

Symbiose

Marc-André SELOSSE

Muséum national d'Histoire naturelle

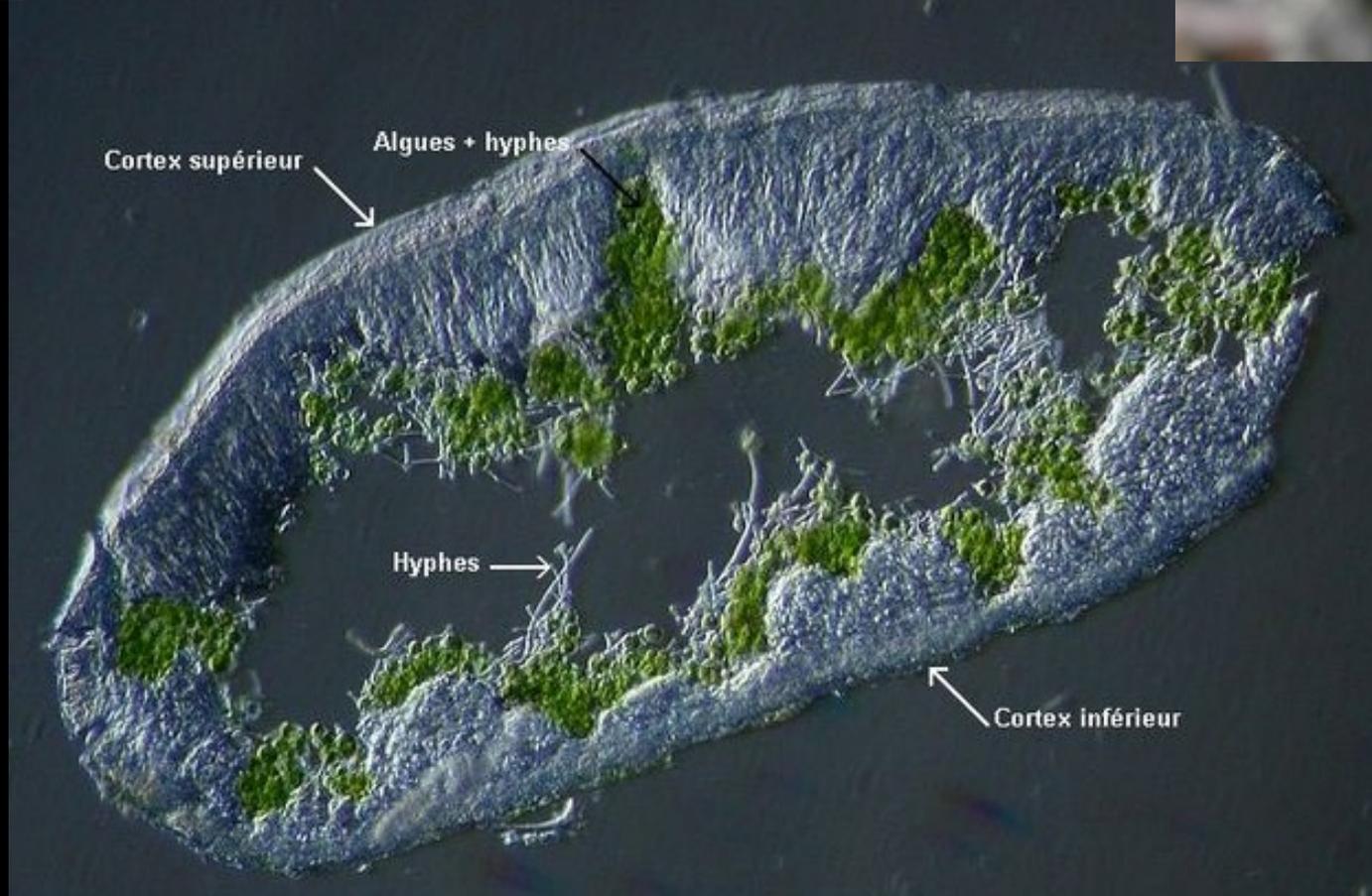
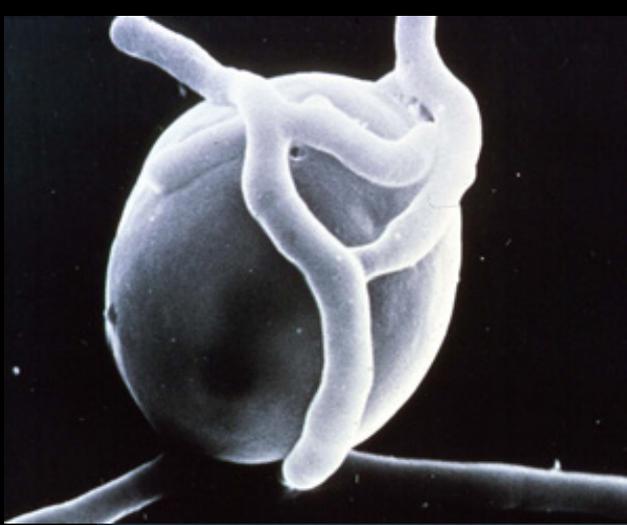
Institut Universitaire de France

Univ. de Gdansk (Pologne) & de Kunming (Chine)

1

... il était une fois,
au XIXème siècle ...





PREMIERE DEFINITION

“das **Zusammenleben** ungleichnamiger Organismen” (De Bary, “De la Symbiose”, 1879) :

- une définition conforme à l'étymologie
- ne préjuge pas des échanges (inclut certains parasites)
- avec un terme sans doute subtilisé à Frank (“Symbiotismus”, 1877)

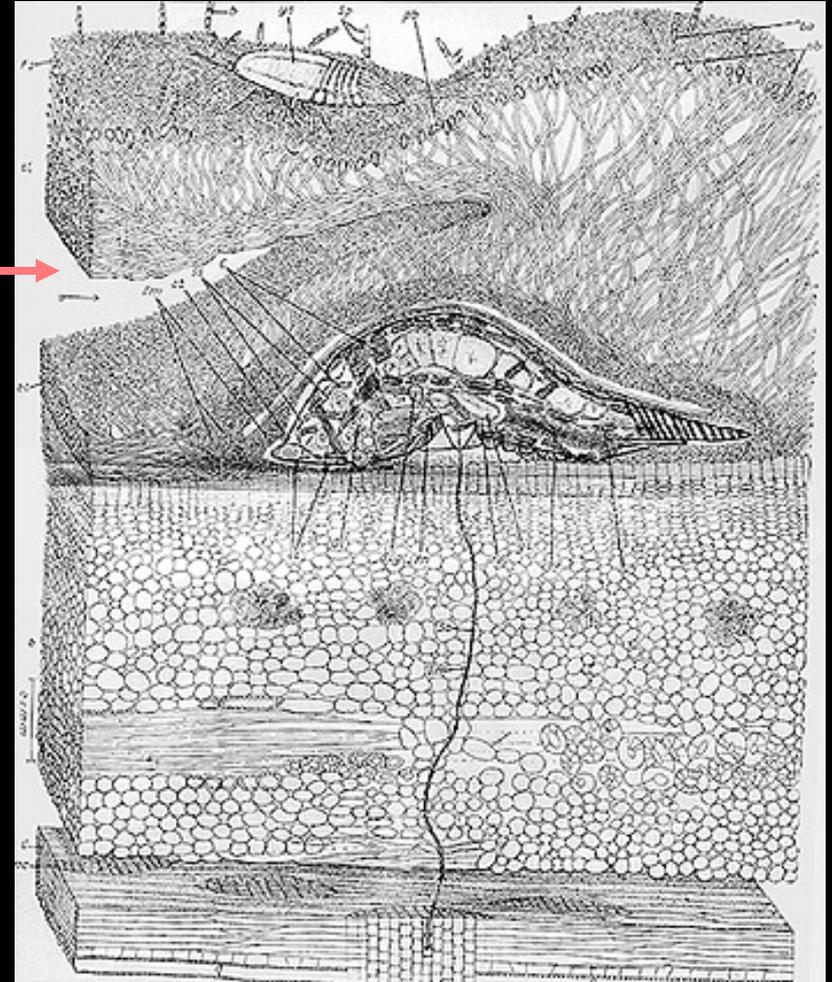


SECONDE DEFINITION

“On voit des animaux qui se rendent mutuellement des services. Il serait peu flatteur de les qualifier tous de parasites ou de commensaux. Nous croyons être plus justes à leur égard en les appelant **mutualistes**” (Van Beneden, 1875)

-> **coexistence & mutualisme**,
une définition plus restrictive

LES AMIS DANGEREUX



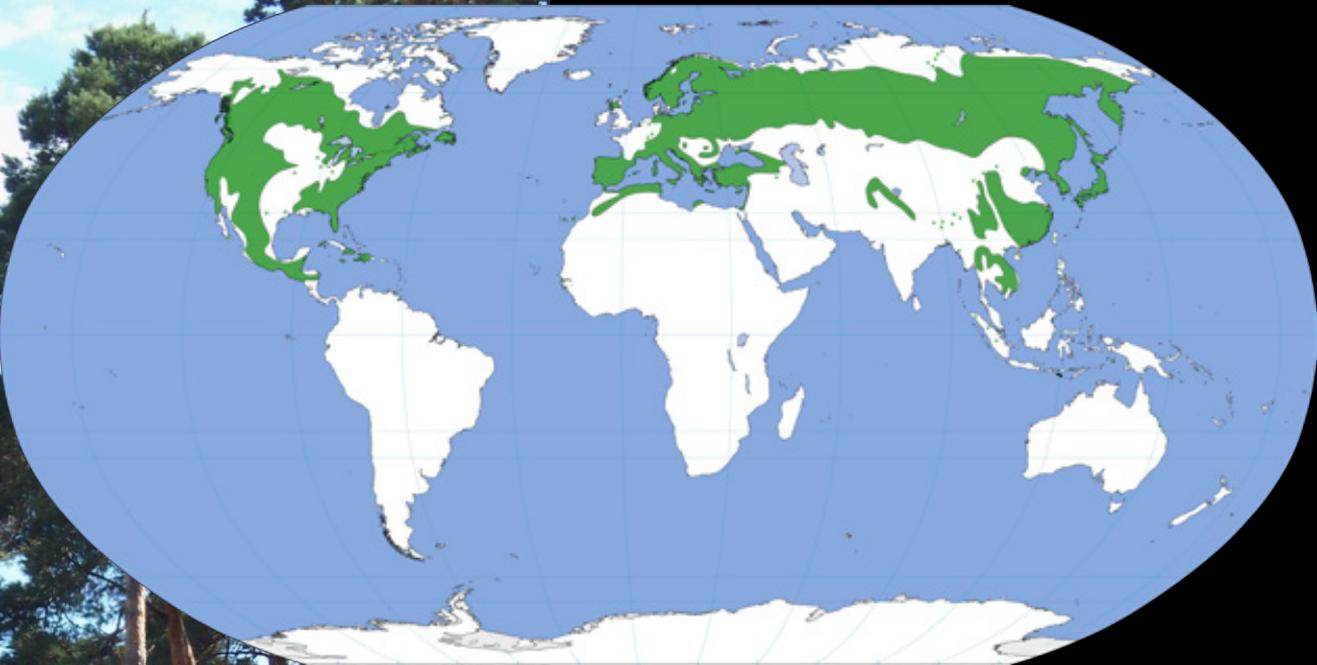
Septobasidium burtii

TROISIEME DEFINITION

Coexistence & mutualisme, celui-ci étant défini comme une *amélioration réciproque* du succès évolutif des deux partenaires en présence.

2

... des symbioses partout,
pour se nourrir...

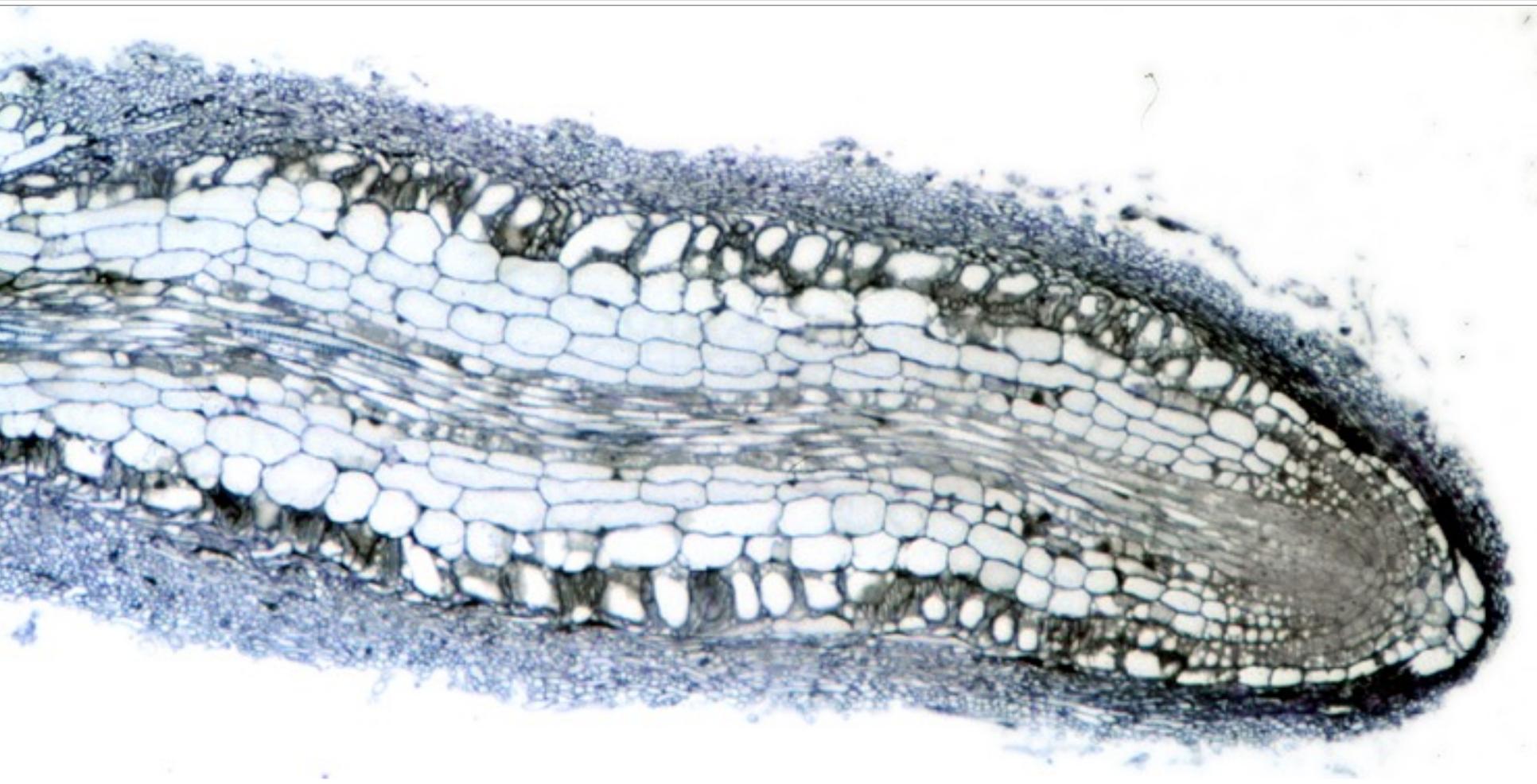




MYCORRHIZE (ARBRES TEMPERES)



MYCORRHIZE (ARBRES TEMPERES)

