

Root causes / drivers of disease and how to manage them

• Deformed wing virus in wild African honeybee colonies

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and on behalf of the Environmental Health theme team, *icip*e

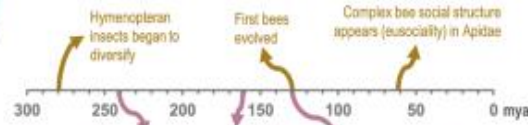


Introduction

- Honeybees are **arthropod insects** from the **Apidae family** (at least 5,700 species of bees out of the 20,000 known);



Bee diversity is greatest in warm temperate and xeric (low moisture) environments, due to strong seasonal flowering events and well-drained soils (the latter are well-suited to ground-nesting bees). The Mediterranean, southern Australia, southern Africa, central Asia, North America, and Brazil have the most diverse bee fauna.

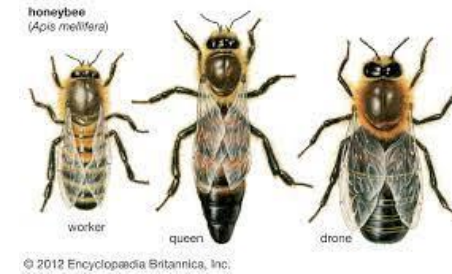


Genetic analyses indicate that the first bees appeared around 130 million years ago, around the same time as eudicot angiosperms (which account for ~70% of all flowering plants). The timeline indicates key events for **bee evolution** and **flowering plants**. Bees are thought to have radiated globally from a Gondwanan origin.

Sourced from, Patel, Vet *al.* (2021). *Ambio* 50, 49–59.

www.icipe.org

- **Highly social** bees (workers, queen drones);



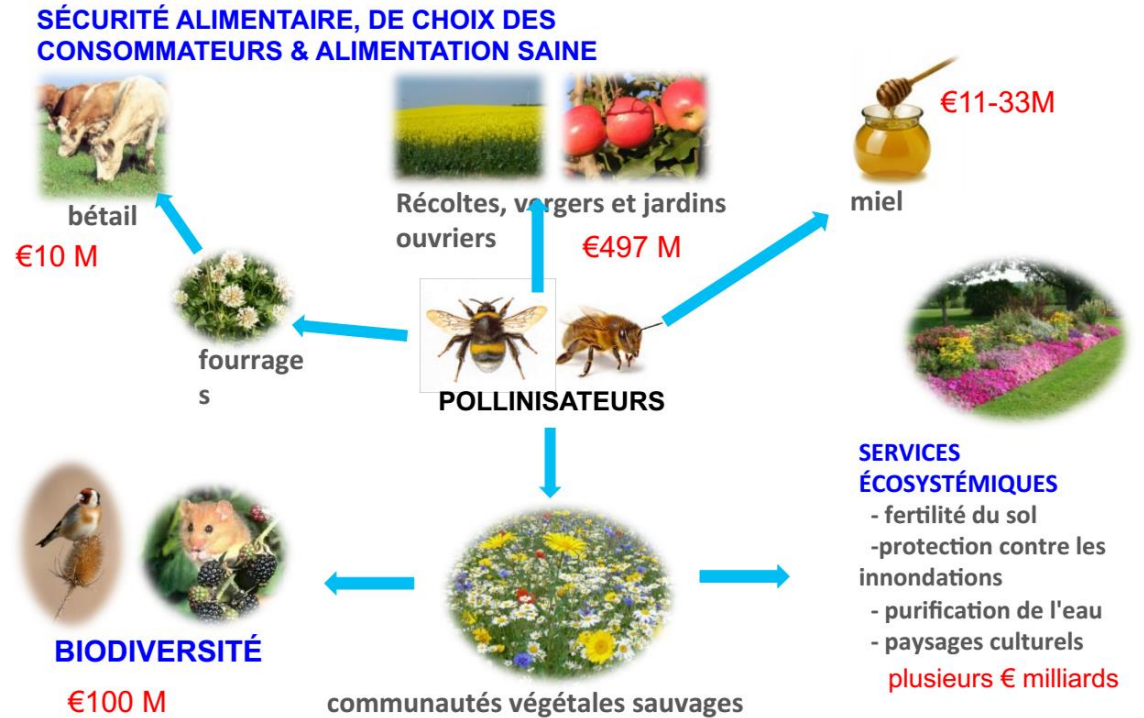
- **Perennial colonial** nests (60,000 workers);
- **8 species (43 subspecies)**: *Apis andreniformis* (the black dwarf honey bee); *Apis cerana* (the eastern honey bee); *Apis dorsata* (the giant honey bee); *Apis florea* (the red dwarf honey bee); *Apis koschevnikovi* (Koschevnikov's honey bee); *Apis laboriosa* (the Himalayan giant honey bee); *Apis mellifera* (the western honey bee); and *Apis nigrocincta* (the Philippine honey bee).

