Environmental risks from existing and emerging parasites

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Impact of infectious diseases on the biodiversity

- Emergence and re-emergence of infectious diseases

  – Mathematical models
    - Measuring the impact of infectious diseases on the populations

→ On humans and wildlife

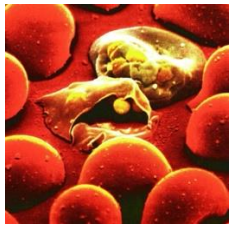
→ Effect of infectious diseases on the biodiversity evolution ?

- During these 500 last years
  - Disappearance of 833 animal species
  - Infectious diseases involved in 3.7% extinctions of species

- Right now
  - Out of 2852 living endangered species (fauna and flora) → 8% threathened by infectious diseases

Examples of human parasitic diseases transmitted by vectors

- Parasitoses

	Parasite: Protist		Responsible for the parasite transmission: Arthropod
– Malaria: France: - 6,000 annual imported cases	*Plasmodium sp*.	←	*Anopheles sp* mosquito
			
– Leishmaniases: France: - Dog: ++++ - Human: +	*Leishmania sp*.	←	Sandfly
			

Definition of « invasive species »

- Invasive species = exogenous intrusive species
- Exotic species
  - → Develops in autochtonous ecosystems
  - → Causes disturbances of the biodiversity

  → Example: processionary caterpillar of pine or oak

→ Urticating hair thrown in the air during the 3rd larval stage

→ Humans: Allergy, itch, oedema, ocular lesions, respiratory disorder

→ Pets → vulnerable
Dogs/cats → tongue necrosis after licking the itch

Origin of invasive species

- Appearance of species
  → Consequence of adaptation of living organisms to new environments

- Indigenous or autochtonous species (micro-organisms, plants, animals)
  → Species that have evolved within a given habitat for a long period

- Co-evolution
  → Long common development story

- Climate changes and invasive species
  → Natural limits of species distribution have followed the climate changes
  → Invasive species: generally more tolerant than indigenous species in regard to their environment → adaptation advantage

- Spreading of invasive species
  → Facilitated by exchanges and transports

Spreading of invasive species

- Intentional introduction of living species
  - → New pets
  - → Plants for food, medicinal or esthetic reasons

- Unintentional introduction of living species
  - → Transport of merchandises

- Species survival during transport
  - → As a function of the transport time
    - → Modern transports
      - → Air conditioning
      - → Chances of organism survival → Enhanced
      - → Transportation areas → Penetration of non-indigenous species
      - → Tropical and temperate zones → Directly in contact

Invasion biology
→ A new science

- Danger of introducing non-indigenous species in a new habitat
  - → Approach considered by Charles Elton on 1958 (British ecologist)
  - → A new scientific discipline: invasion biology
    - → Evaluating the ecological effects of new species on indigenous biodiversity
    - → Proposing means to control these adverse effects

- Scientific research studying
  - → Means of dissemination of non-indigenous species
    - → Conditions favouring their spreading
  - → Modifications provoked in the ecosystems
    - → Influence on species (autochtonous and non-autochtonous) within an habitat
  - → Development of means for early detection
    - → Monitoring the threat of these species to control their invasion

Intentional introductions of invasive species

- Various living organisms: plants (ornamental plants/trees, fruit trees, cultivated plants, medicinal plants, lactating / meat producing / draft animals, pets,…)

→ Some examples

- Cultural history of humanity

→ Involves pets

Eurasia

→Domestication of goat, sheep, rabbits and dog

→ have accompagnied humankind since 10 000 - 16 000 years

→ Horse, muskox, pigs

→ 6 000 - 9 000 years

→ Breeding of these animals → extensive = cattle free in huge areas without fences

→ Sometimes, some animals escape and constitute wild populations

Intentional introductions of invasive species

- In several centuries
  → European navy → colonization of islands by domestic animals

- Wild goats (*Capra hirta*)
  → Can eat a wide range of plants (stems, roots, bark)
  → Climb up trees
  → Disappearance of many indigenous plant species

- Australia
  → Proliferation of rabbits
    → In 1859, Thomas Austin, British hunter, imported from UK 12 couples of rabbits in Southern Australia
    → 50 years later → 600 millions rabbits have colonized 60% of the territory (no natural predator in Australia)

Intentional introductions of invasive species

- Australian rabbits → participate to the desertification through the removal of vegetation → Serious ecological and agricultural crisis
- Implemented means: hunting, explosive, traps, … → Failure
- Introduction of fox as predator
    → Catastrophic effects
        → Fox → More affinity for marsupials yet threatened by rabbits
        → In the 1950s → introduction of the lethal myxomatosis
            → Specially designed to affect wild rabbits
            → Efficient during the first years of use with 80% reduction of the rabbit population
            → Transmitted by mosquitoes, ticks, fleas → poorly adapted in Australia comprising a huge desert
            → Rabbits became virus-resistant
            → Some years later → Virus effect → non existent