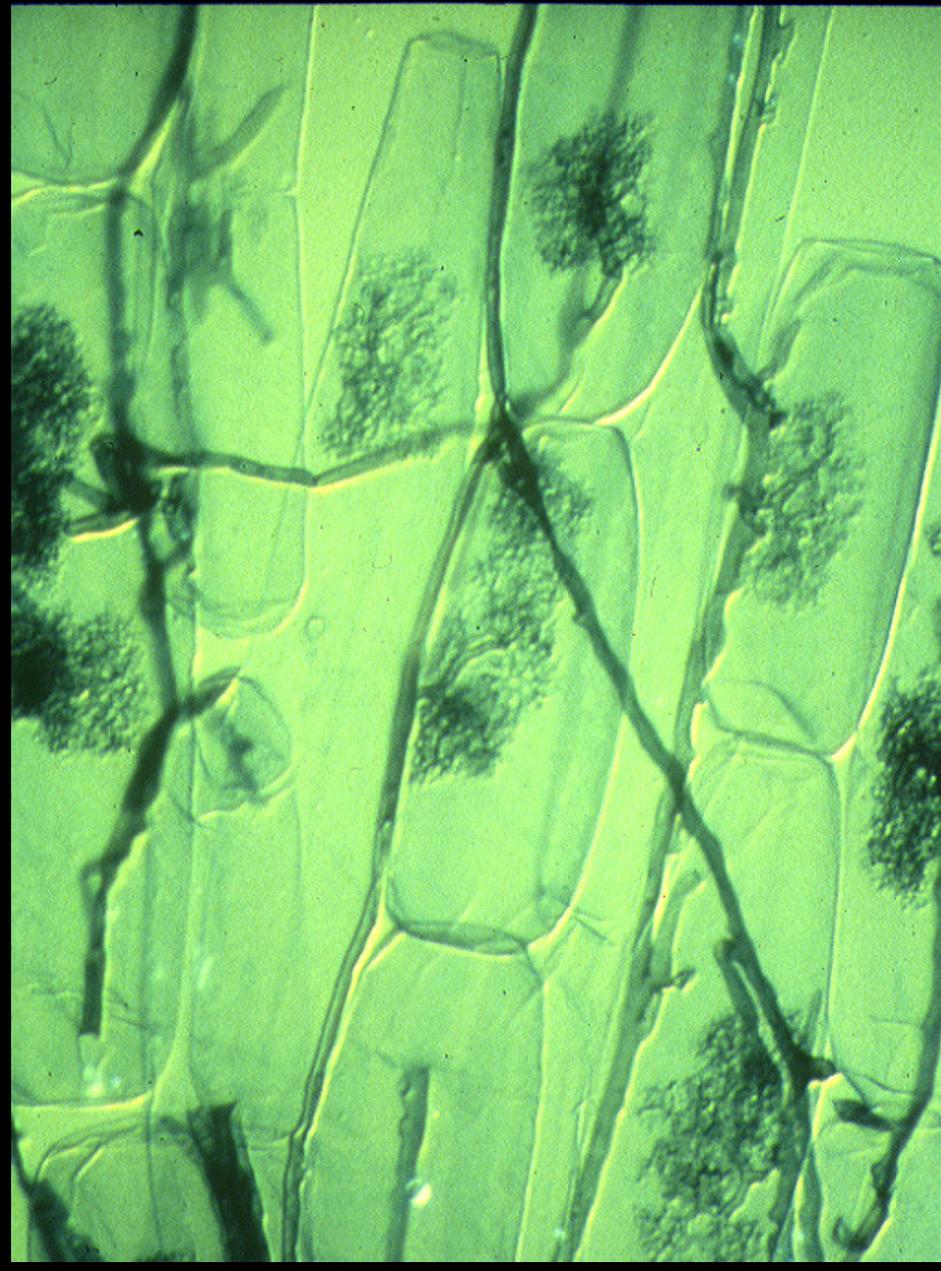




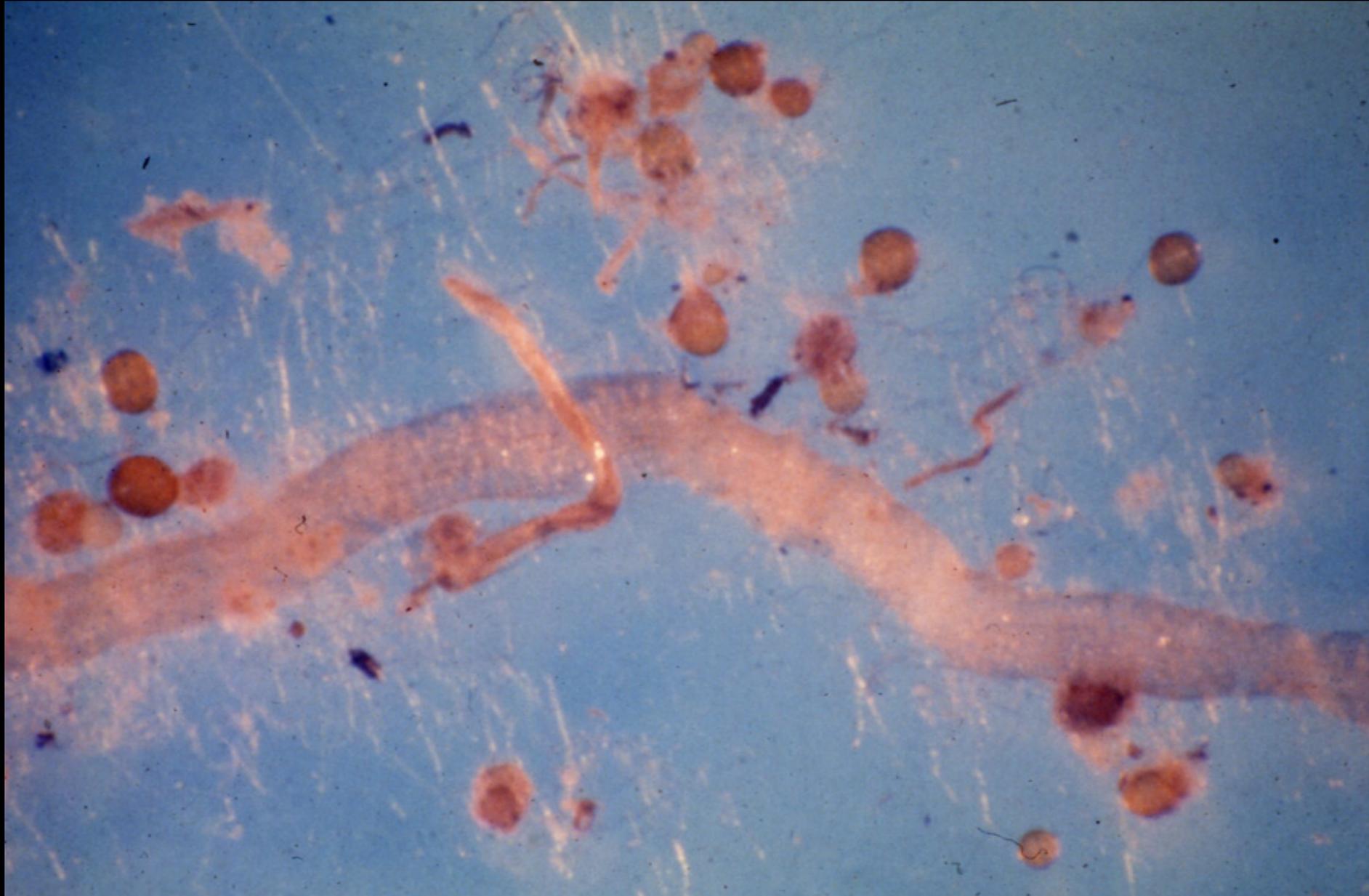
MYCORRHIZE DES HERBACEES



MYCORRHIZE DES HERBACEES



MYCORRHIZE DES HERBACEES

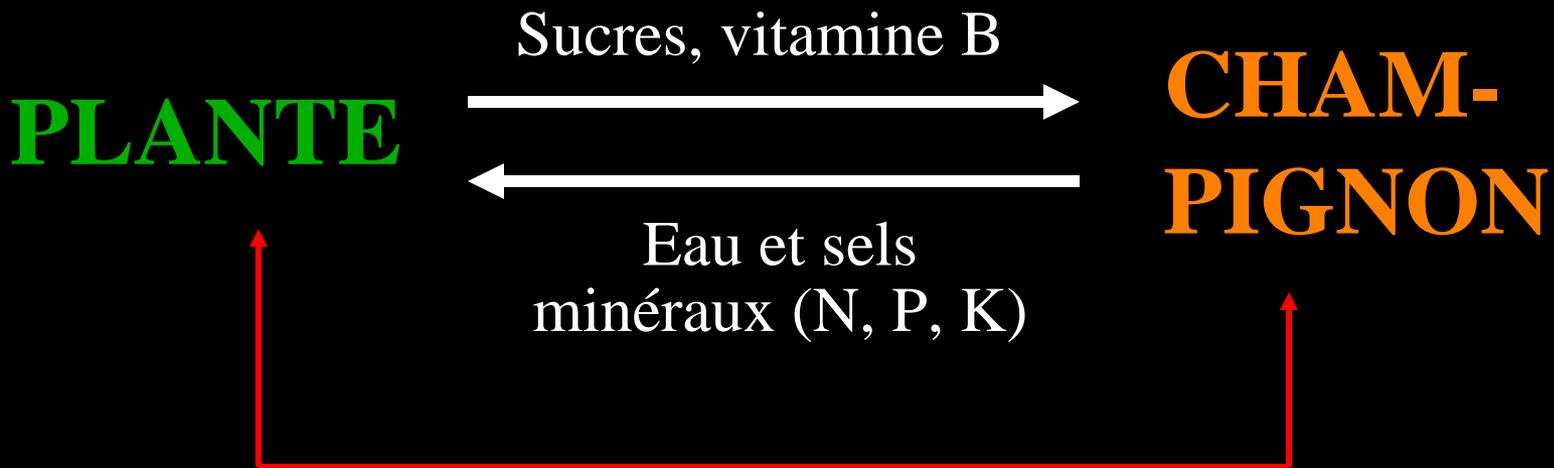


MYCORRHIZE DES HERBACEES



LA MYCORHIZE = LES LICHENS

Des échanges nutritifs réciproques :



Protection contre les agressions
physiques et biologiques

3

... des symbioses protectrices ...

DES ACARIENS POUR LES ARBRES



DES ACARIENS POUR LES ARBRES



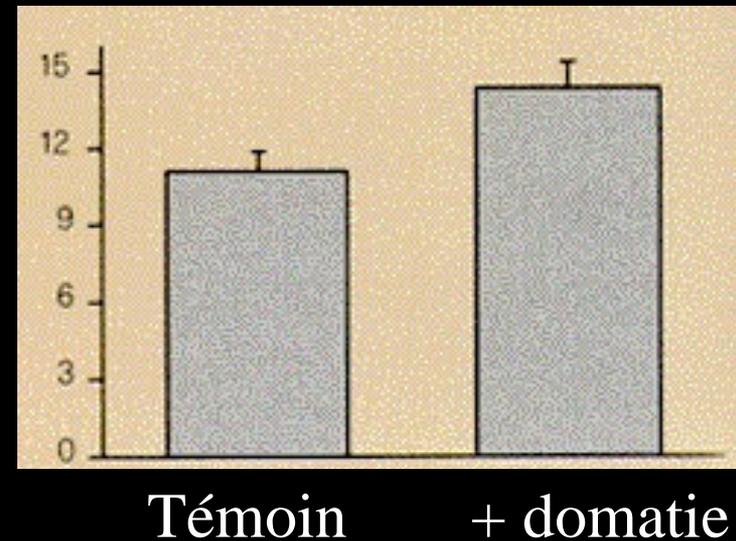
Les domacies à acariens
protecteurs des arbres

DES ACARIENS POUR LES ARBRES



Les domaties à acariens
protecteurs des arbres

Nbr. de capsules
de coton



Anurag *et al.*,
Nature, 387, 562



Protection foliaire

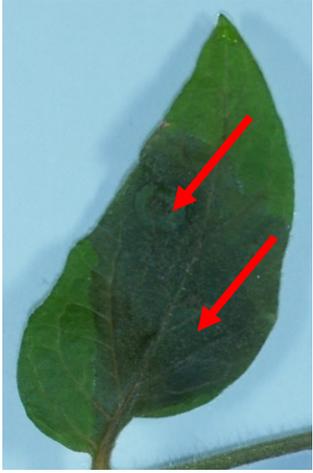


Non
mycorrhizé



Myco-
rhizé

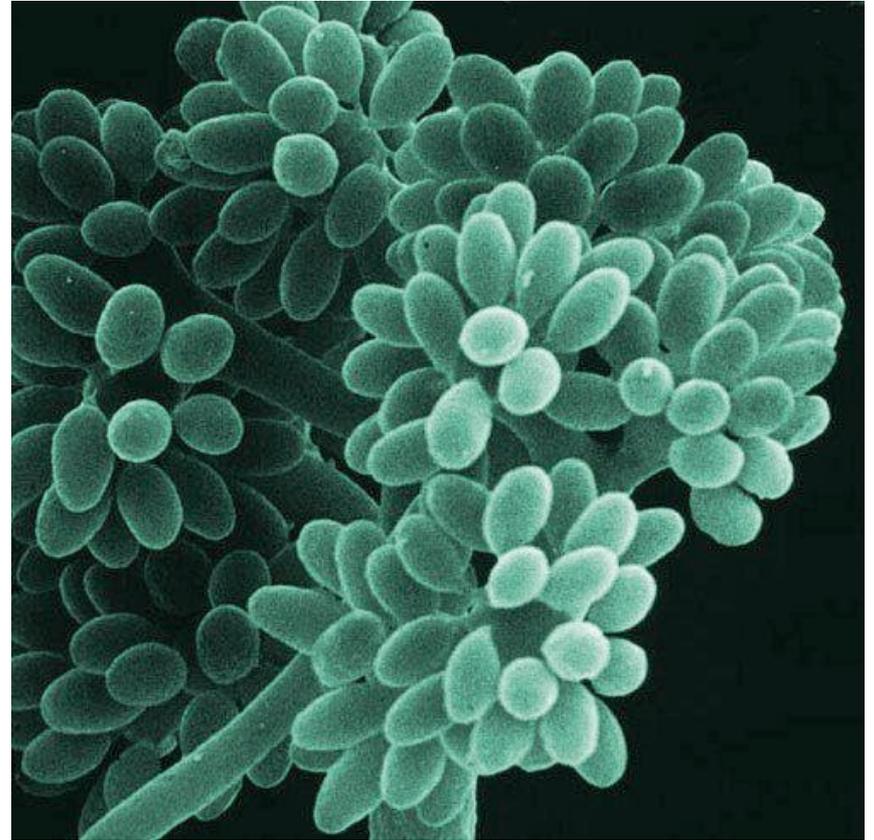
Protection foliaire contre *Botrytis cinerea*



Non
mycorrhizé



Myco-
rhizé



Protection foliaire contre *Botrytis cinerea*

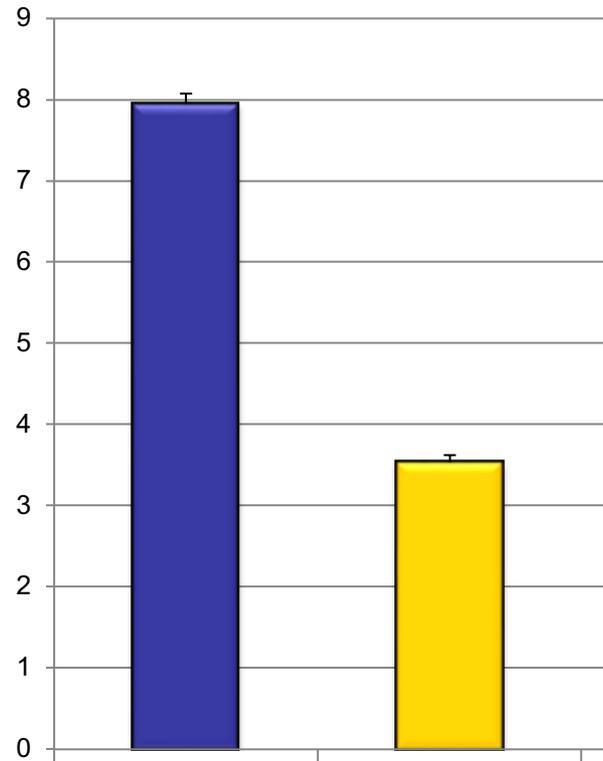


Non
mycorhizé



Myco-
rhizé

Dégâts (% surface feuille morte)



Non
mycorhizé

Mycor-
rhizé

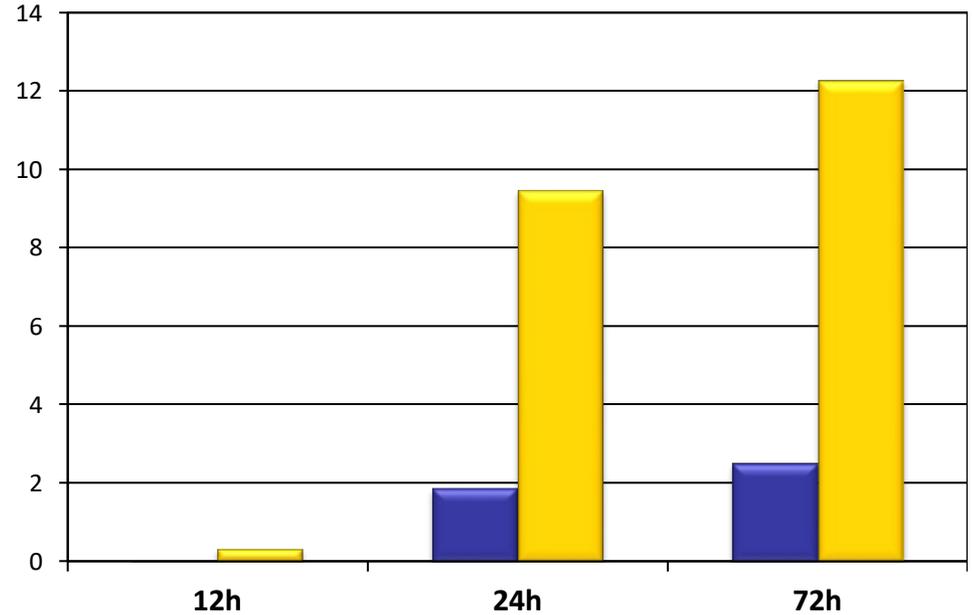
Protection foliaire contre *Botrytis cinerea*



Non
mycorhizé

Myco-
rhizé

Accumulation des
composés de défense



Non
mycorhizé

Mycorhizé

Petits peptides sécrétés modificateurs

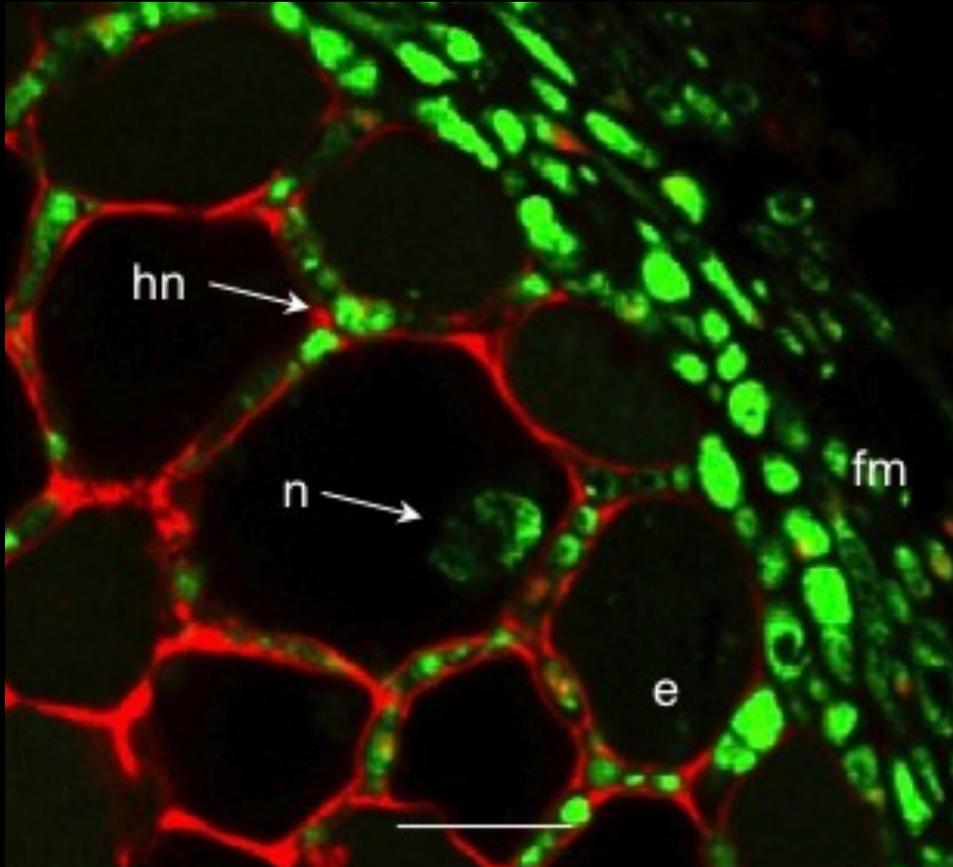
Petits peptides sécrétés modificateurs



RALG

cell entry motif

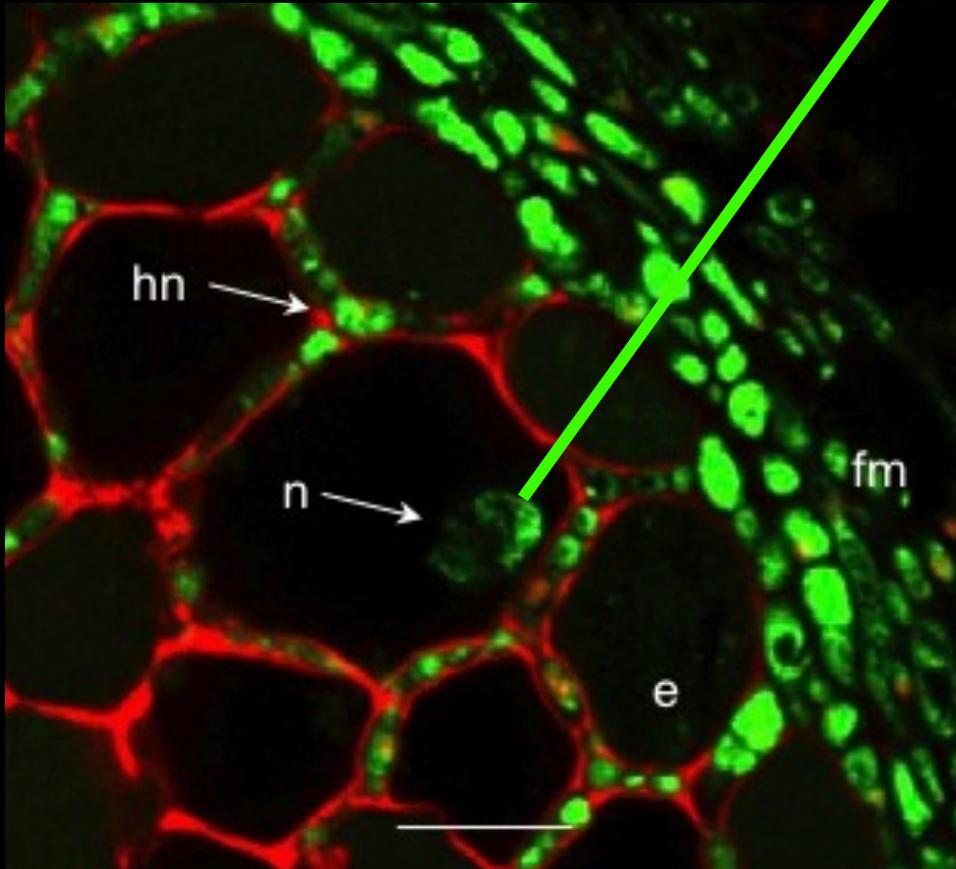
5,6-carboxyfluorescein
(FAM)-tagged synthetic
MiSSP7 protein