Introduction

□ *Apis mellifera* is essential for **the health of people** and **the planet**:

- important role in the ecological sector **as pollinators** (valuable pollinators in natural habitats and for agricultural crops);
- important role in the commercial sector as a high-valued and income-generating activity (valuable source of carbohydrate, food, and raw materials (cosmetic, pharmacology,...)).

La valeur ajoutée des abeilles pollinisatrices

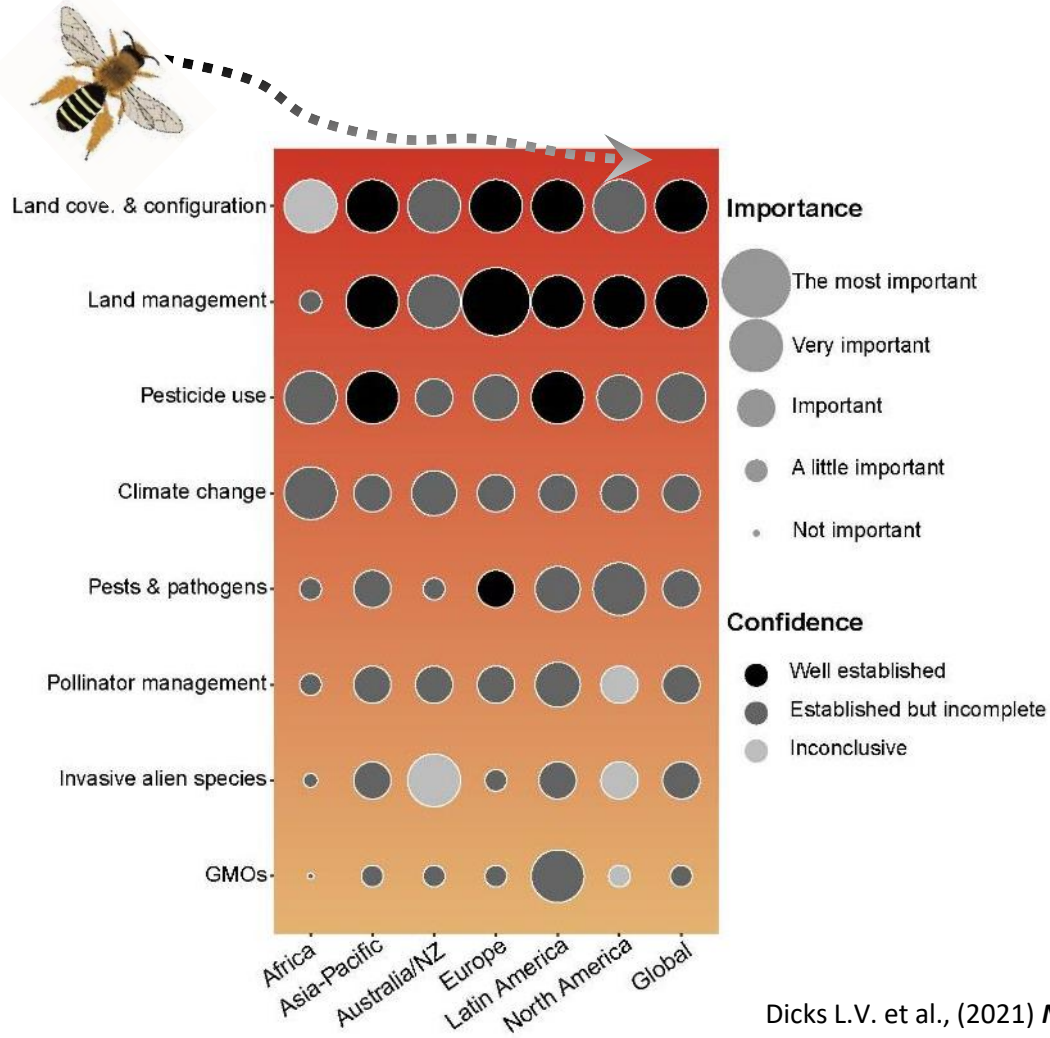


e.g.:

- more than 90% of the world's top 107 crops are visited by bees.
- annual value of pollination service in Kenya alone is **186 m USD**, while in Ethiopia it is estimated at **815 m USD**.
- annual honey production potential in Tanzania is **30,400 tons** which is **4.5% of its estimated production potential of 138,000 tons per year**.
- annual honey production potential in Uganda is **5,000 tons**, which is **1% of its estimated production potential of 500,000 tons**.