Intentional introductions of invasive species

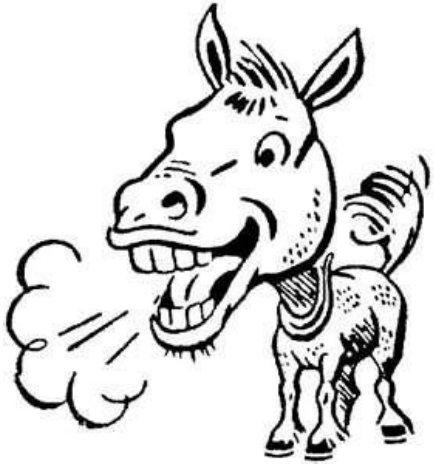
- Introduction of a Spanish flea → more adapted to arid environment
→ Failure
- Introduction of new and more infectious strains after myxomatosis virus
    → But not stable
    → Risk of mutations
        → Risks for humans and other animals ???

- In 1995 → Introduction of the hemorrhagic fever virus
    → Death of rabbits in 24 to 48 h par asphyxiation and cardiac arrest
    → But, in wet areas → Competition with another virus which annihilates its virulence

- At present → investigation on new viruses → acting on reproduction

- Presently = 200 million rabbits in Australia

Intentional introductions of invasive species



- Australia
  - → Proliferation of donkeys
    - → Donkey coming back to the wild life
    - → 1.5 million wild donkeys
      - → Destruction of vegetation
      - → Danger for indigenous herbivores

  - → Proliferation of wild dromedaries
    - → Introduced in Asia in the 19th century as draft animals
    - → Some of them escaped, other were released
      - → More than one million dromedaries currently
        - → Annihilate the protection measures for vegetation in this arid continent
        - → Danger for plants and animals

Unintentional introductions of invasive species

Asiatic hornet

Yellow-legged hornet (*Vespa velutina nigrithorax*)

→ Hymenoptera

→ Family *Vespidae*

Geographical origin

→ Continental Asia: Northern India, Chinese mountains and Indonesia

→ Areas with similar climate as in Southern Europe

Diagnostics:

European hornet: *Vespa crabro,* yellow, black

Asiatic hornet: dark with orange bands

Unintentional introductions of invasive species

Asiatic hornet

The founding queen

→ Size: up to 3.5 cm

→ Lifetime: one year

→ Establishes its own colony in spring from March to early August

→ Larvae, workers

→ Late summer: males and sexual females (future queens)

→ Wintering and foundation of new colonies

Unintentional introductions of invasive species

Asiatic hornet

Hornet's nest
→ Cellulosic fibrous
→ Spherical
- Asiatic hornets
    → Large nests (> 40 cm diameter, sometimes 80 cm) mainly in trees
    But → hornets → opportunistic
    → Nests in chimneys, ground, …
- European hornets
    → Nests in tree hollows or ground