Plett et al. (2011) Current
Biology 21, 1197-1203

Petits peptides sécrétés modificateurs

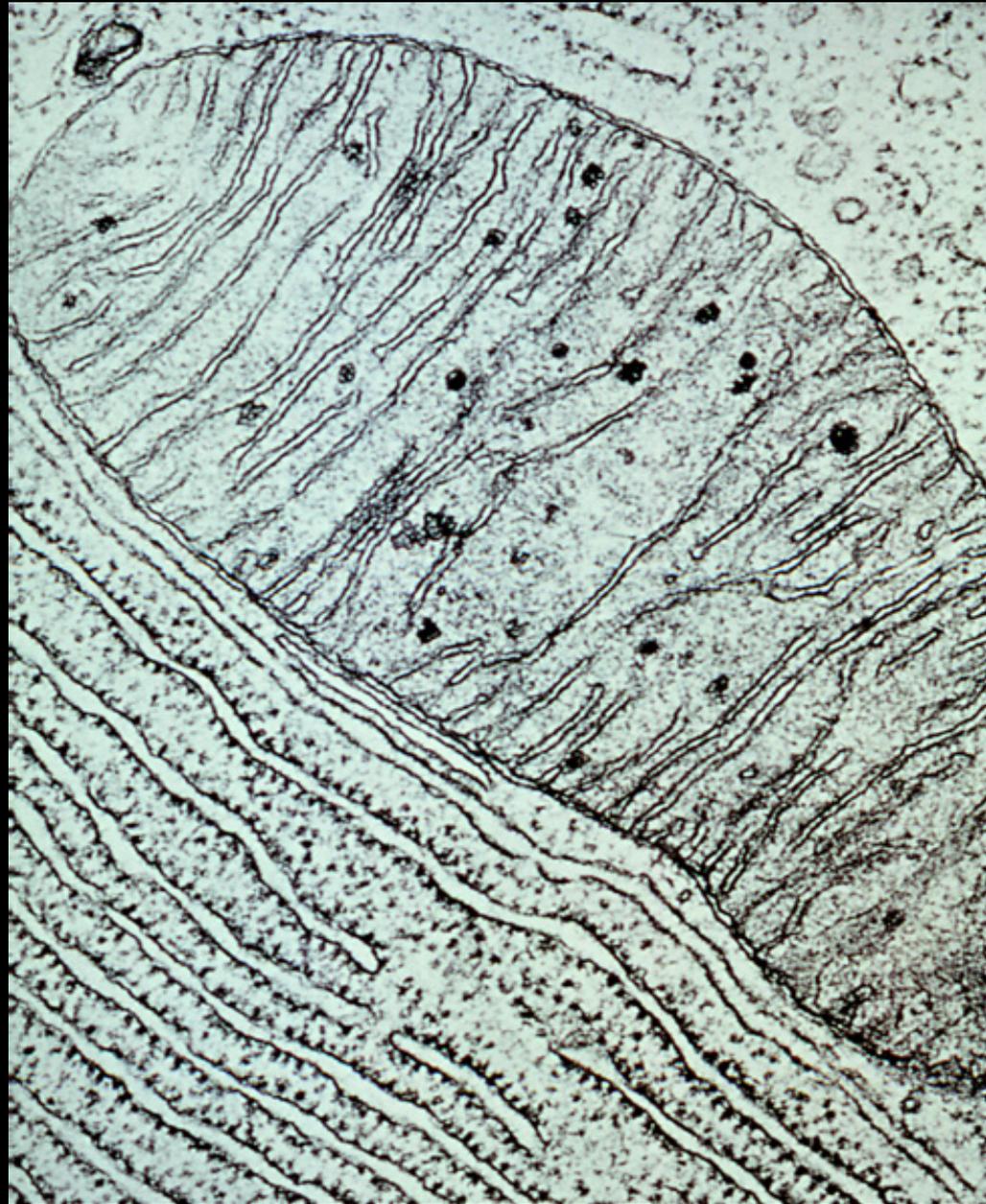
Boque le récepteur nucléaire de l'acide jasmonique (hormone d'alerte en cas d'attaque parasitaire)



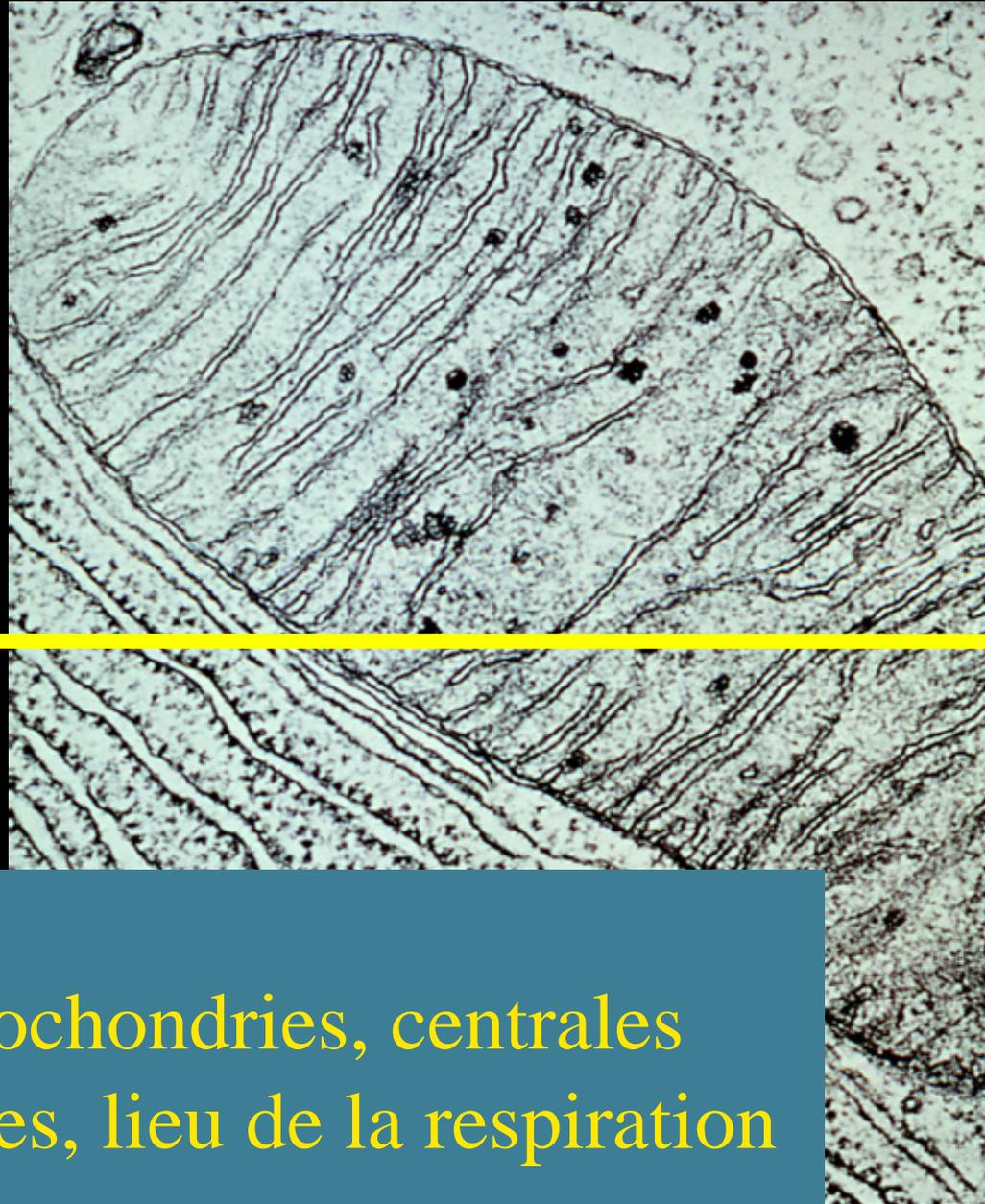
Plett et al. (2011) Current
Biology 21, 1197-1203

4

... en nous, profondément...



sucres



CO_2
+ énergie

Les mitochondries, centrales énergétiques, lieu de la respiration

PAUL PORTIER

Maître de Conférences à la Faculté des Sciences de Paris.
Professeur à l'Institut océanographique.

LES SYMBIOTES

*Toute synthèse biologique est
l'œuvre d'un symbiote VIVANT.*

AVEC 63 FIGURES DANS LE TEXTE ET 1 PLANCHE

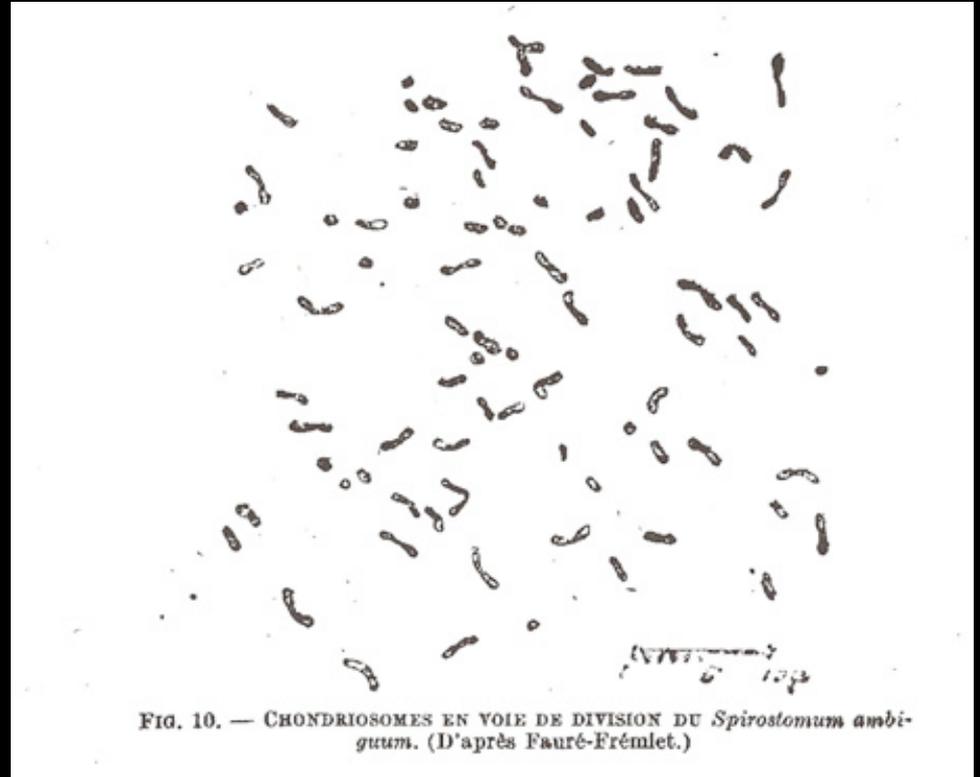
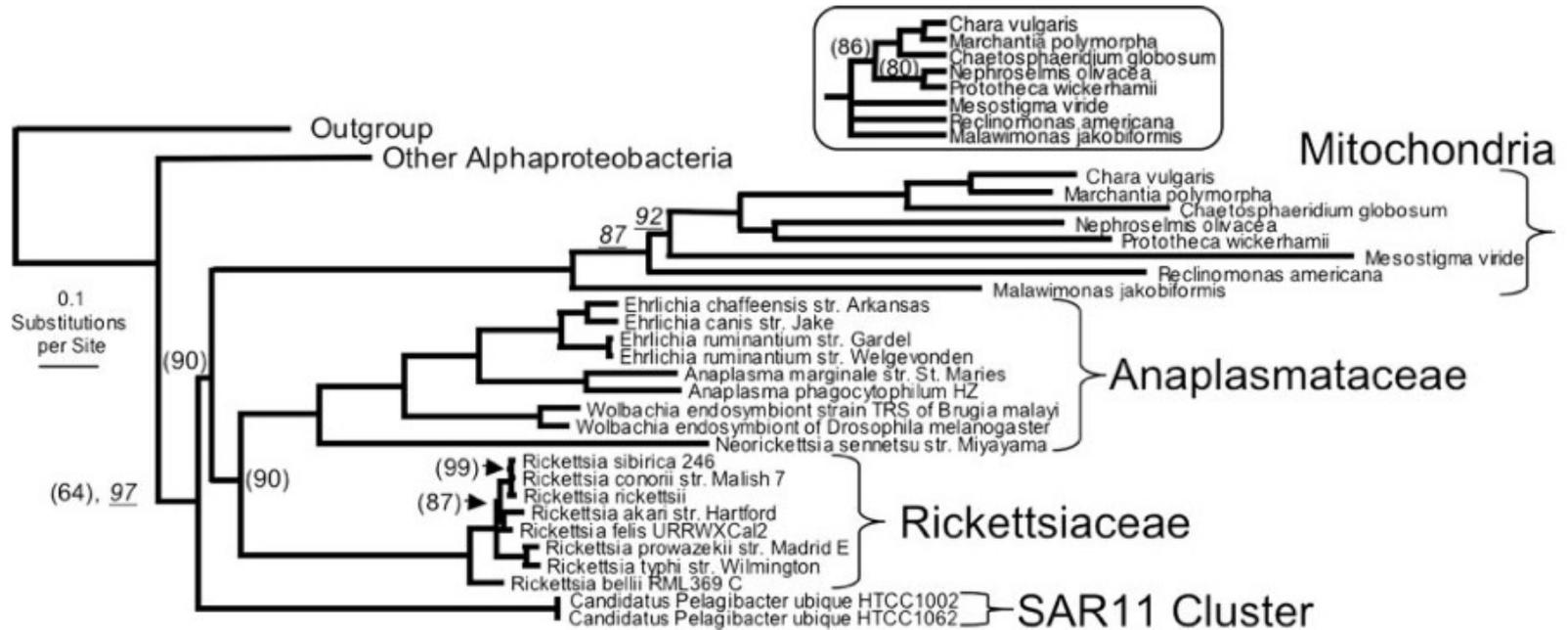


FIG. 10. — CHONDRIOSOMES EN VOIE DE DIVISION DU *Spirostomum ambiguum*. (D'après Fauré-Frémlet.)

Les mitochondries, centrales
énergétiques, lieu de la respiration



Mitochondrial branch. The portion for *Rickettsiales* is shown for the most likely tree found by Bayesian analysis of the concatenation of masked alignments for 16 selected protein families (4,830 characters), in which each node received 100% Bayesian support, except those indicated with underlined values. Identical topologies for bacterial strains arose as the ML bootstrap consensus, from which all nodes received 100% support, except those indicated in parentheses. The inset shows the topology for the mitochondrial branch from the ML bootstrap consensus, collapsing nodes with <50% support. The outgroup and alphaproteobacterial portions of the tree that are collapsed in this depiction had the same topology as those shown in Fig. 3.