Bee decline

What's driving **pollinator decline** in different parts of the world?



Climate change



Landscape degradation



Invasives species and other biotic threats



Bee pests and diseases

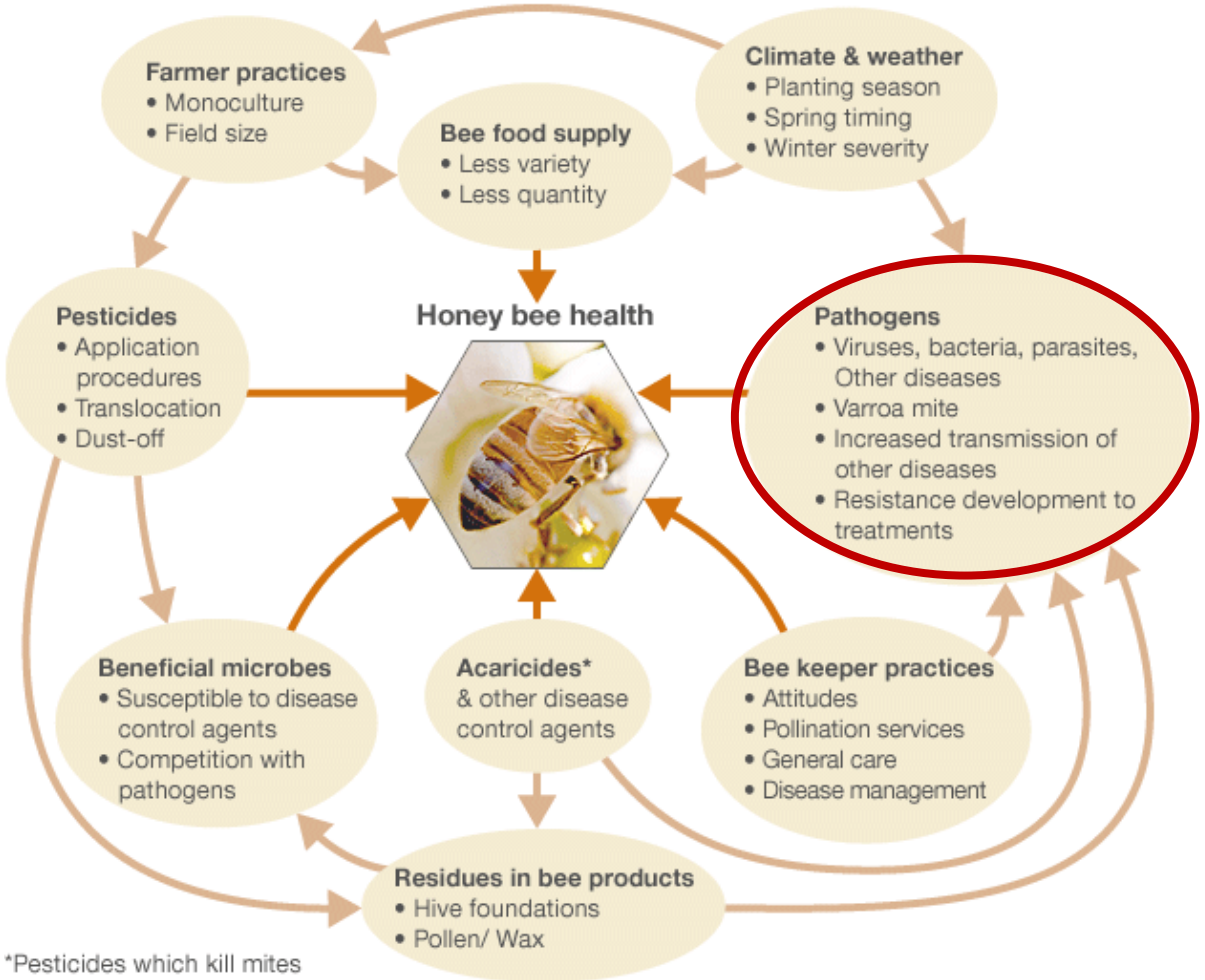


Intensive agriculture

Dicks L.V. et al., (2021) *Nature Ecology and Evolution*.