Each nest
    → 2000 hornets including 150 founding queens

Hornet bite
- Not more dangerous than those of European hornet but more painful

Unintentional introductions of invasive species

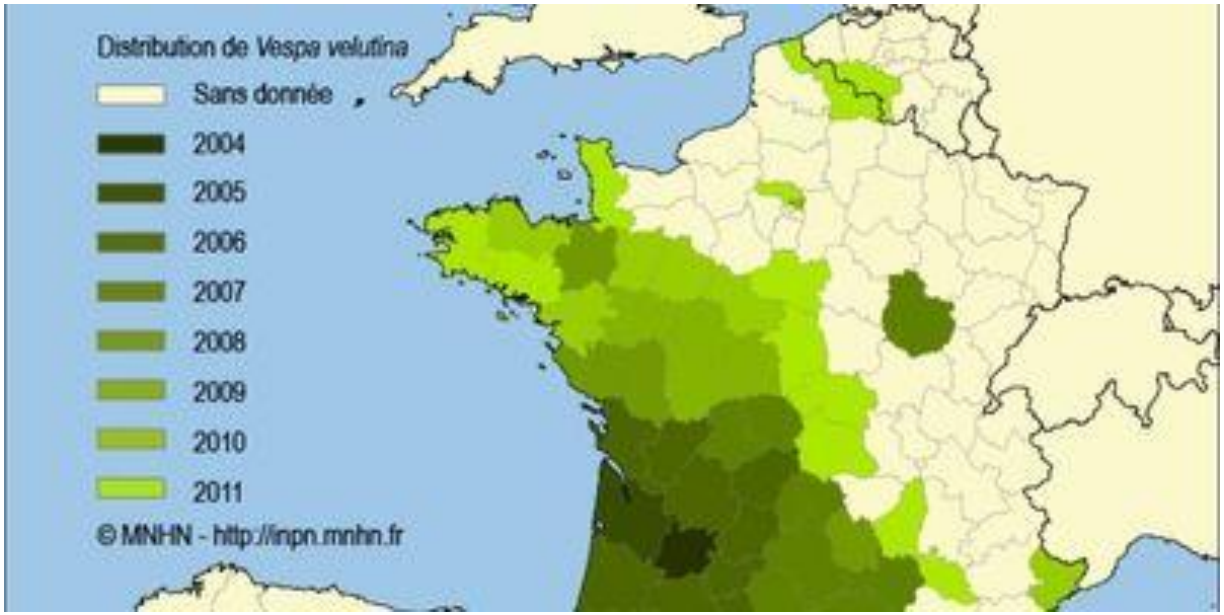
Asiatic hornet

Appearance in France before 2004

→ Arrived in pieces of pottery imported from China

→ Acclimatization: in 2006 → presence in 6 South Western departments

→ Continuous expansion: in 2011 → 50 French departments colonized



Unintentional introductions of invasive species

Asiatic hornet

Environmental incidences

In Kashmir and China → Considered as an enemy of the Asiatic bees: *Apis cerana*

Strategy of hornet worker

→ Decimate hives: feed on the bee larvae

Defence strategy of *Apis cerana*

→ Hornet quickly surrounded by a mass of bees

→ Vibration of bee wings

→ Increase of the T°C in the mass of bees

→ Death of the hornet

Apis mellifera → Similar defence technics but less efficient since recently

Repeated attacks of the hives

→ Weakening of the colonies

Unintentional introductions of invasive species

Asiatic hornet

Diet

→ 30% bees

→ Co-responsible for the reduction of the bee number in France

→ 30% wasps

→ 30% flies

attacks the weakest preys

→ Predator modifying ecosystems by eliminating weak species

Hornet incidence on environment

- Possible advantage → Eliminating the weakest preys
- Drawback → Growing threat for bees

Unintentional introductions of invasive species

Mosquitoes

Dissemination of mosquito by airline traffic

Ex.: Monitoring alive mosquitoes in London airports

→ 12 planes out of 67 were positive
(despite insecticide use)

Anopheles and *Aedes* → the most dangerous mosquitoes

Anopheles → vector of malaria (5 000 cases of importation in France every year + some cases in airport areas)

Malaria → provoked by the protozoan parasite *Plasmodium*

→ Lethal cases of cerebral malaria with infections caused by *P. falciparum*

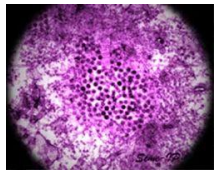
Aedes → viruses vector

Ex.: West Nile virus → introduced in USA from Israel by an airliner

→ Asymptomatic infection/febrile syndrome/meningoencephalitis

→ Vertical transmission in other female mosquitoes (*Culex*)

→ observed in laboratory



Unintentional introductions of invasive species

Mosquitoes

Aedes → virus vector

Ex.: Dengue virus (*Flavivirus*)

→ 4 different serotypes (DENV-1 to DENV-4)
→ One of the most prevalent viruses worlwide
→ 100 million fever cases
→ 500 000 hemorragic fevers
→ 25 000 deaths a year
→ Present in Asia and Southern America → Humid forests and areas
→ Two forms : mild form / haemorrhagic form
→ No vaccine yet available
→ Vertical virus transmission by female mosquitoes to their descendants

Unintentional introductions of invasive species

Mosquitoes

Dissemination of *Aedes albopictus*

= tiger mosquitoe
→ Insect of the *Culicidae* family
→ Native from South East Asia
→ One of 10 species the most invasives worldwide
→ Present in 80 countries on the 5 continents
→ In France (since 2007)

→ Vector of dengue virus
→ Vector of Chikungunya virus

First autochtonous cases of Chikungunya and dengue fevers observed in South East France in 2010

Unintentional introductions of invasive species

Mosquitoes

Tiger-mosquitoe

→ Dark and white stripes on the body and legs

Biological cycle

→ Development → mainly in urban area

→ Egg-laying by females in stagnant water (anthropic breeding sites: saucers under flower pots, old tires, poorly drained gutters, pools of water after the rain…)

→ T°C between 25 and 30°C: laying of 74 eggs/female every 3-4 days

→ Half of the female mosquitoes live about one month at 25°C

Behaviour

→ Aggressive behaviour → bites during daytime with aggressivity peak during dawn and dusk

→ Infection of mammals and birds through the saliva containing pathogens

Unintentional introductions of invasive species

Mosquitoes

Aedes albopictus dissemination

Main reasons :

→ Transport of old tires containing larvae in water

→ Climate warming

→ Dissemination in temperate areas and higher in altitude

→ Permanently installed in France since 2006-2007

Vectorial capacity

- Only female mosquitoes are hematophagous and anautogenous (= have to feed on mammal blood for egg maturation)

Unintentional introductions of invasive species

Mosquitoes

Chikungunya virus transmission

RNA arbovirus with 2 genotypes

→ Occidental Africa

→ Southern and East Africa

→ Epidemy in La Réunion island in 2005-2006

→ 40% of the population affected

→ Variant of classical virus named CHIKV

- In the 2000's: mutation in a single amino acid of a gene encoding for a viral envelope protein