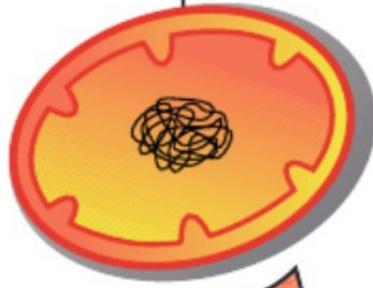
Les mitochondries, centrales
énergétiques, lieu de la respiration



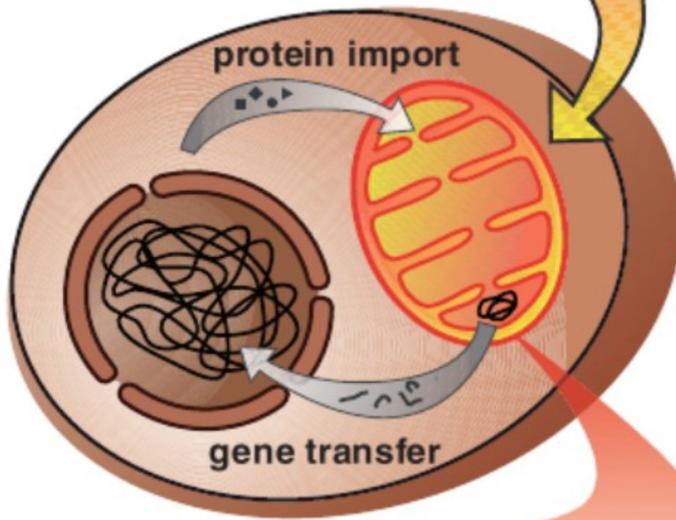
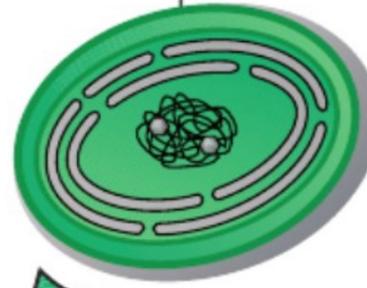
Les mitochondries, centrales
énergétiques, lieu de la respiration

Mitochondries et chloroplastes

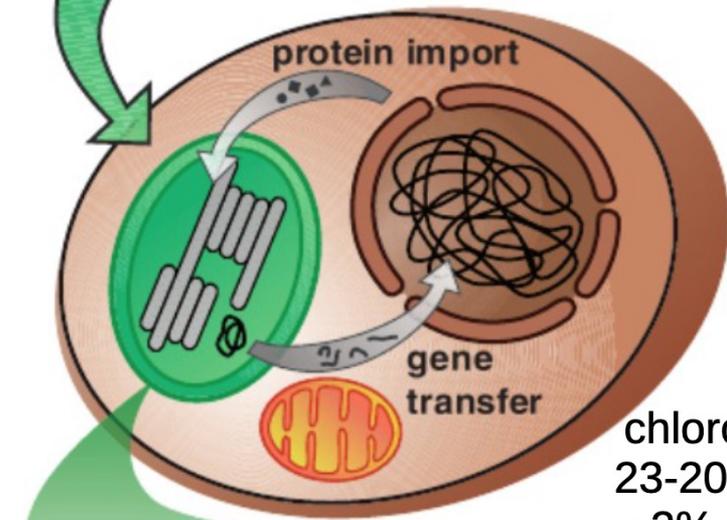
bactérie aérobie
~5000 gènes



bactérie
photosynthétique
~5000 gènes



mitochondrie
3-67 gènes
~1% retenus

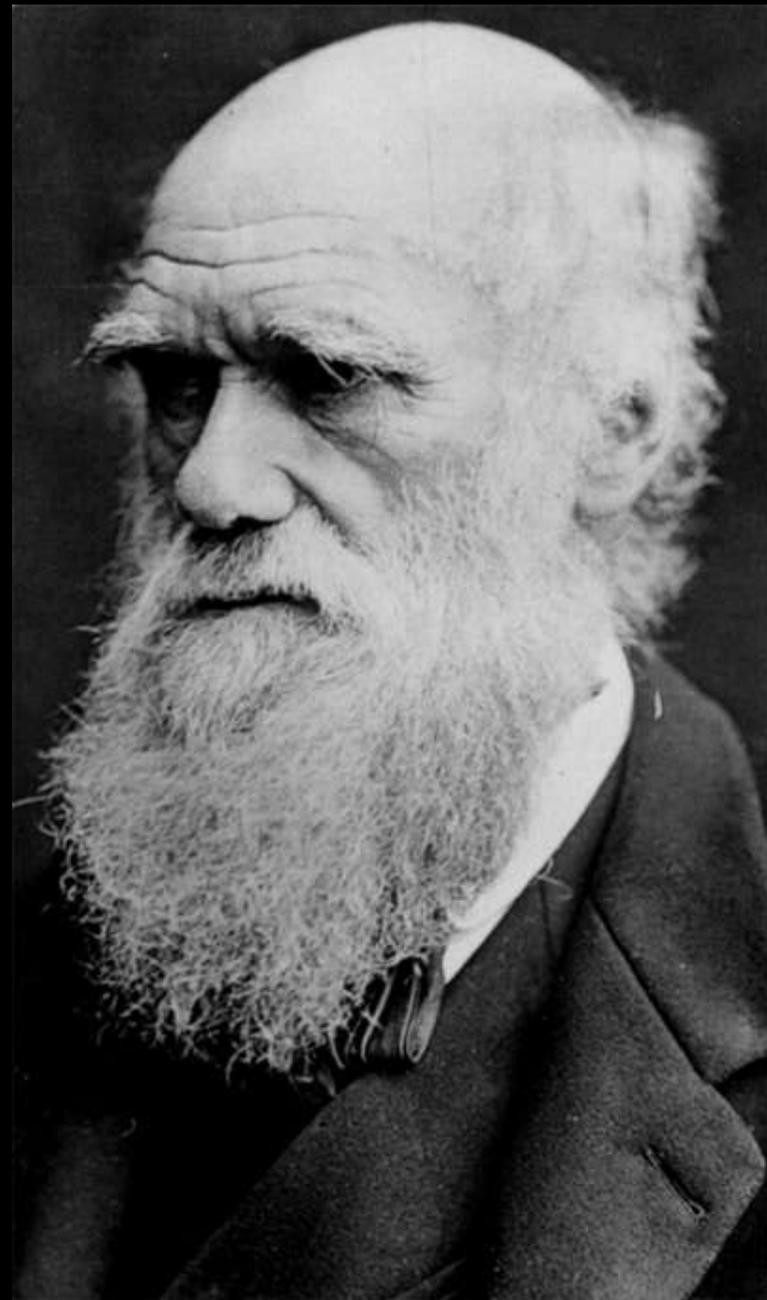
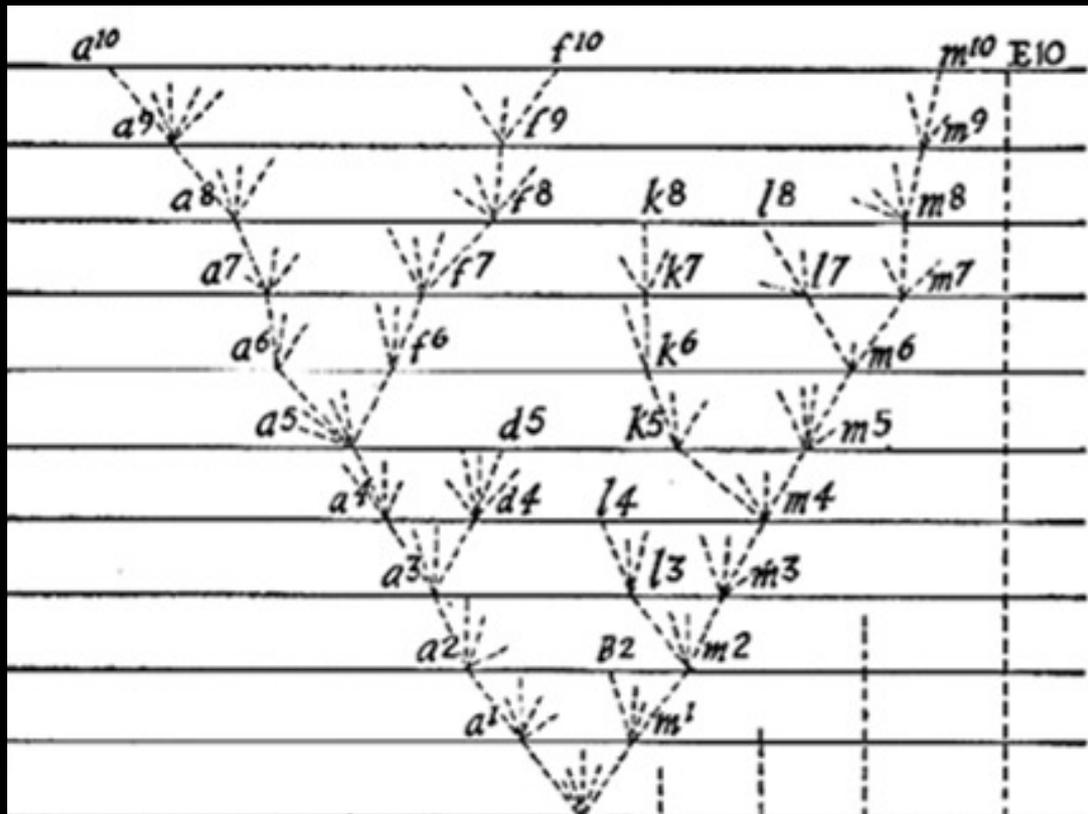


chloroplaste
23-200 gènes
~2% retenus



Chimère, à tête de lion, corps de chèvre et queue de serpent, est la fille du géant Typhon et d'Echidné, la femme-serpent.

Elle est la sœur de Cerbère, le gardien des Enfers, de l'Hydre à neuf têtes et d'Orthrus, un chien multicéphale

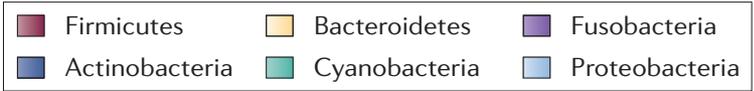
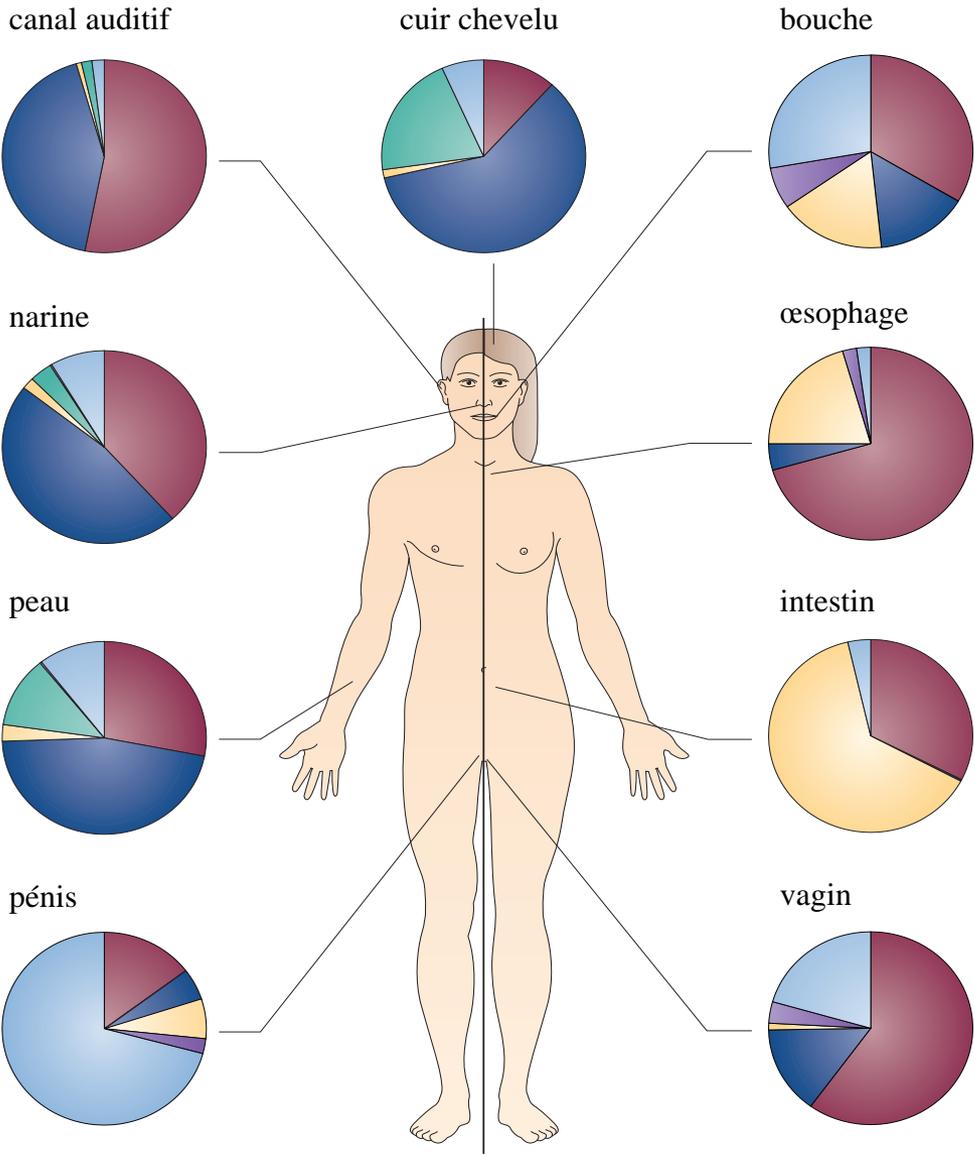


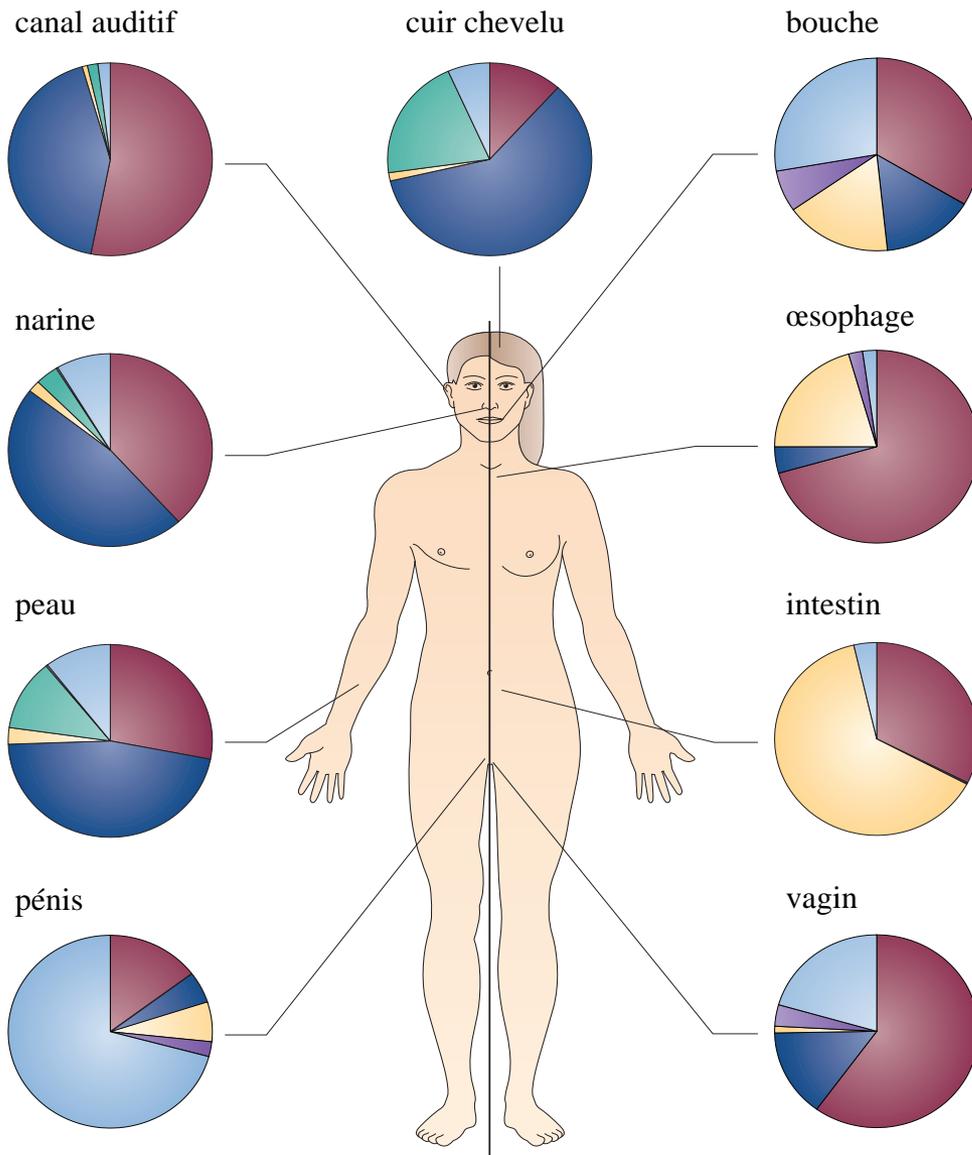
Darwin, 1859
On the origin of species

5

... en nous et sur nos surfaces...