Stressors affecting *Apis mellifera* colony Health

What's are the stress factors in *Apis mellifera* population?



*Pesticides which kill mites

Source: OPERA Bee health in Europe, 2013

Common pathogens associated with African honeybee

Bacteria

- ❖ American foulbrood (AFB) disease caused by *Paenibacillus larvae*
- ❖ European foulbrood (EFB) disease caused by *Melissococcus plutonius*

Fungi

- ❖ Nosema disease caused by *N. ceranae*, *N. apis*, *N. neumannii*
- ❖ Chalkbrood disease caused by *Ascosphaera apis*

Viruses

Negative-sense single-stranded RNA (-ssRNA) viruses

- ❖ Lake Sinai Virus (LSV1-7)
- ❖ Apis rhabdovirus-1 (ARV-1&2)

Double-stranded DNA (dsDNA) viruses

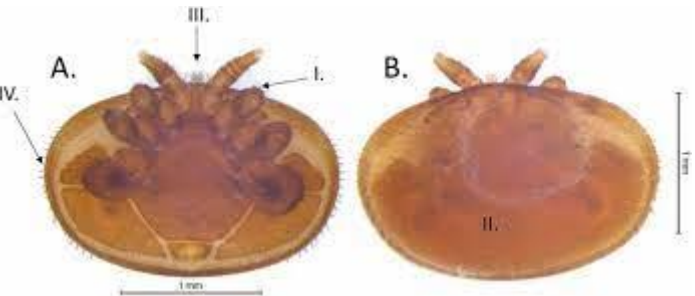
- ❖ *Apis mellifera* filamentous virus (*AmFV*)

Positive-sense single-stranded RNA (+ssRNA) viruses

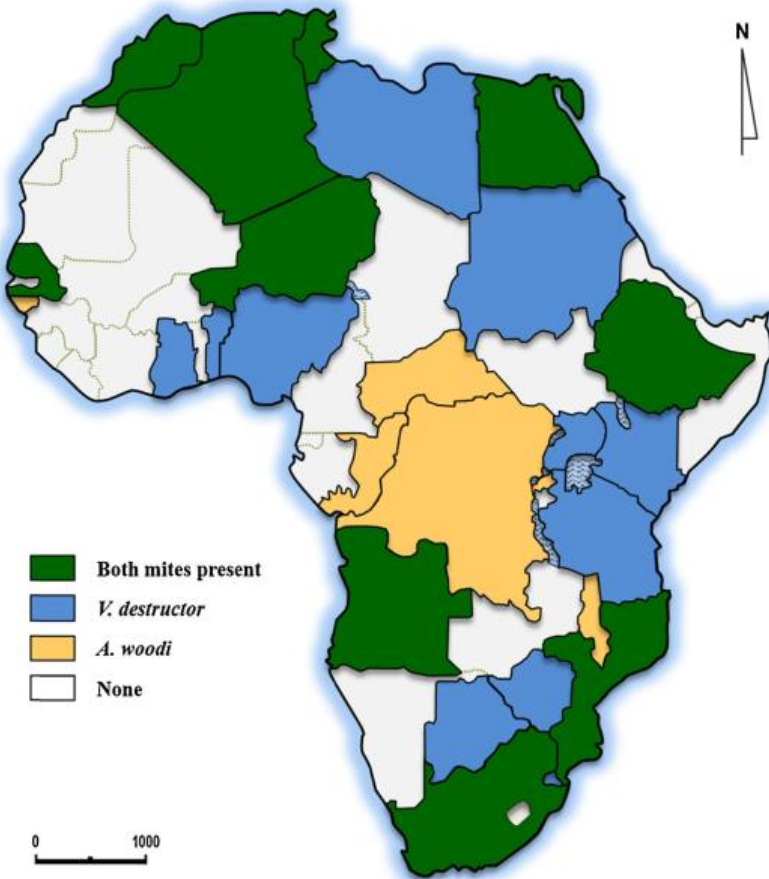
- ❖ Acute bee paralysis virus (ABPV)
- ❖ Israeli acute paralysis virus (IAPV)
- ❖ Sacbrood virus (SBV)
- ❖ Black queen cell virus (BQCV)
- ❖ Chronic bee paralysis virus (CBPV)
- ❖ Deformed wing virus (DWV)