→ Modification of the infectious properties of the mosquitoe vector:

→ Better infection of *A. albopictus*

→ Higher dissemination of the disease

→ More efficient spreading than with its original vector, *A. aegypti*

Unintentional introductions of invasive species

Mosquitoes

Chikungunya virus transmission

→ Virus multiplication in the mosquito digestive tract
→ Virus migration in salivary glands
→ Infectious female mosquitoes
→ remain infectious for the rest of their life (about 1 month)
→ bites and lays every 4 days
→ 1 mosquito: 7 to 8 transmissions are therefore possible with contaminations of 7 to 8 persons

→ Insect control in breeding sites and elimination of stagnant water

→ Insecticide sprays, insecticide-treated bednet
→ No vaccine

Leishmaniases

Infectious diseases caused by Euglenozoa parasites from the genus ***Leishmania sp.***

Human leishmaniases

CUTANEOUS / MUCOCUTANEOUS FORMS

VISCERAL FORM

Localized cutaneous

Diffuse cutaneous

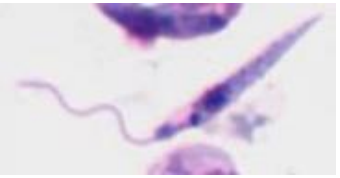
Muco-cutaneous

- 350 million people at risk worldwide (Africa, South America, Asia, Southern Europe)

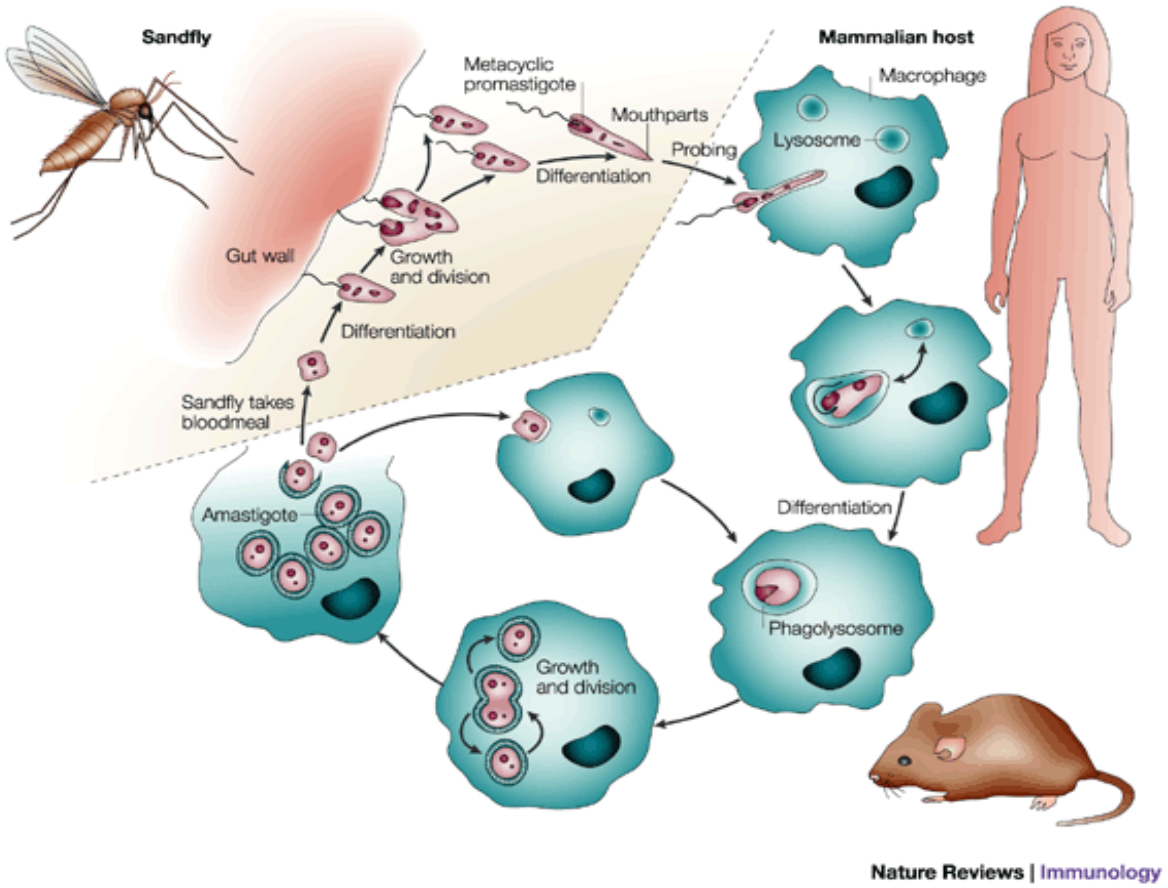
- 12 million cases worldwide and 2 million new cases per year (500 000 new cases of VL in India, Bangladesh, Nepal, East Africa)