Notre microbiote



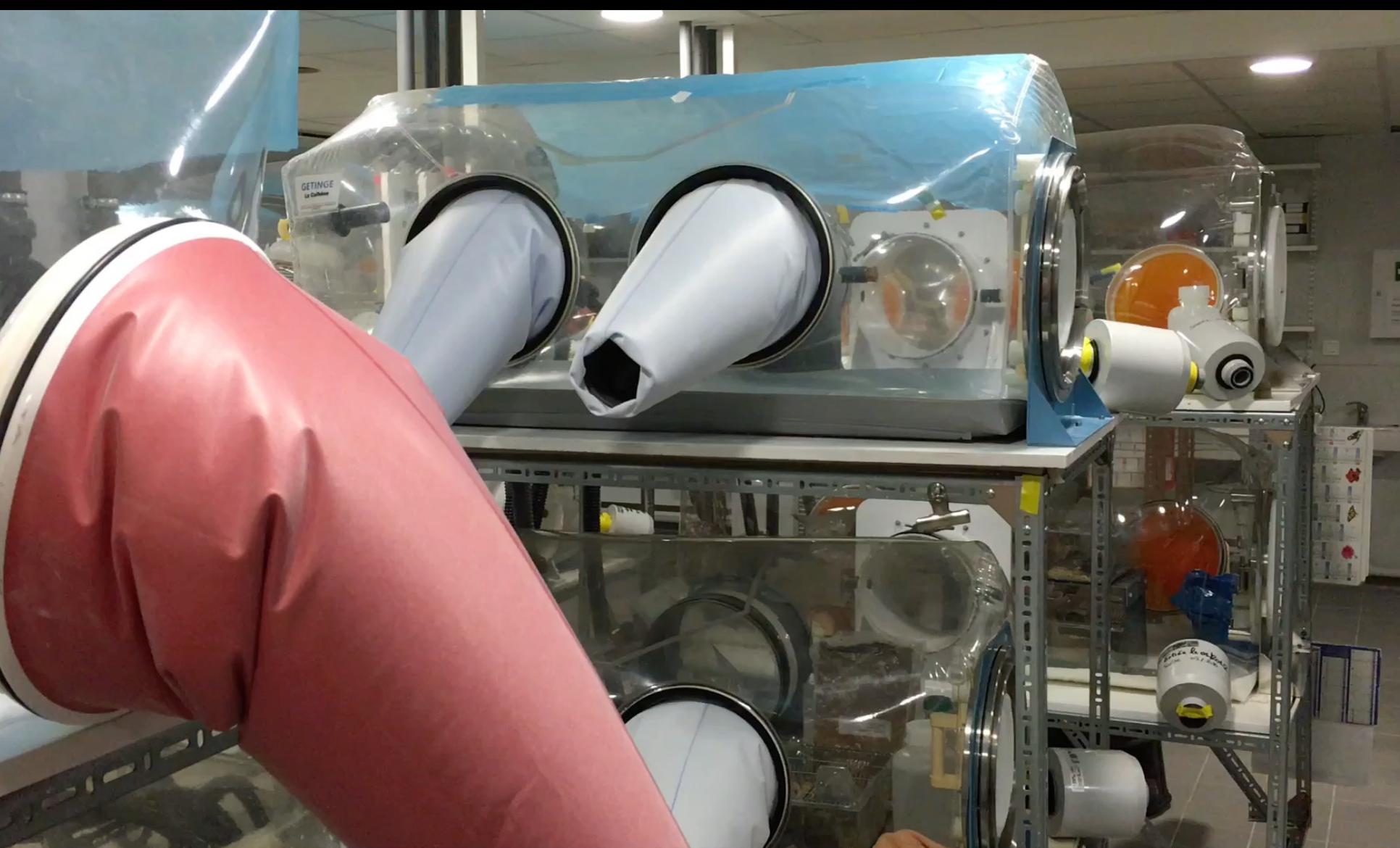


10 000 milliards de bactéries dans l'intestin

1 000 milliards sur la peau

100 milliards ailleurs

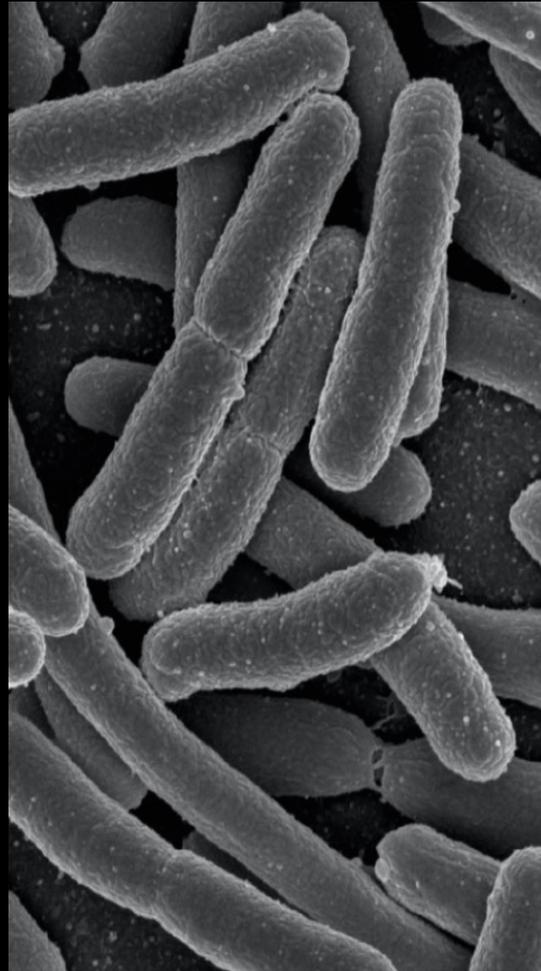
... contre 10 000 milliards de cellules humaines



Souris axéniques

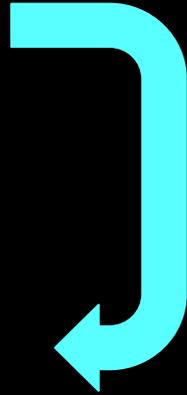
INRA Jouy

MICROBIOTE INTESTINAL

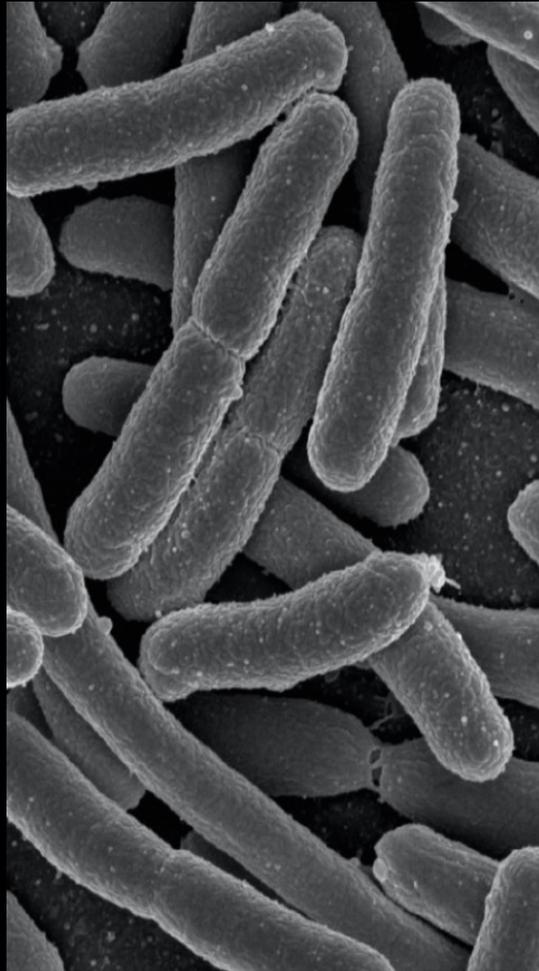


MICROBIOTE INTESTINAL

**Aliments
complexes**



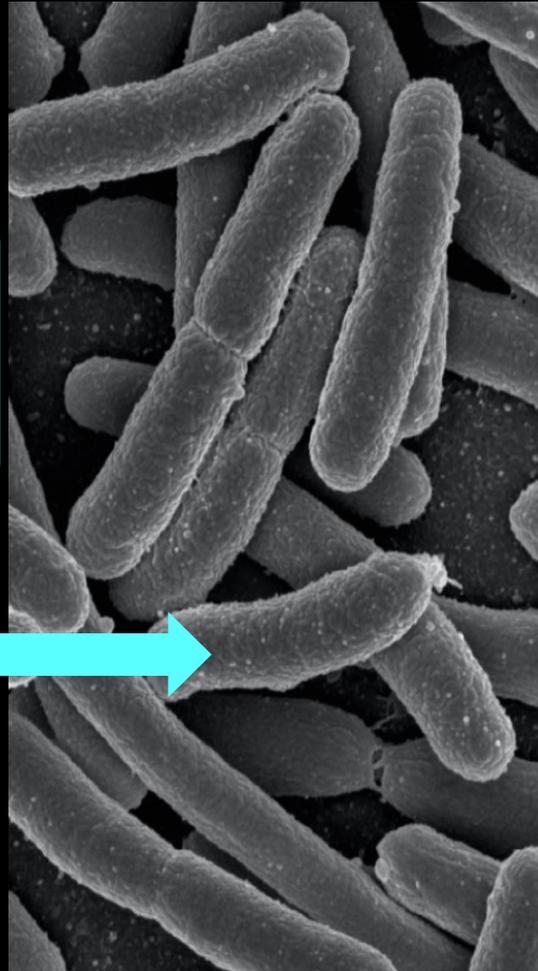
**Aliments
assimilables**



MICROBIOTE INTESTINAL

**Aliments
complexes**

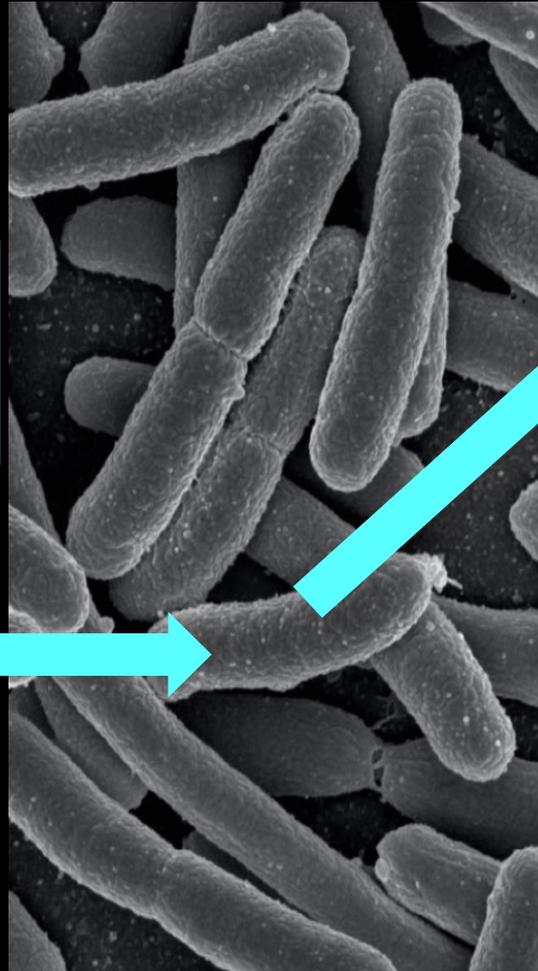
**Aliments
assimilables**



MICROBIOTE INTESTINAL

Aliments complexes

Aliments assimilables

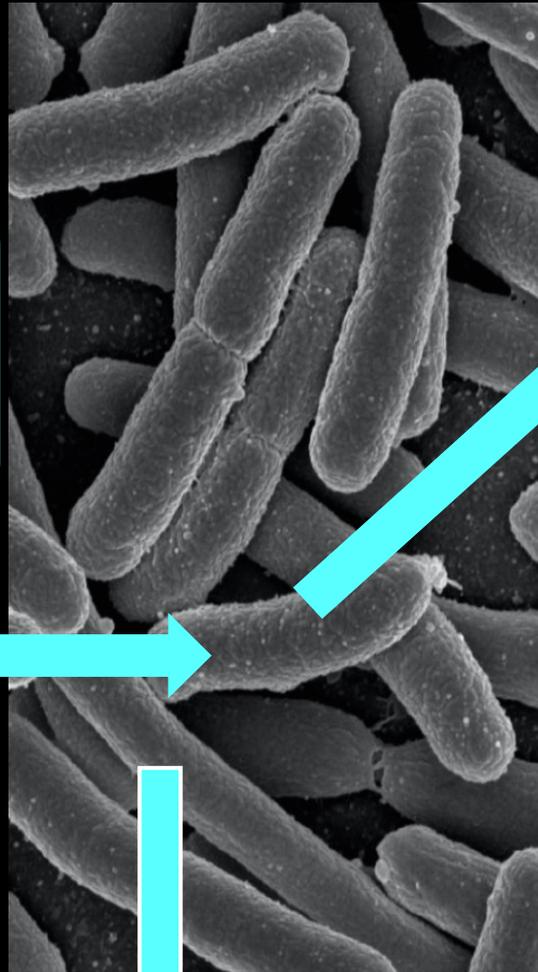


**Déchets de fermentation :
butyrate,
acétate...**

MICROBIOTE INTESTINAL

Aliments complexes

Aliments assimilables



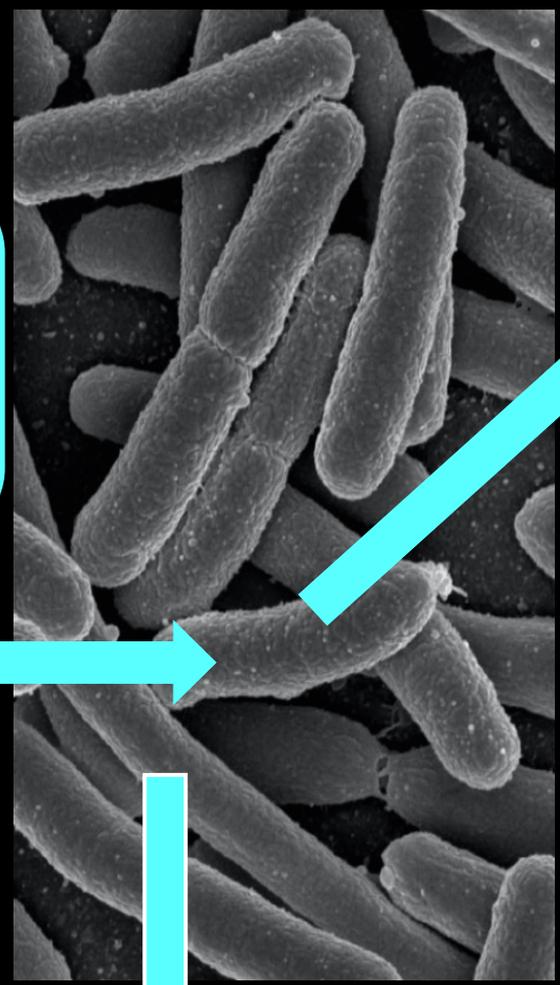
**Déchets de fermentation :
butyrate,
acétate...**

Cell. mortes

MICROBIOTE INTESTINAL

Aliments complexes

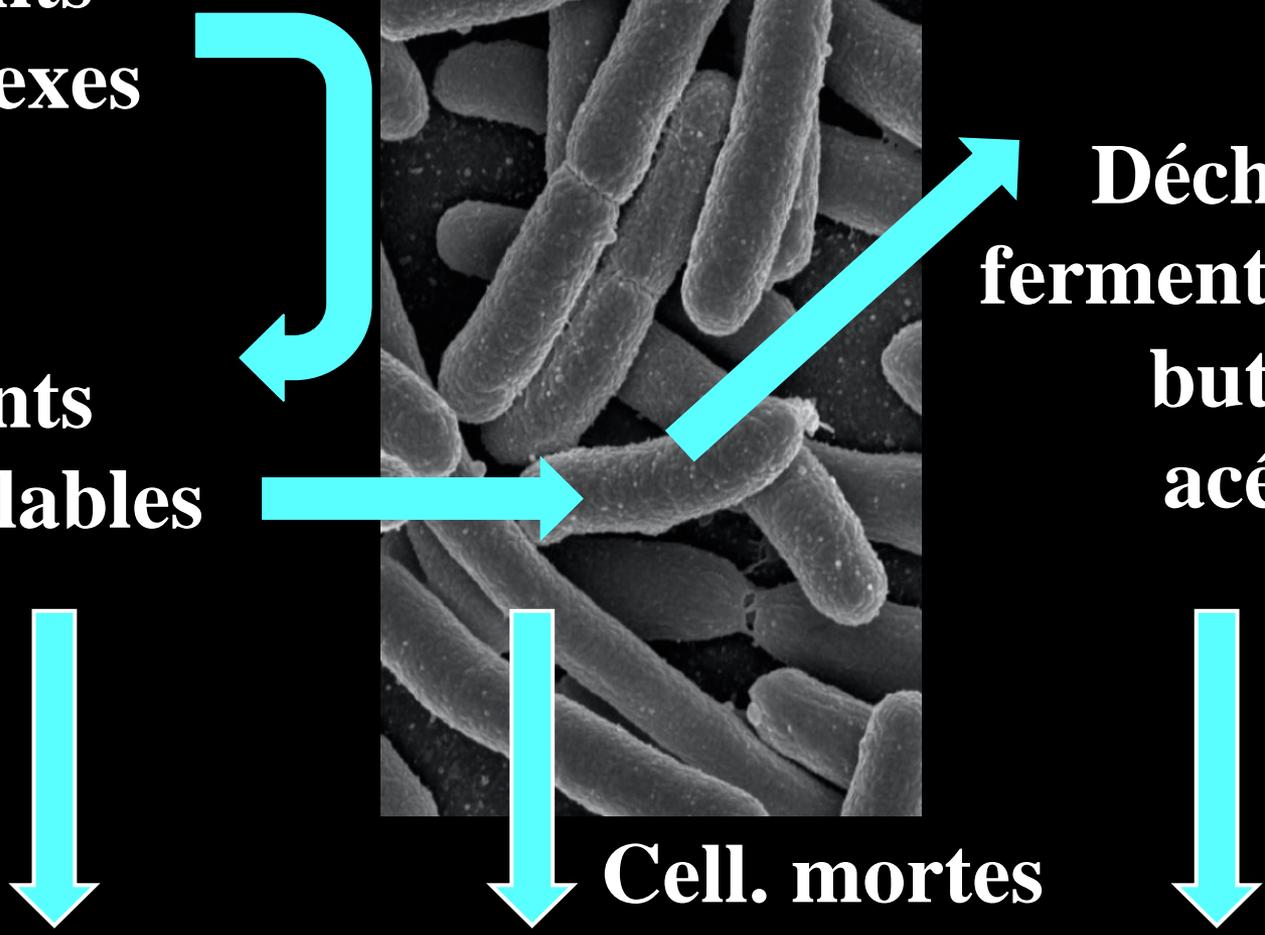
Aliments assimilables



**Déchets de fermentation :
butyrate,
acétate...**

Cell. mortes

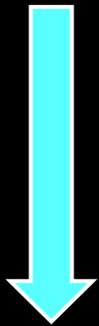
EPITHELIUM INTESTINAL



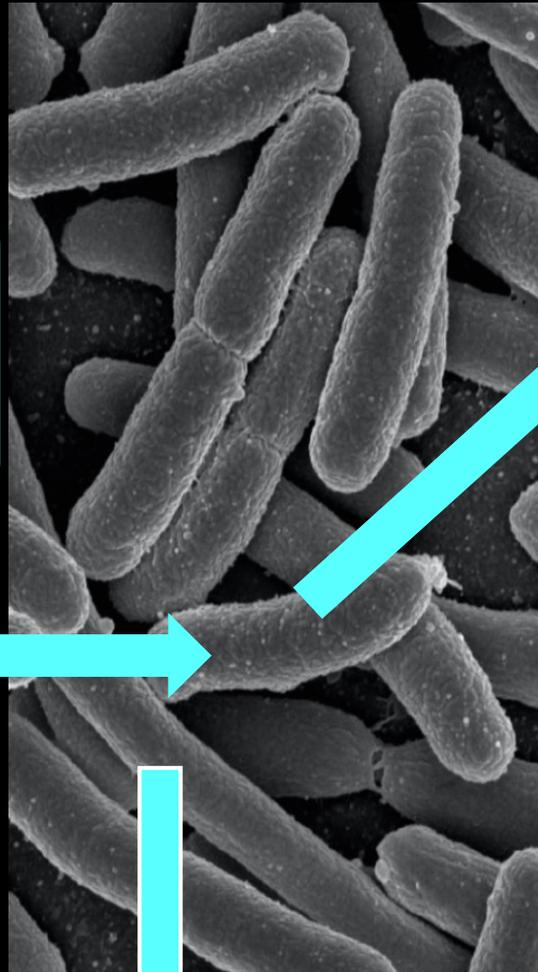
MICROBIOTE INTESTINAL



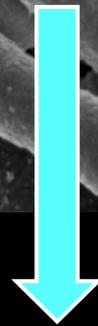
**Aliments
assimilables**



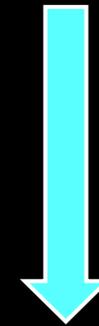
sucres



Cell. mortes



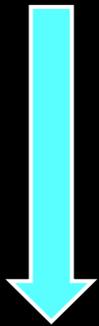
**Déchets de
fermentation :
butyrate,
acétate...**