Some of the pathogens are vectored by common pests associated with honeybee

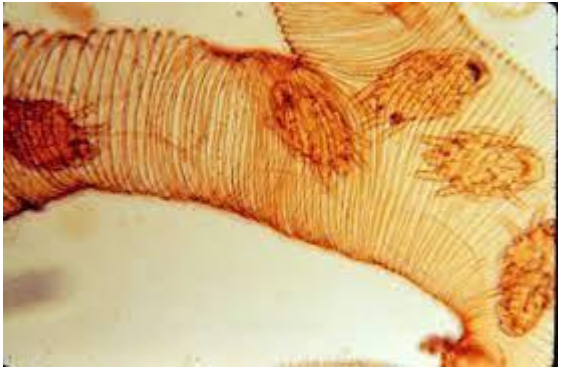
Common pests associated with African honeybees



Varroa mites (*Varroa destructor*)



Distribution of *Varroa* and tracheal mites in Africa



Tracheal mites (*Acarapis woodi*)



Small hive beetle (*Aethina tumida*)

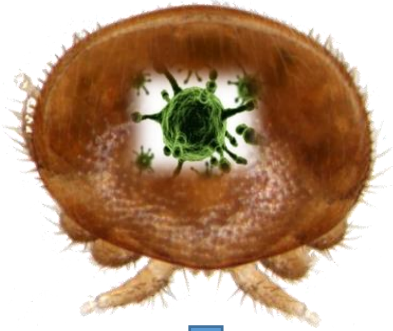


Large hive beetle (*Oplostomus* sp)



Greater wax moth (*Galleria mellonella*)

Varroa destructor (Acari: Varroidae): the major pest and vector of viruses to *Apis mellifera*



Understanding the life cycle of the Varroa mite

1

The queen is the largest in the beehive. She lays up to 2,000 eggs per day in the brood cells.

2

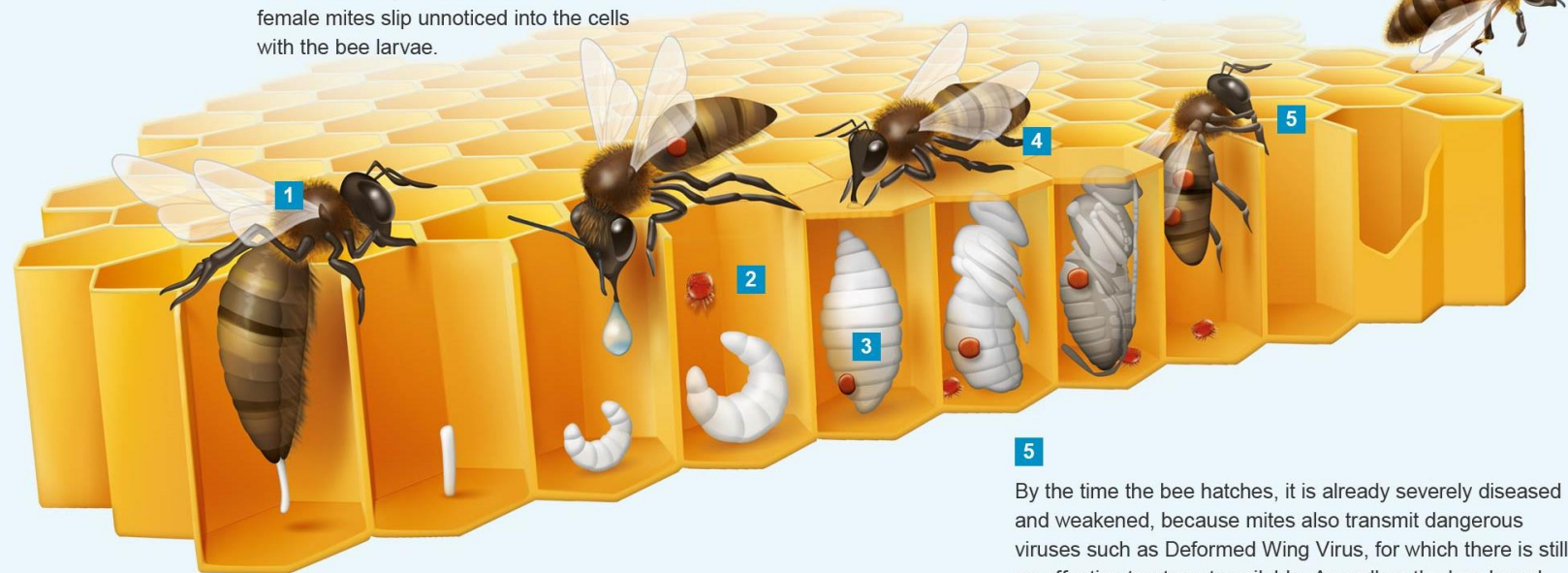
Worker bees often carry Varroa mites with them into the hive. Despite being deaf and blind, these mites can find their ways to the brood chambers thanks to their olfactory sense and numerous fine sensory hairs on the legs. Shortly before the workers cap the brood cells, the female mites slip unnoticed into the cells with the bee larvae.