Life cycle of *Leishmania sp.*

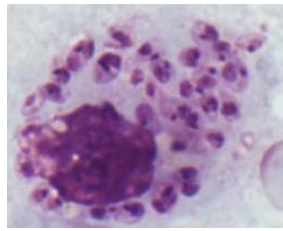
Promastigote form in the sandfly



Sandfly



Amastigote form in macrophage



VL

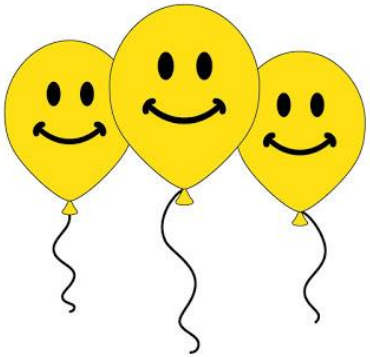
Leishmania donovani → Anthroponotic disease

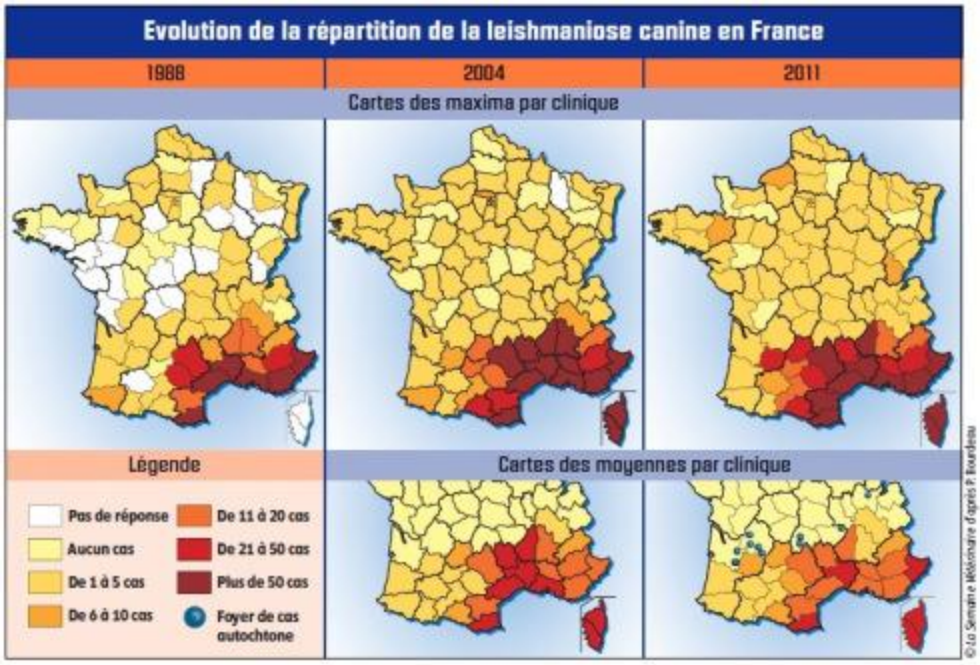
Leishmania infantum → Zoonotic disease

Leishmaniases

Canine leishmaniasis

→Zoonotic disease



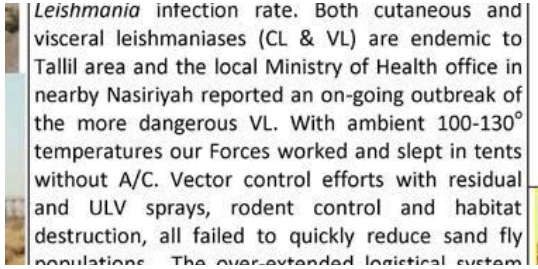


- *L. infantum* → responsible for canine leishmaniasis in the Mediterranean basin
- Dog → *Leishmania* reservoir for humans
- Annually, the number of new cases of canine leishmaniasis is estimated at 10 000 in France

Controlling the insect vector

The sandfly

- Phylum: Arthropoda
- Class: Insecta
- Order: Diptera
- Family: Psycodidae



24% *Phlebotomus papatasi*
30% *Phlebotomus alexandr*
45% *Sergentomyia* spp.

Distribution → Found in warm countries

Bites → Only female sandflies can bite: in the home at night

During the day → stay in holes and cracks of walls and dark areas

Breeding → The eggs are laid in humid and dark places in cattle and poultry sheds

Feeding → Most species are nocturnal

Dispersal → The range of flight distance is about 200 meters from their breeding places

Life Span → Average life of sandflies is about 2 weeks

Controlling the insect vector

The sandfly

Control measures

→ Necessity of sandfly surveys

Sandflies are easily controlled because they do not move long distance from their breeding places

Female sand fly, *Phlebotomus papatasi*. Photo: Frank Collins, CDC.