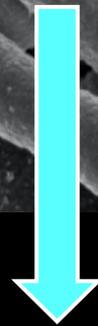
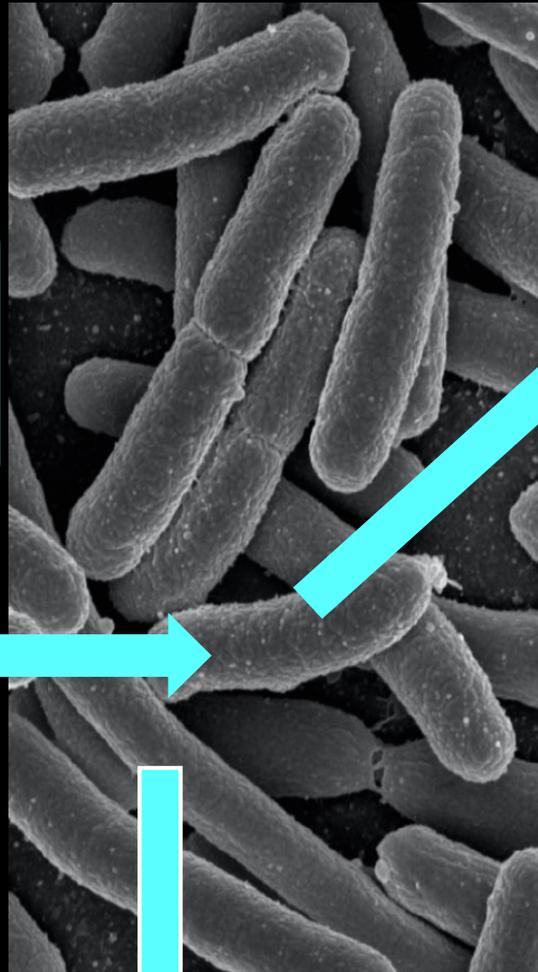
MICROBIOTE INTESTINAL



**Aliments
assimilables**



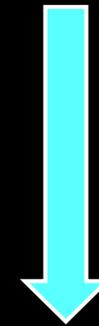
sucres



vitamines

Cell. mortes

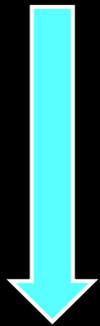
**Déchets de
fermentation :
butyrate,
acétate...**



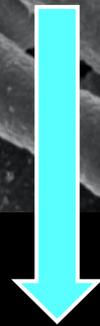
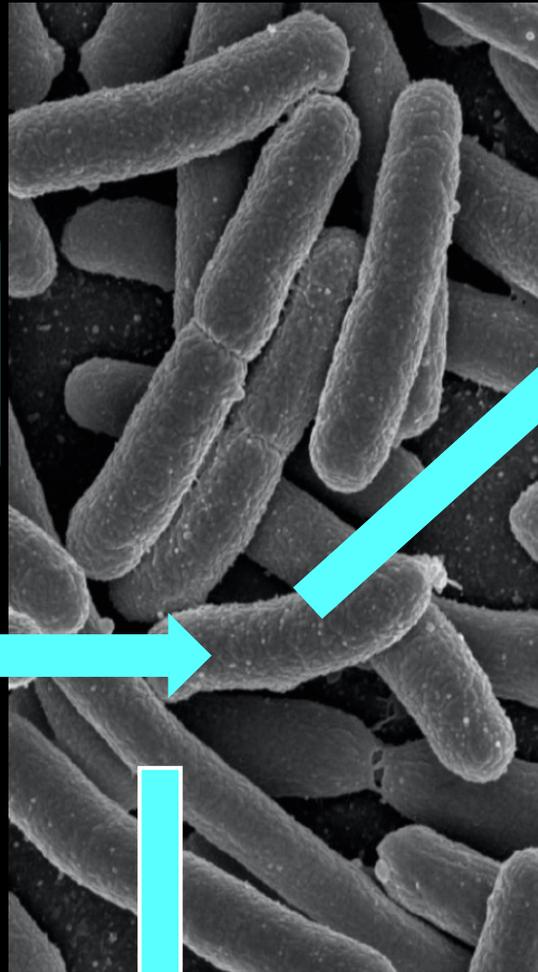
MICROBIOTE INTESTINAL



**Aliments
assimilables**

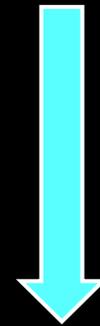


sucres



vitamines

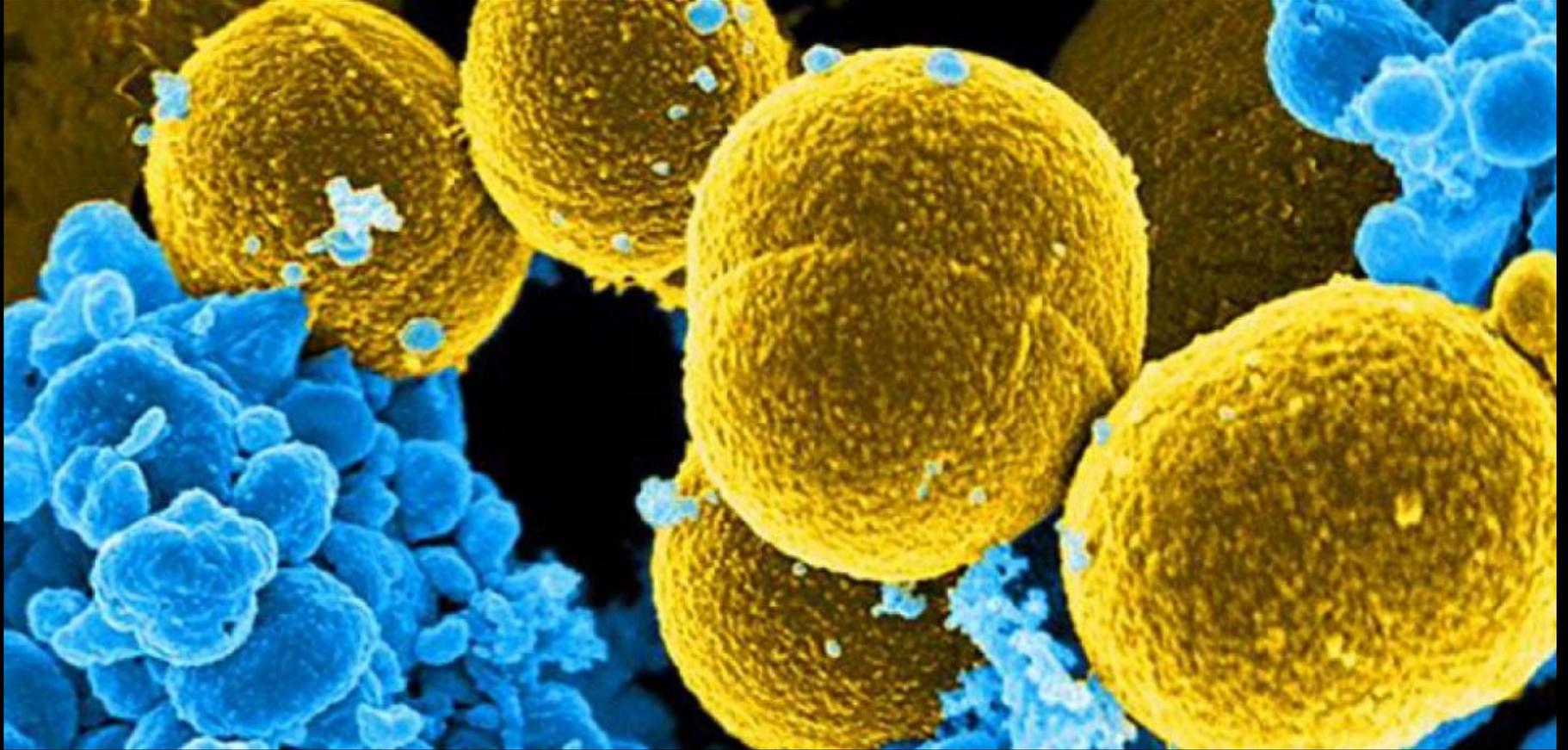
Cell. mortes



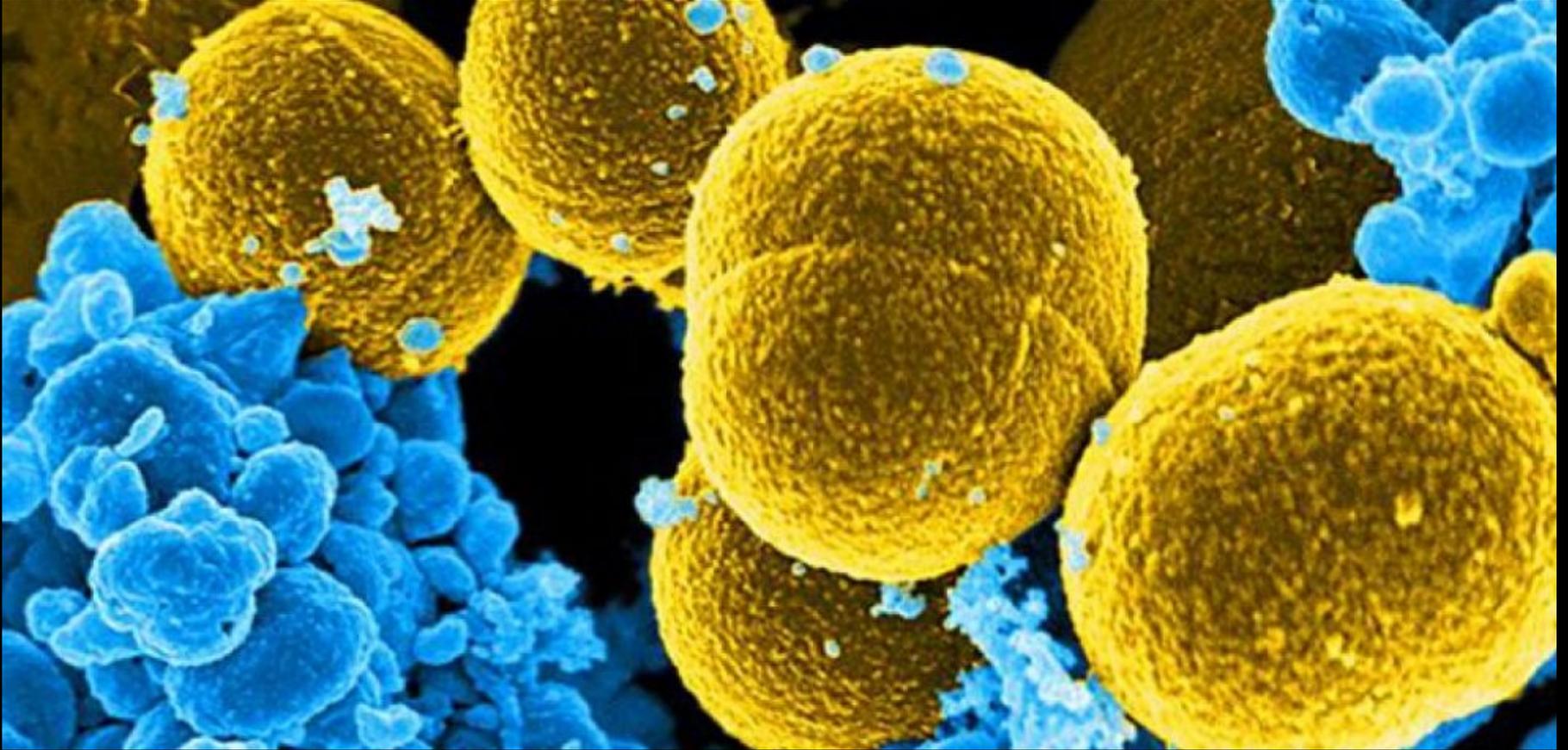
5-10% des besoins

**Déchets de
fermentation :
butyrate,
acétate...**

Staphylocoque doré...

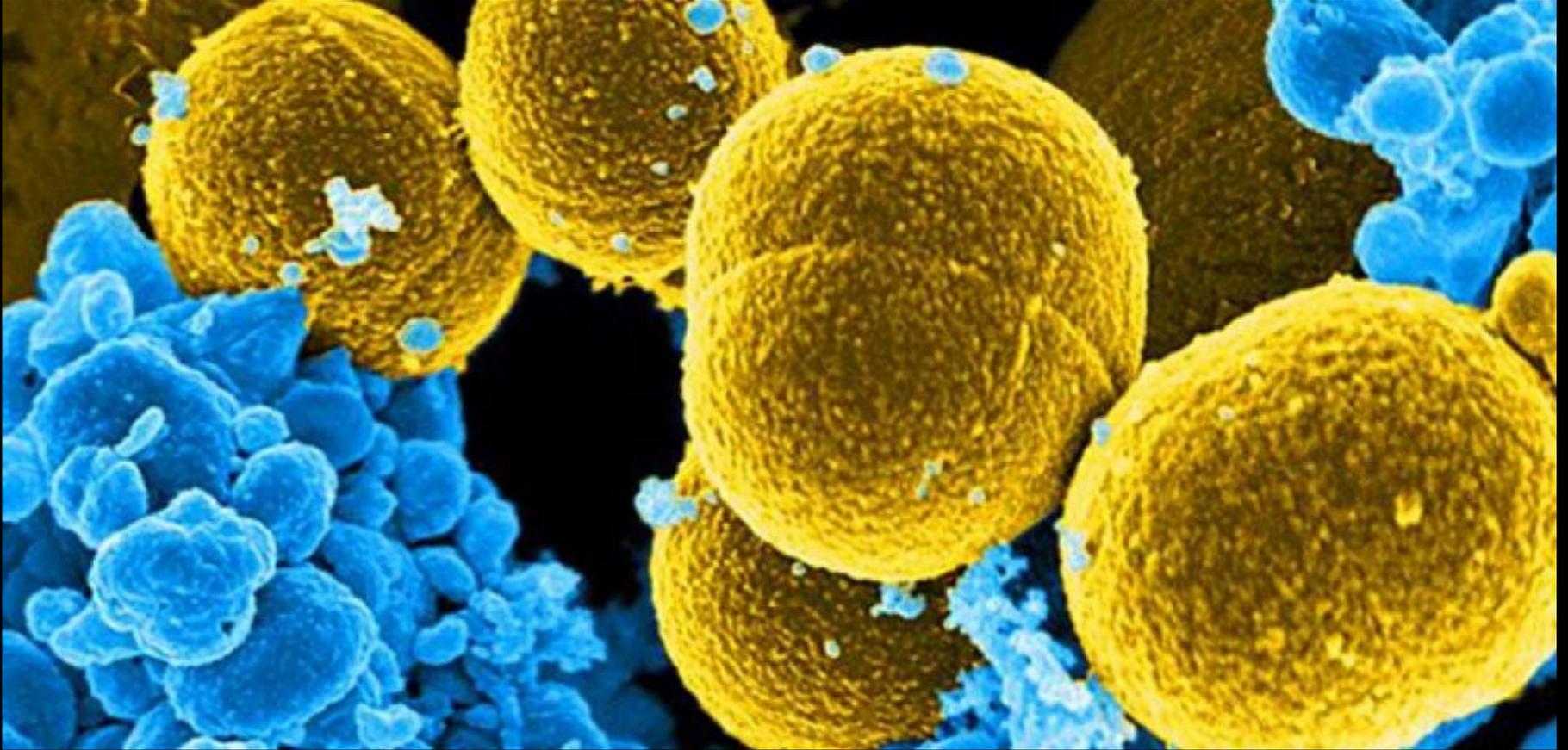


Staphylocoque doré...



...& Staphylocoque de Lyon

Staphylocoque doré...