3

A few days later, the mites lay the first eggs. The first to hatch is always a male. It is followed by up to five more eggs from which female mites hatch.

4

To feed its offspring, the mother mite pierces a feeding hole in the bee pupa which has developed in the meantime. Before the bee hatches, the mites mate again – during the bee season, the Varroa population in a hive can double every four weeks.



5

By the time the bee hatches, it is already severely diseased and weakened, because mites also transmit dangerous viruses such as Deformed Wing Virus, for which there is still no effective treatment available. As well as the bee brood, Varroa can also infest adult bees.

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Common virus pathogens associated with varroa mites on *Apis mellifera*

Viruses

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- ❖ Black queen cell virus (BQCV)
- ❖ Chronic bee paralysis virus (CBPV)
- ❖ **Deformed wing virus (DWV)**

Main honeybee disease but it is detected in **65 arthropod species** spanning **8 insect orders** and **3 orders of Arachnida.**



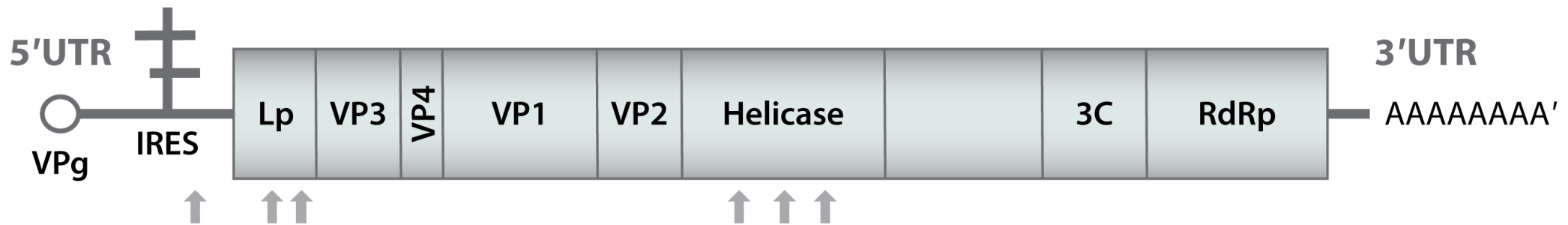
Deformed Wing Virus (DWV) in *Apis mellifera*

- ❑ DWV is a newly emerging pathogen that within 40 years from its discovery has become **the most widespread insect virus**.
- ❑ DWV has been detected in over **50%** of all honeybee colonies in **32 countries** at high viral loads.
- ❑ DWV affect all honeybee castes (queens, workers, and drones) and all developmental stages (sperm, eggs, larvae, and pupae).

The success of DWV is due to its **close association with an ectoparasitic mite (*Varroa destructor*)** that lives on honeybees and during the past 70 years has spread globally.

Genome of Deformed Wing Virus in *Apis mellifera*

Deformed wing virus is a **picorna-like virus** from the **Flaviridae family** and **genus Iflavirus**. The single-stranded positive-sense RNA genome **encodes a polyprotein flanked by 5'- and 3'-untranslated regions (UTR)**.