Light trap → with collecting bag → efficient

Drawback: soil development of the larvae (≠ mosquitoes)

CDC miniature light trap with collecting bag. Photo: SSG Walker, USAPH

Insecticides

→ Permethrin / fipronil (Frontline Tri-Act®): pipettes

100% efficiency after topical treatment 1 / month

→ Afoxolaner (NexGard®): tablets

64% efficiency after oral treatment 1 / month

→ Deltamethrin (Scalibor®): collars

90% efficiency for 1 year

Directly delivered onto the dog's skin

→ spreading through the skin lipid layer

Controlling the insect vector

The sandfly

Sanitation

→ Remove vegetations and fill holes and cracks in the walls and floor

→ Distance of cattle and poultry sheds from human home

Global changes and consequences for leishmaniasis spreading

Climate change

→ Temperature, rainfall distribution

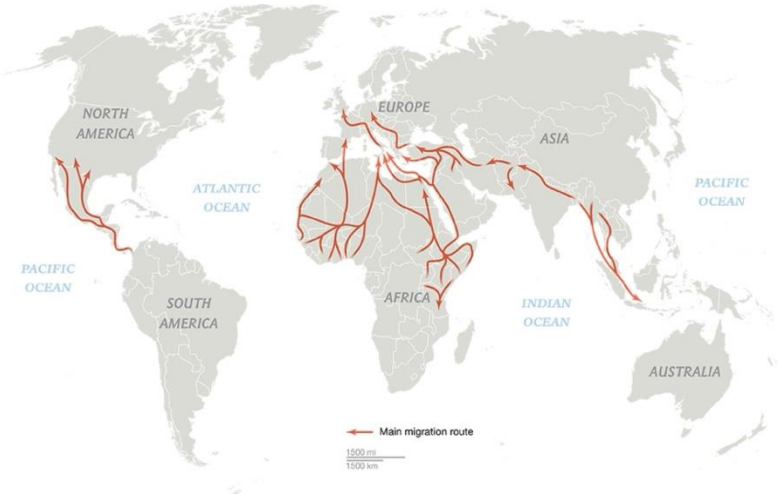
→ Changes in

- seasonality / persistance of vector distribution
- human migratory flux

Globalization

→ Trade, economic and political impacts

→ Changes in human migratory flux



Human pressure

→ Deforestation, urbanization, water management

→ Increase of human contact with vectors and parasites

Unintentional introductions of invasive species

Ticks

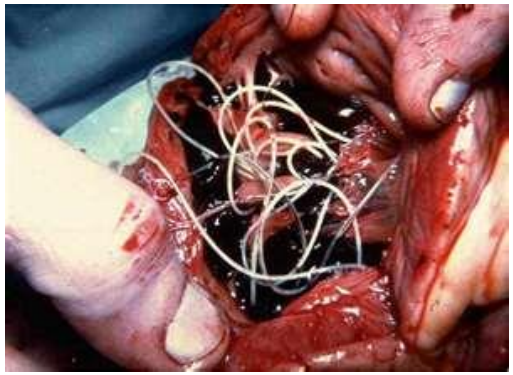
Tick dissemination through dog transports
→ Illegally imported from distant countries to Europe
→ Absence of veterinary control

- Dog ticks:
→ *Rhipicephalus sanguineus*
→ African origin
→ Disseminated in Mediterranean areas
→ Dissemination in Europe
→ Responsible for canine hepatozoonosis
→ *Hepatozoon canis* and *Hepatozoon americanum* (Protista: Apicomplexa) → incurable disease
→ Loss of appetite, anemia, loss of weight, digestive disorders, muscle rigidity
→ 2 forms of the disease:
→ Chronic (successive remission phases and relapses)
→ Acute (fatal outcome in several weeks)

Unintentional introductions of invasive species

Worms

Spreading of the worm *Dirofilaria immitis* through dog transports



- Canine heartworm:

→ *Dirofilaria immitis* (Nematode)