...& protéases des *Malassezia*

MICROBIOTE ANIMAL



*Leishmania
major*



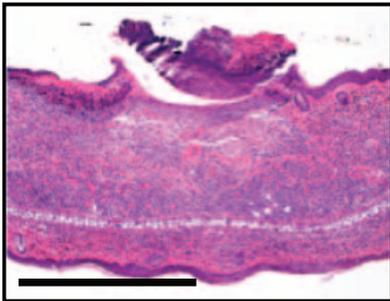
MICROBIOTE ANIMAL



*Leishmania
major*



Contrôle



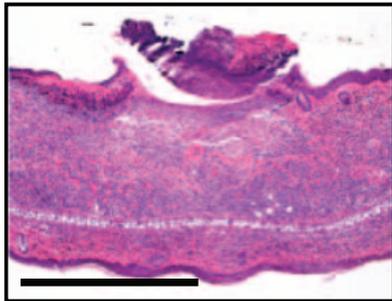
MICROBIOTE ANIMAL



*Leishmania
major*



Contrôle Axénique



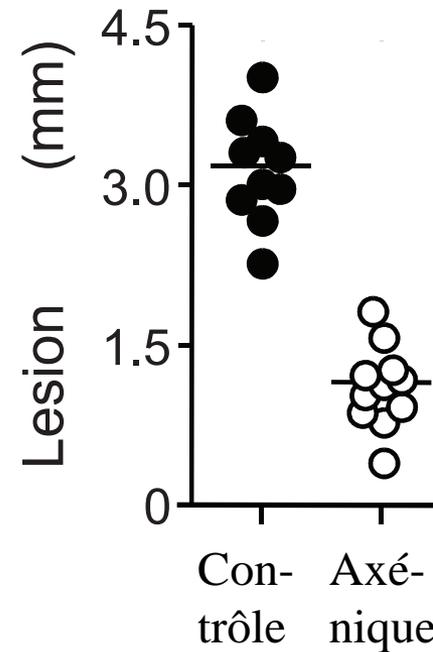
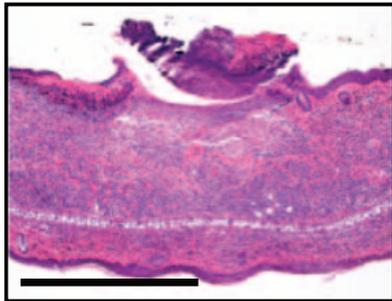
MICROBIOTE ANIMAL



Leishmania major

Contrôle

Axénique



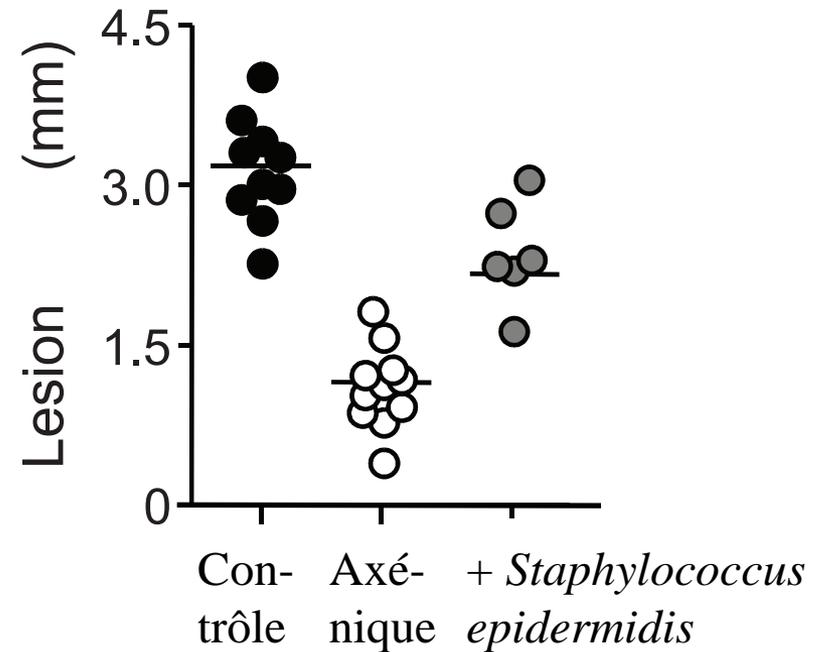
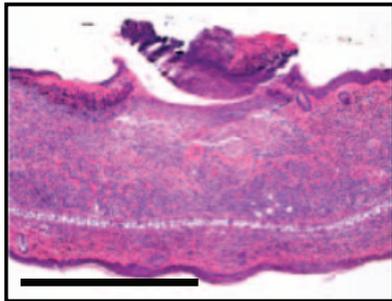
MICROBIOTE ANIMAL



Leishmania major

Contrôle

Axénique



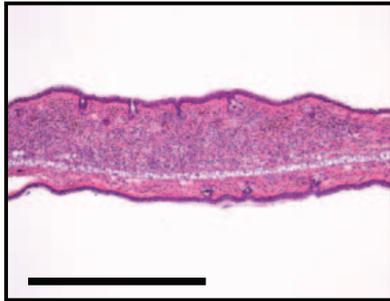
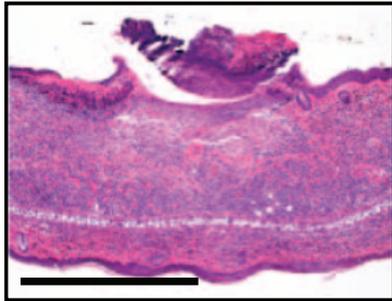
MICROBIOTE ANIMAL



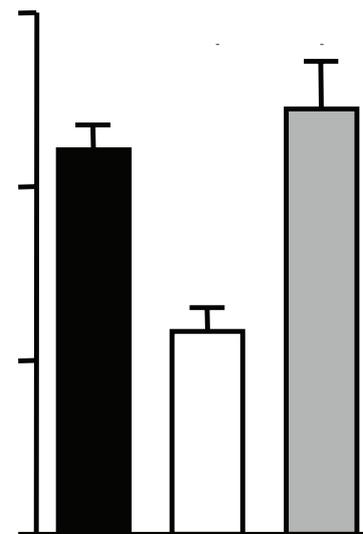
Leishmania major

Contrôle

Axénique



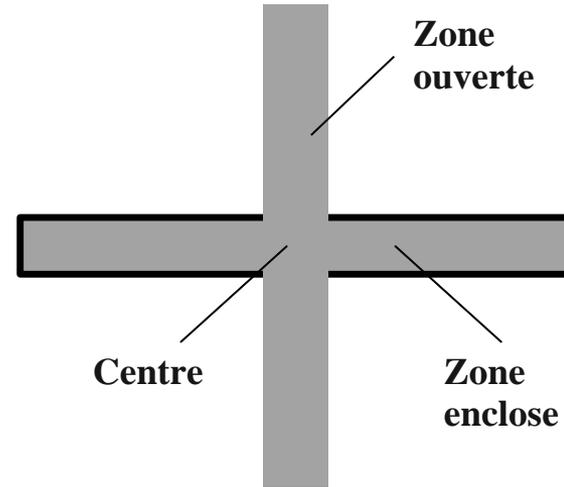
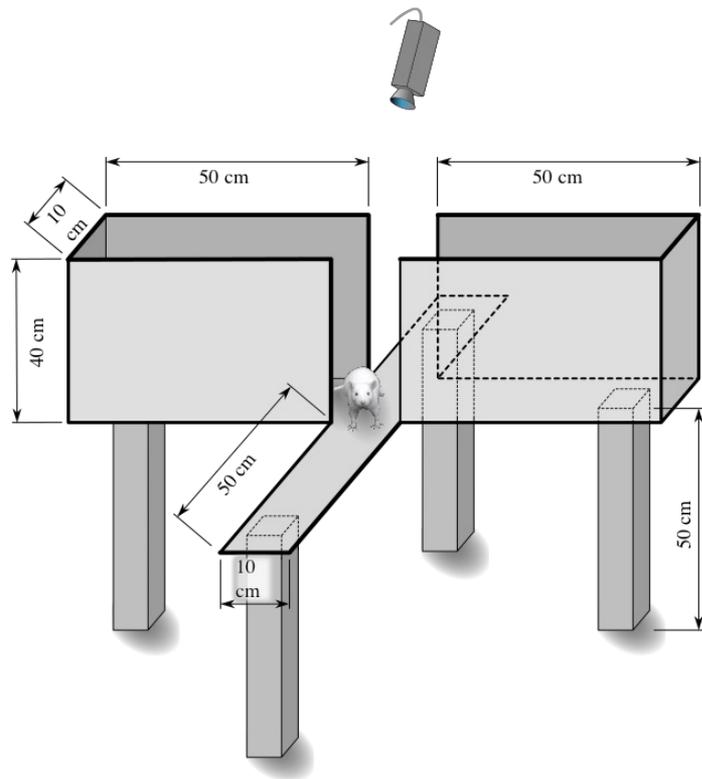
Nombre de lymphocytes



■ Contrôle

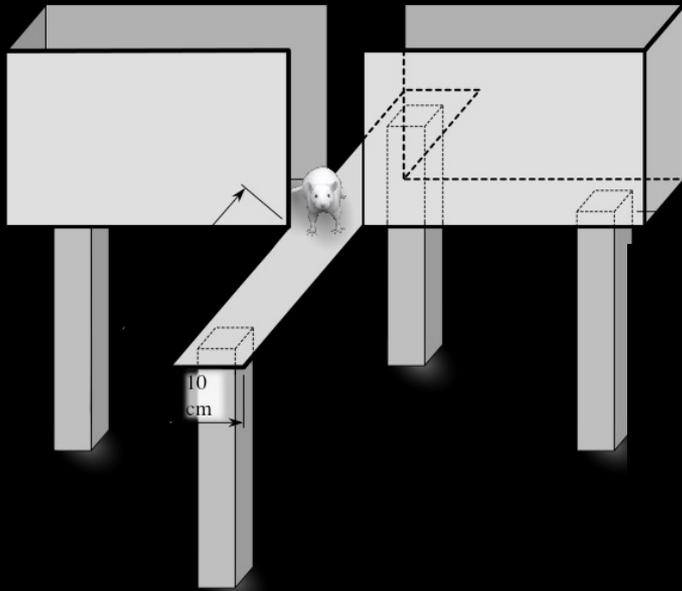
□ Axénique

■ Axé. + *S. epidermidis*

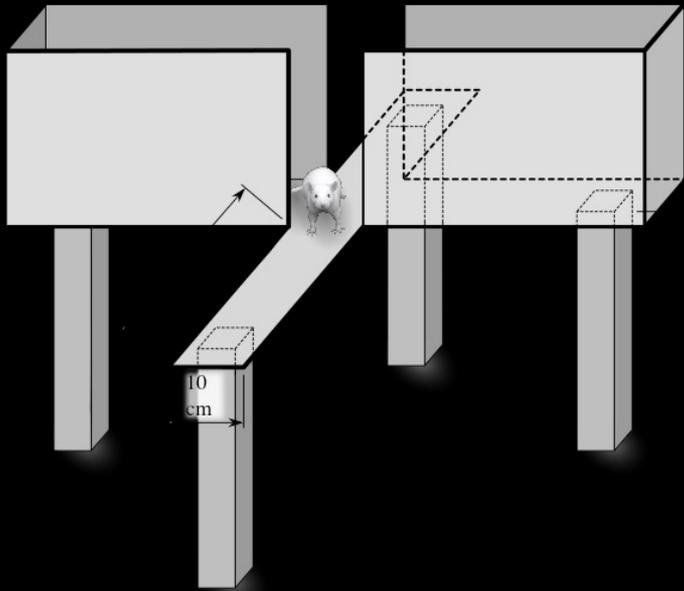
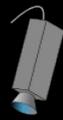


**Diaz Heijtz *et al.*,
2011. *PNAS***

**Souris normale
= avec bactéries**

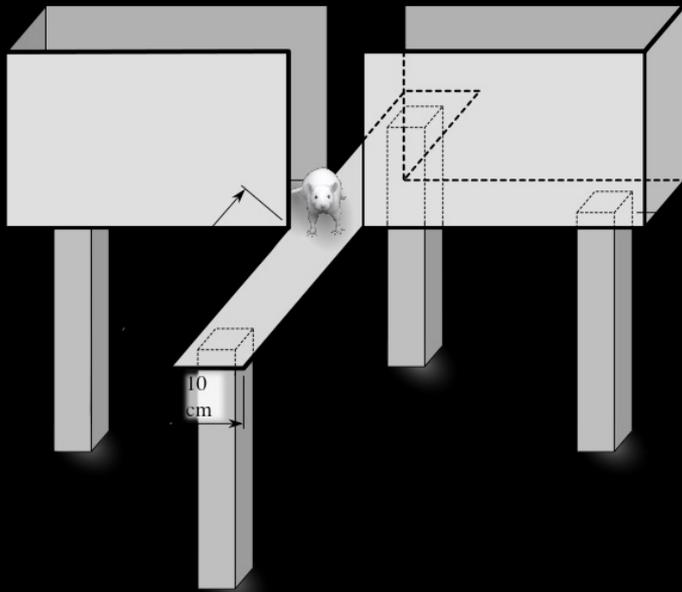


**Diaz Heijtz *et al.*,
2011. *PNAS***

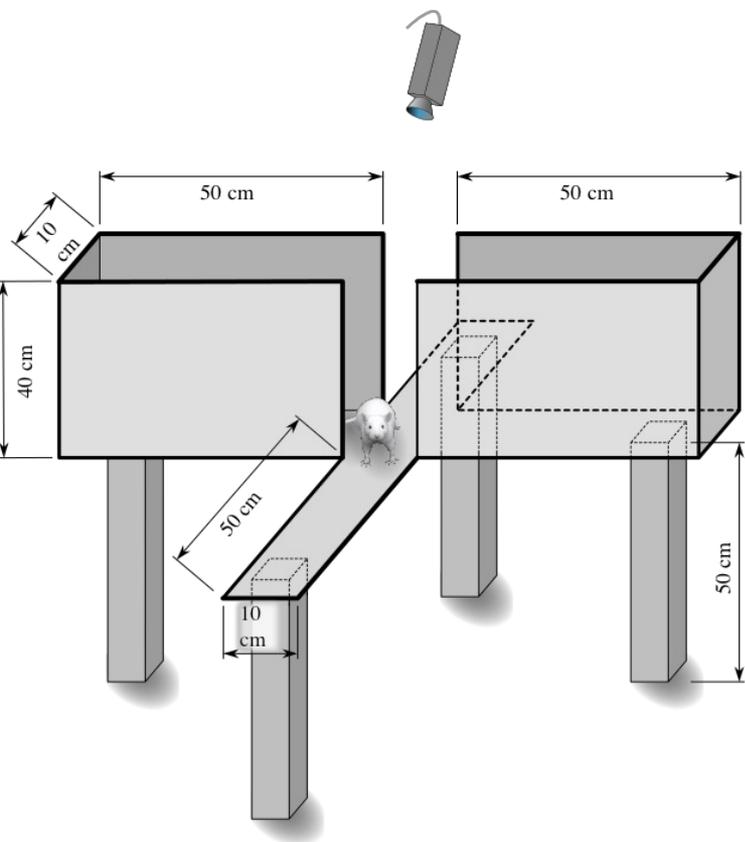


**Diaz Heijtz *et al.*,
2011. *PNAS***

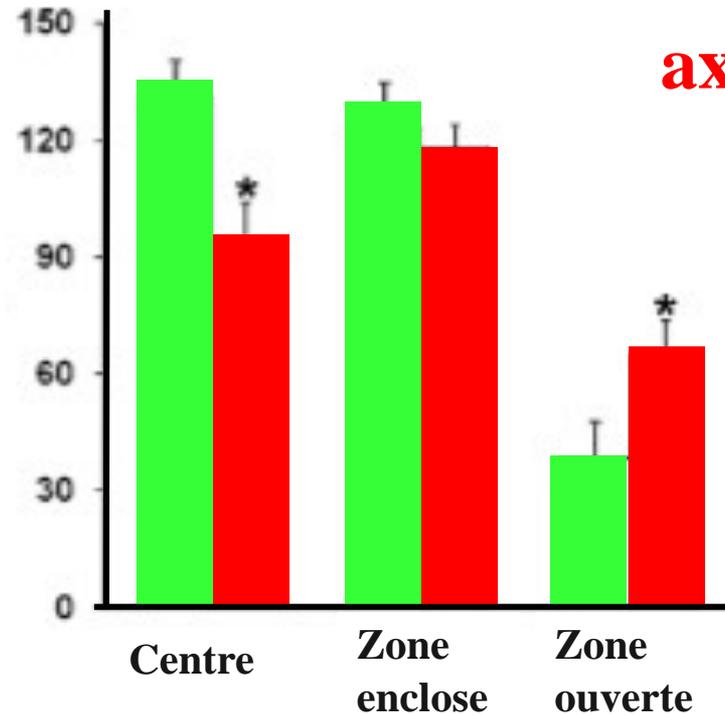
Souris axénique = sans bactérie



Diaz Heijtz *et al.*,
2011. *PNAS*



Temps(sec.)