 Martin SJ, Brettell LE. 2019.
Annu. Rev. Virol. 6:49–69

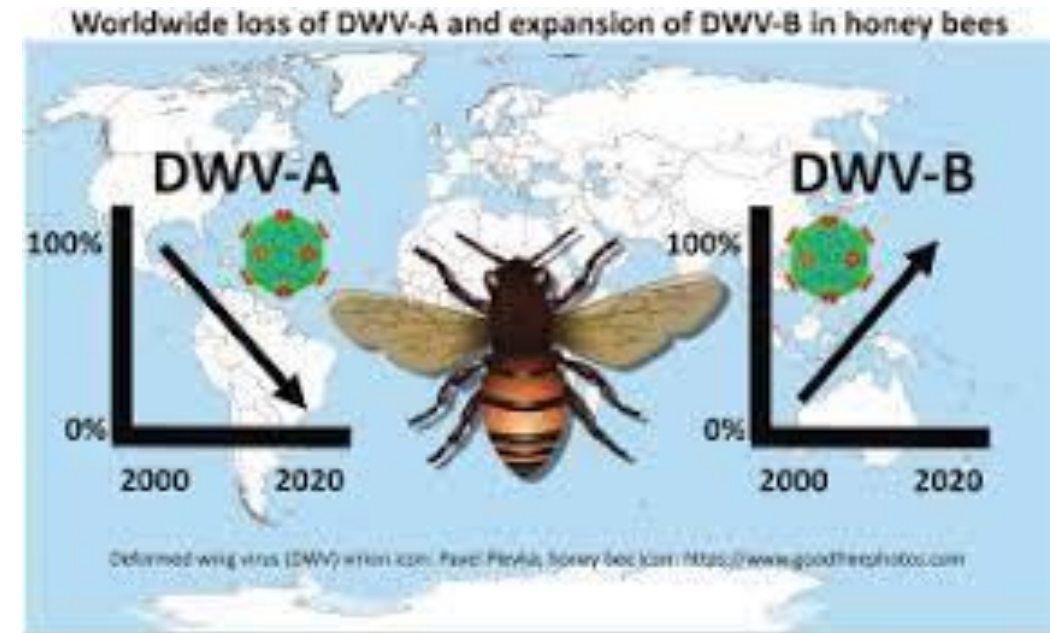
Figure: The basic structure of the DWV genome: The IRES in the 5' untranslated region may initiate translation of the polyprotein. Arrows indicate some of the key recombination regions. Abbreviations: **DWV**, deformed wing virus; **IRES**, internal ribosome entry site; **Lp**, leader protein; **RdRp**, RNA-dependent RNA polymerase; **VPg**, viral protein genome-linked.

Types of Deformed Wing Virus in *Apis mellifera*

❑ **3 “master” variants** of DWV were discovered:

- DWV-A (DWV genotype A)
- DWV-B (DWV genotype B, also known as *Varroa destructor virus-1* (VDV-1))
- DWV-C (DWV type C)

❑ **Many recombinants**



Deformed wing virus in African *Apis mellifera*

- ❑ Pathogen is present in Africa
- ❑ DWV-B is the most prevalent
- ❑ DWV-A, DWV-B and recombinants (DWV-VDV-1)
- ❑ Very few studies exist and data on DWV genotypes infecting African honeybee

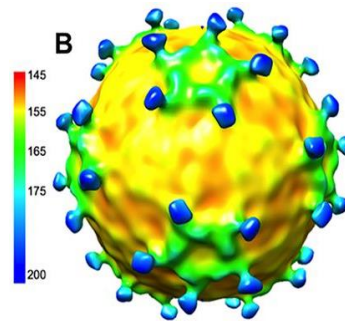
Country	Prevalence	Reference
Algeria	40%	Loucif-Ayad W et al. (2013) Phytoparasitica
Egypt	20%	Haddad N et al. (2018) Apidologie
Kenya	50%	Ongus JR et al. (2017). International Journal of Tropical Insect Sciences
Libya	20%	Haddad N et al.(2018) Apidologie
Marocco	45%	Haddad N et al. (2018) Apidologie
South Africa	13%	Strauss U et al. (2013) Journal of Invertebrate. Pathology
Tunisia	34%	Abdi K et al. (2018) Insectology
Zanzibar	28%	icipe Bee Health
Soudan	0%	Haddad N et al. (2018) Apidologie
Mauritius	0%	icipe Bee Health unit
Sychelles	0%	icipe Bee Health unit

Etiology of Deformed Wing Virus in *Apis mellifera*

- Synergy between parasitic varroa mite load and health status of the colony.



Varroa mite



DWV



Mode of transmission in *Apis mellifera*

□ Horizontal transmission:

- by **Varroa mite** when feeding on larvae, pupae and bee hemolymph.

This mode transformed this covert virus into a highly virulent virus. Led to **overt symptoms**