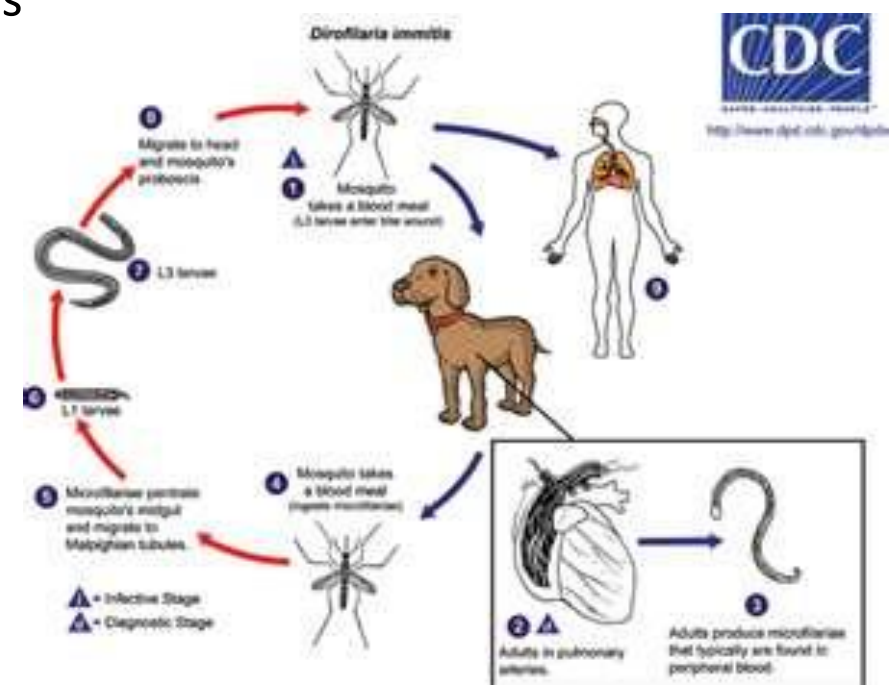
→ American origin

→ Dissemination in Europe

→ Responsible for the canine dirofilariasis

→ transmitted by mosquitoes

→ canine heart failure



Unintentional introductions of invasive species

Worms

Dirofilaria immitis → Cardiopulmonary heartworm disease (dirofilariasis)
Dirofilaria repens → Subcutaneous dirofilariasis

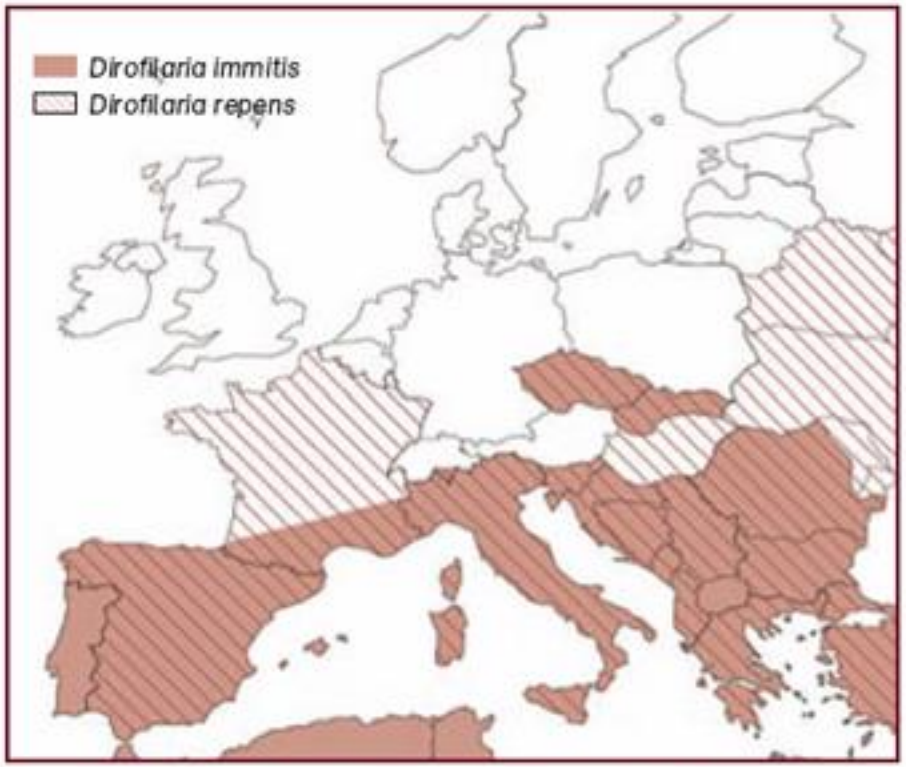


Figure 3. Zones approximatives d'enzootie de *Dirofilaria immitis* et *Dirofilaria repens* en Europe.

