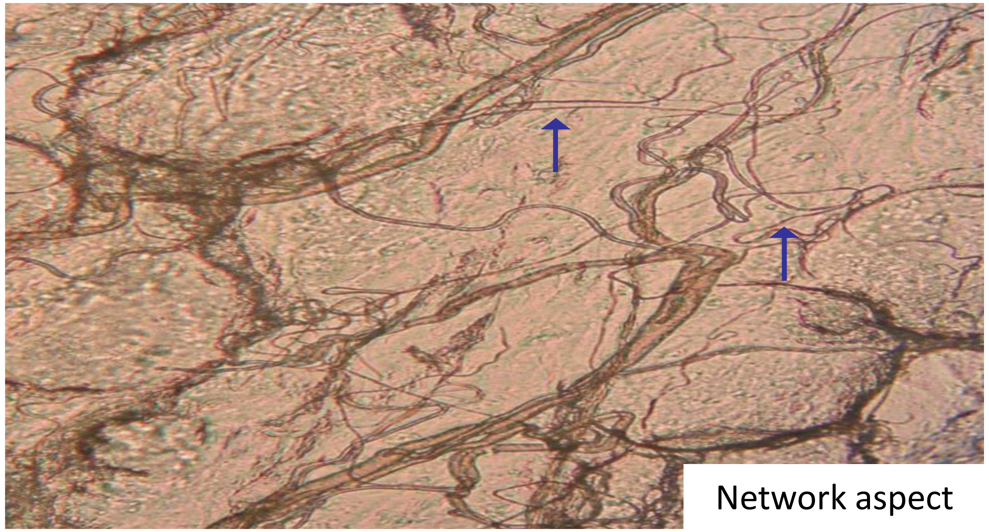




Nulliparous female



Parous female









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Vector Control

Igor Pajovic

Assistant Professor – University of Montenegro

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