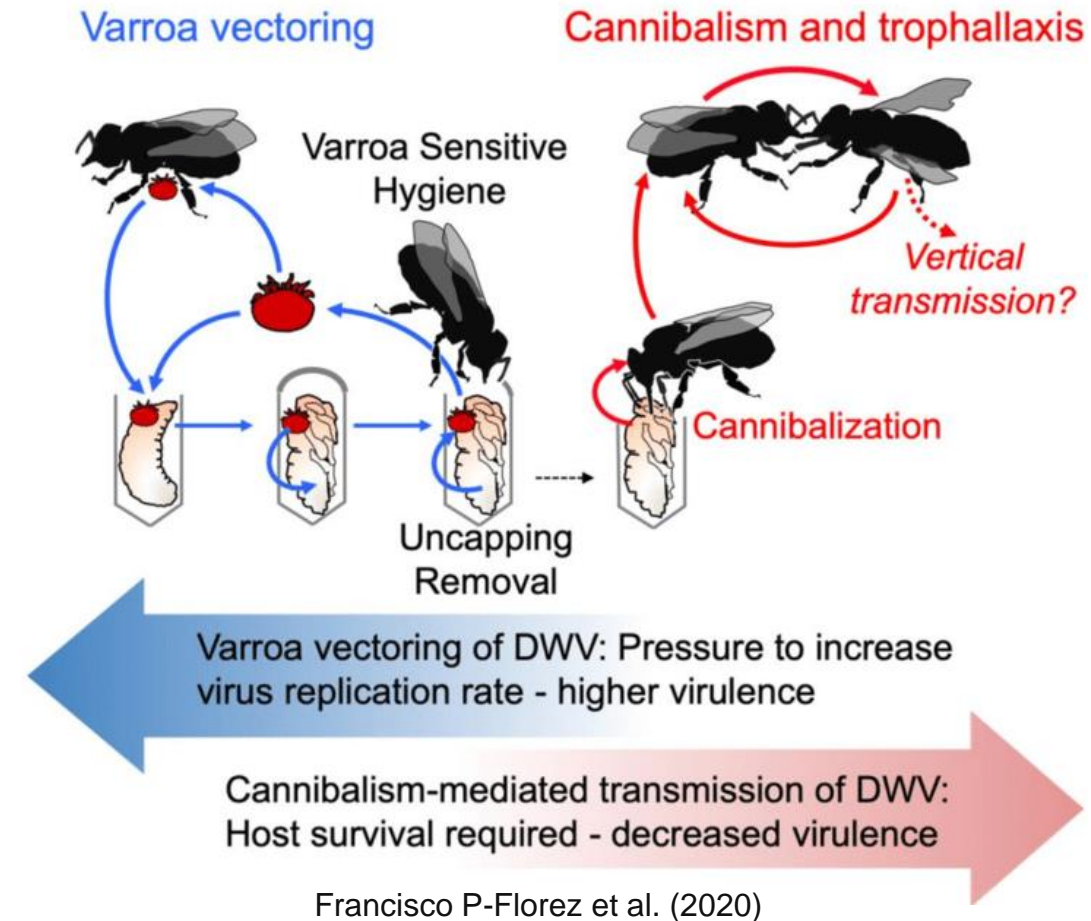
- by **adult bees** to larvae and among adult bees through common visits to flowers, pollen, trophalactic activities, hygienic behavior, grooming and cannibalism.

led to **covert symptoms**.

□ Vertical transmission:

- by **the queen's unfertilized eggs** or **drone sperm** has also been reported.

led to **covert symptoms**.



Symptoms of Deformed wing virus in *Apis mellifera*

❑ Symptomatic DWV on adult honeybee :

- twisted wings
- shrivelled wings
- bloated abdomens
- decreased body size
- body discoloration
- paralysis
- rapid mortality of emerging adult bees

Infected *Varroa* mite as vector



Pupae infected



❑ Asymptomatic DWV on adult honeybee :

- reduce lifespan and precocious behaviour
- impaired learning and memory
- perturbed immunity

Infected adult bees as vector



Adult bee infected

Drivers of Deformed Wing Virus in Africa

- ❑ Immunosuppressive of the bees by virus pathogens
- ❑ Pesticides that weaken bee colony
- ❑ Poor nutrition



Neonic pesticide reduces bees' ability to cleanse deadly mite. (University of Guelph Honey Bee Research Centre)

How to manage Deformed Wing Virus

The most effect way to treat for DWV is by controlling mite populations within domesticated colonies:



Swarms from wild colonies
supplies African beekeepers



Swarms from beekeeping in
Africa supplies wild colonies



African People & Wildlife Fund / Felipe Rodriguez

How to manage Deformed Wing Virus

Some management methods:

- Use resistant lines of bees with good hygienic behavior
- Use resistant lines of bees with good grooming behavior
- Maintain strong colonies with a young, prolific queen
- Use of miticides

Conclusions

- Deformed wing virus is present in African honeybees.
- **DWV B** is the most common and can affect >50% of colonies.
- Domesticated colonies infected by DWV **through swarming** contribute to disease propagation in the wild.

There is need to promote honeybee colonies with:

- **good hygienic behavior**
- **good grooming behavior**

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