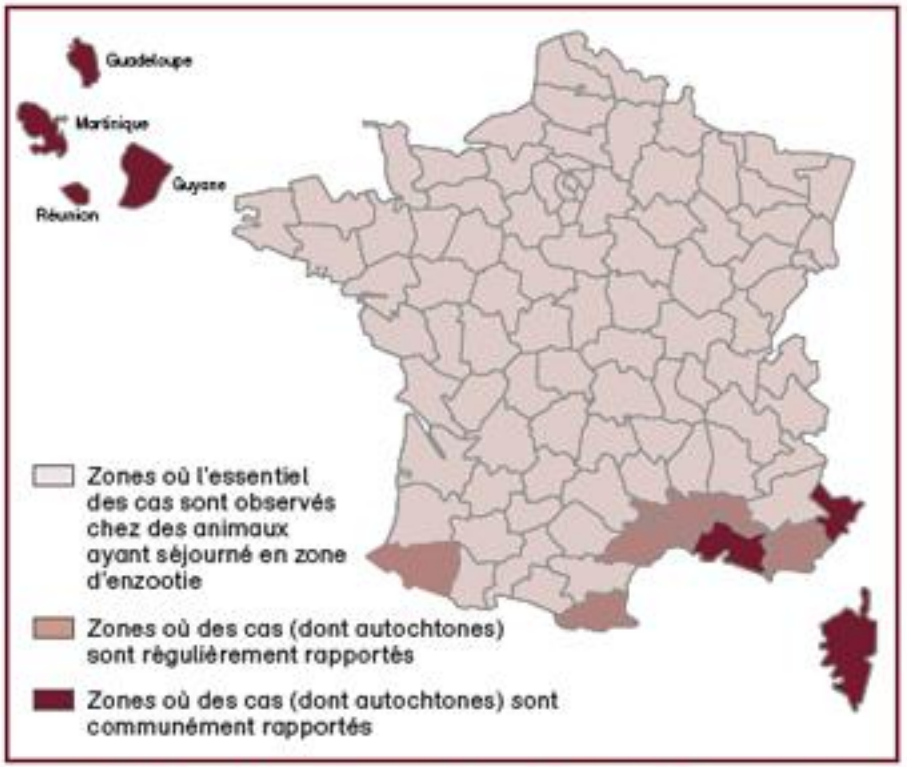
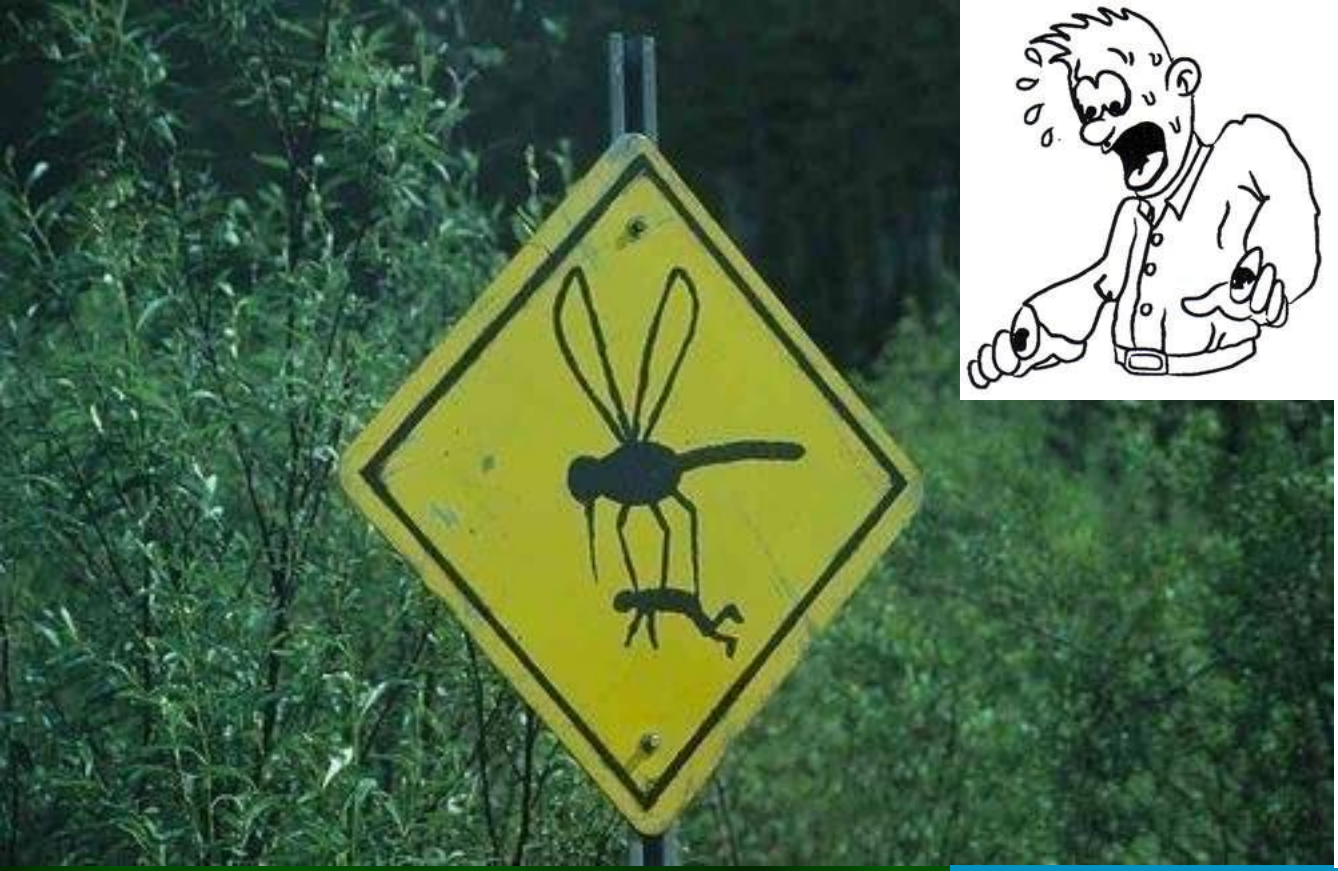


Figure 4. Répartition géographique des cas de dirofilariose cardio-pulmonaire des carnivores en France (d'après Bourdeau *et al.* 2008).



WHAT IS THE PRICE
FOR PEACE OF MIND?