normale
axénique

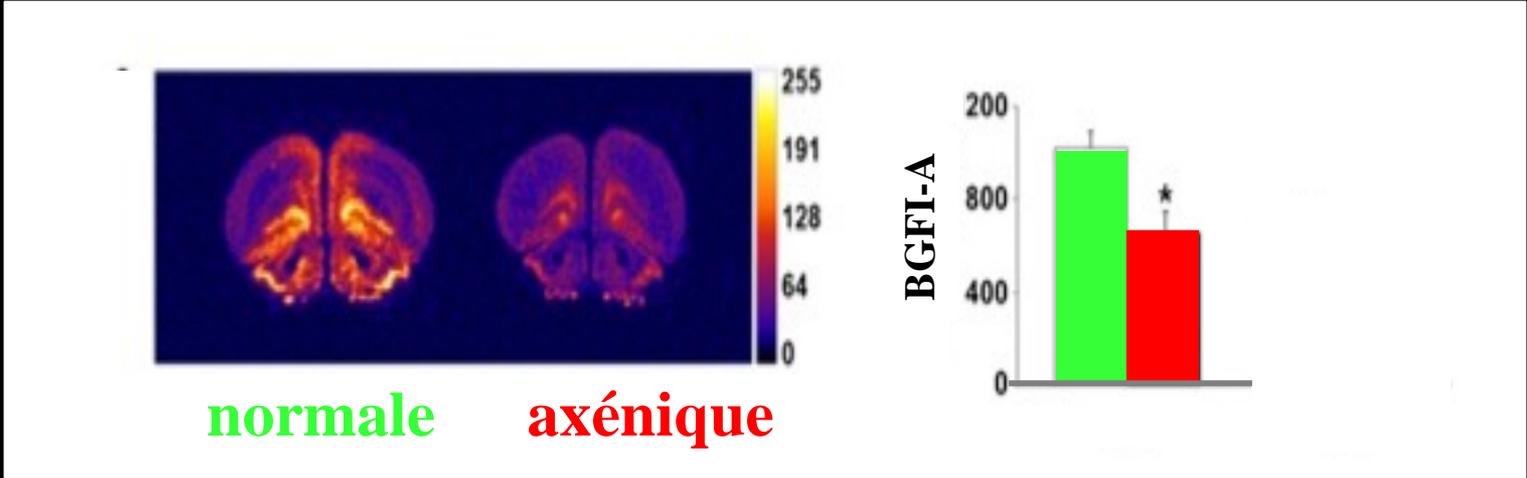
Diaz Heijtz *et al.*,
2011. *PNAS*

Essai de 5 minutes sur des
souris normales (= sym-
biotiques) ou axéniques

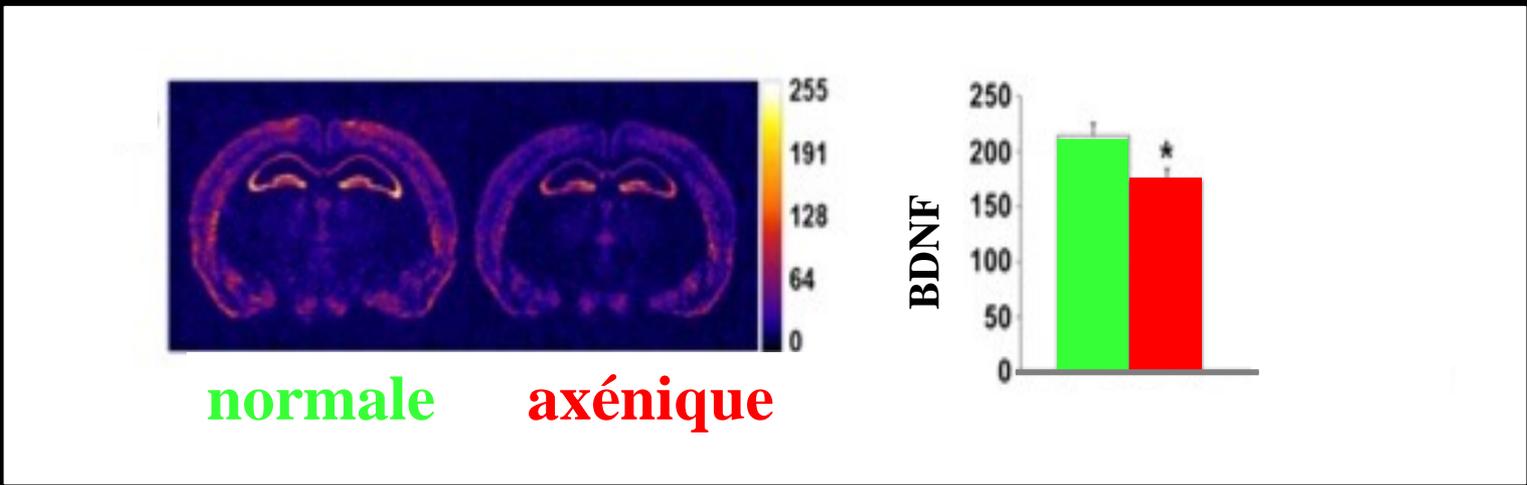
Expression génétique cérébrale

normale *ou* axénique

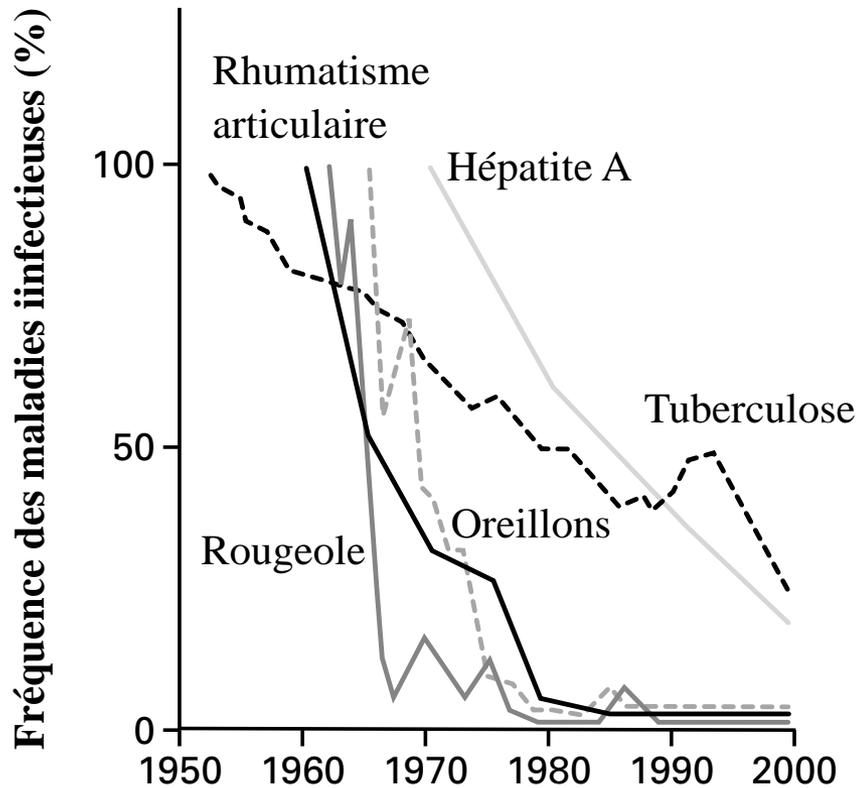
Nerve growth factor-inducible clone A, marqueur de l'anxiété



Brain-derived neurotrophic factor, marqueur de plasticité synaptique

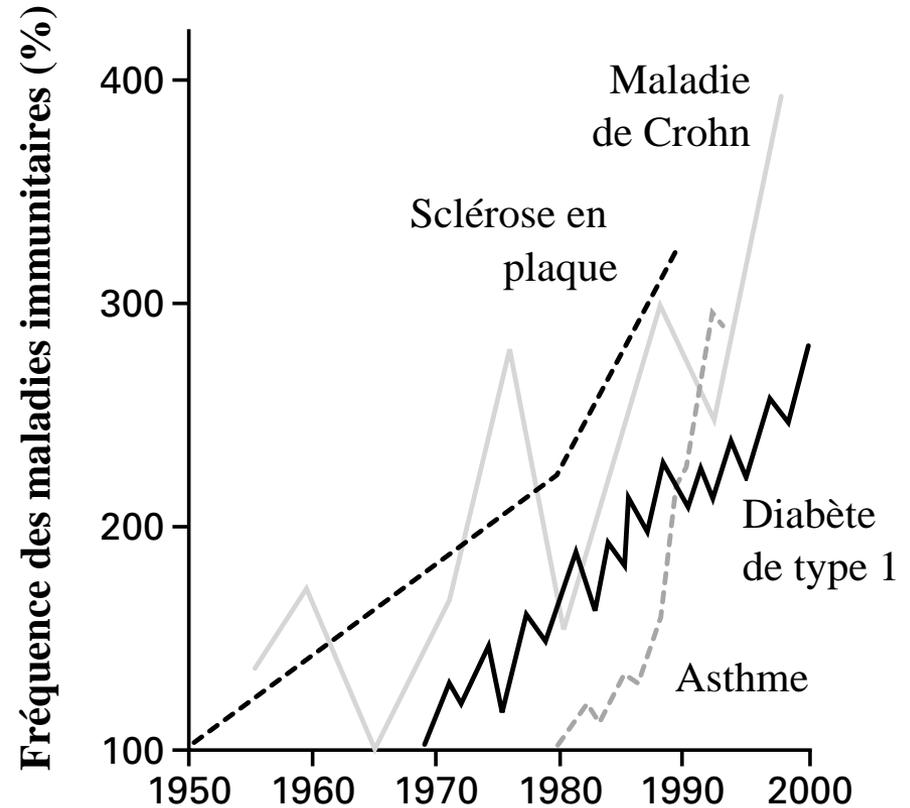
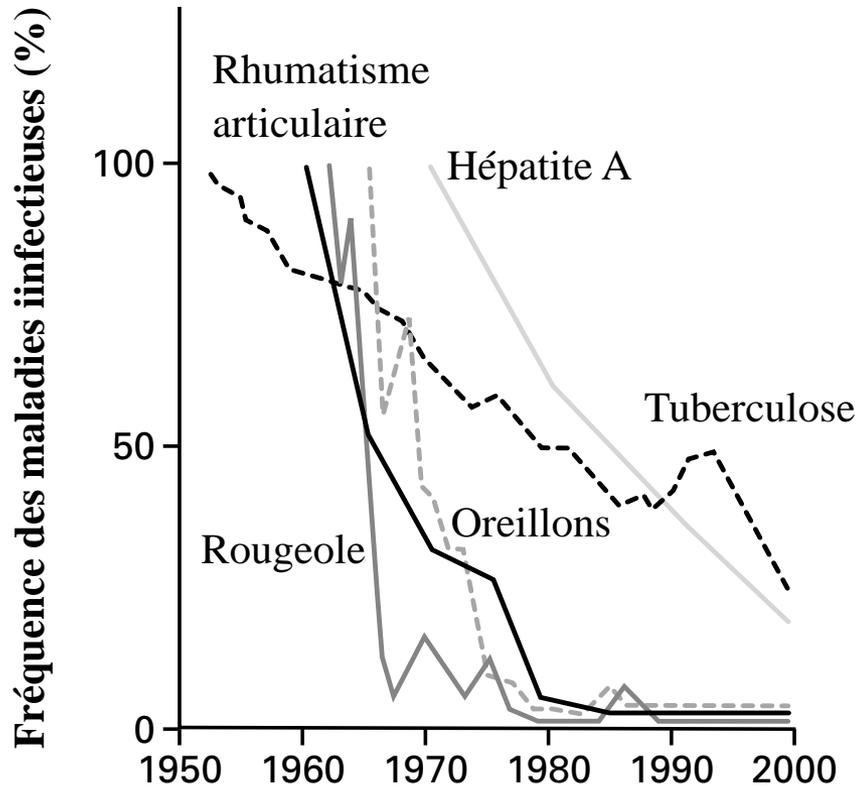


MICROBIOTE HUMAIN



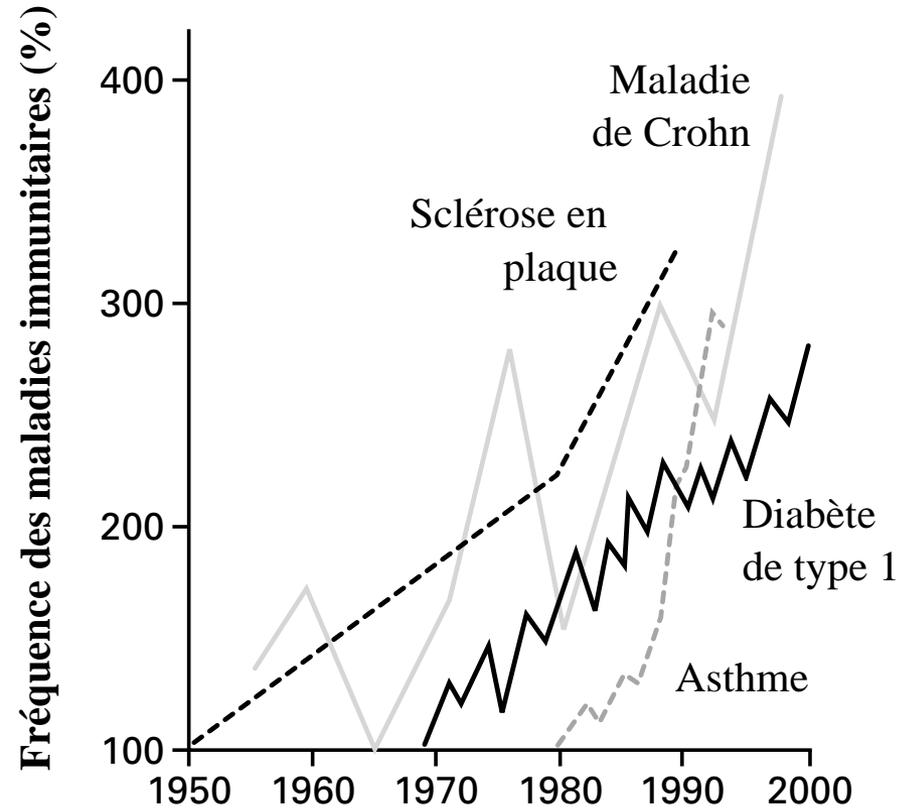
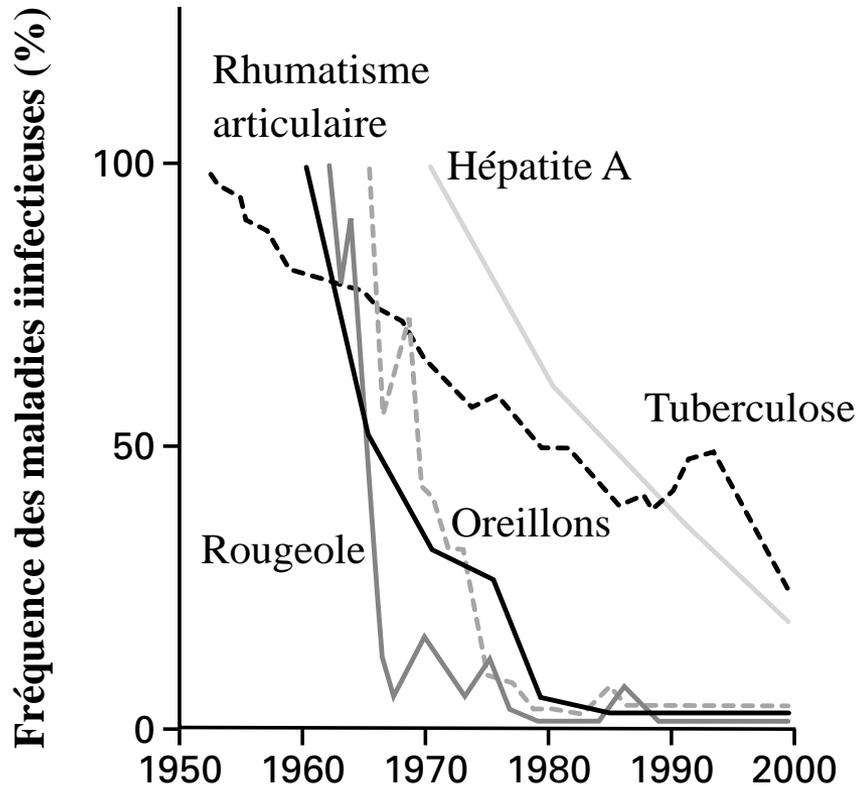
D'après J.-F. Bach

MICROBIOTE HUMAIN



D'après J.-F. Bach

MICROBIOTE HUMAIN

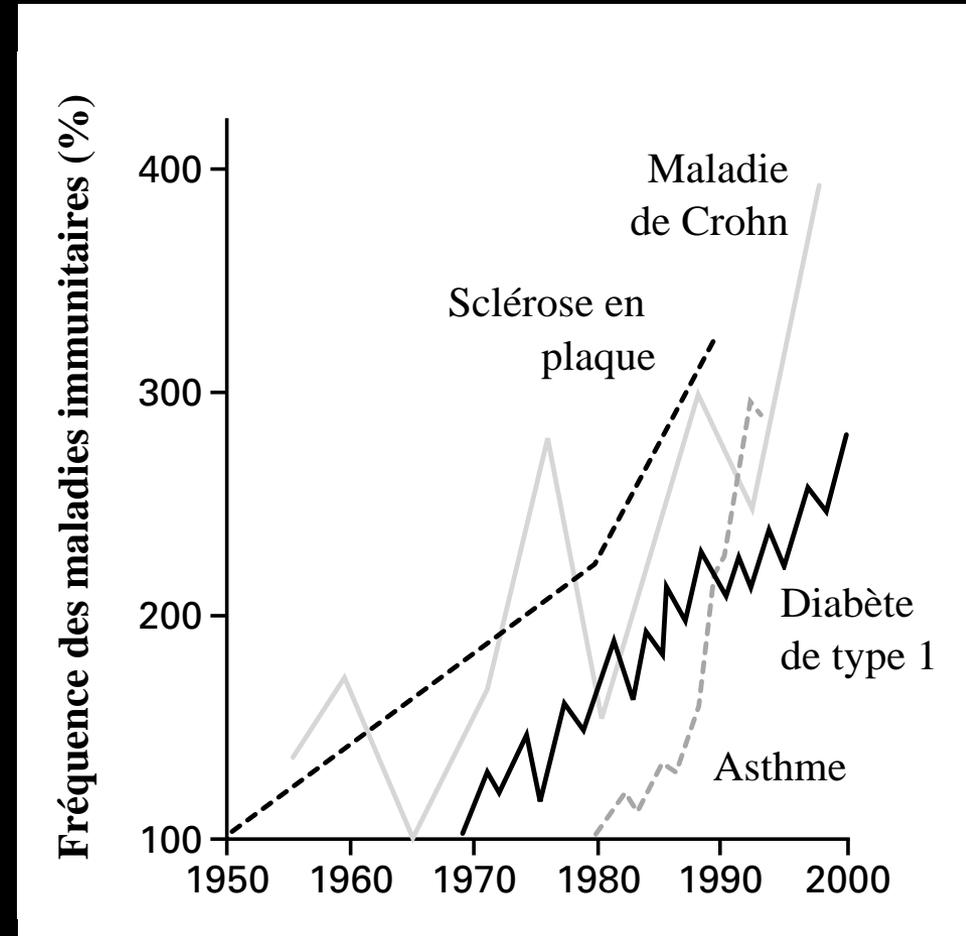


D'après J.-F. Bach

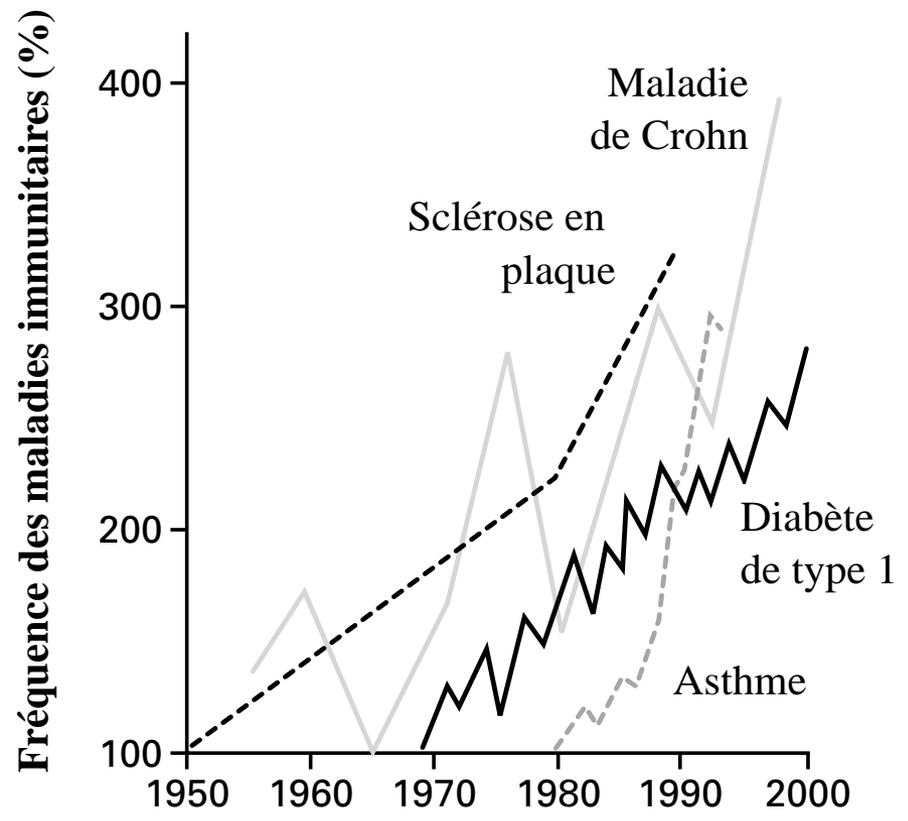
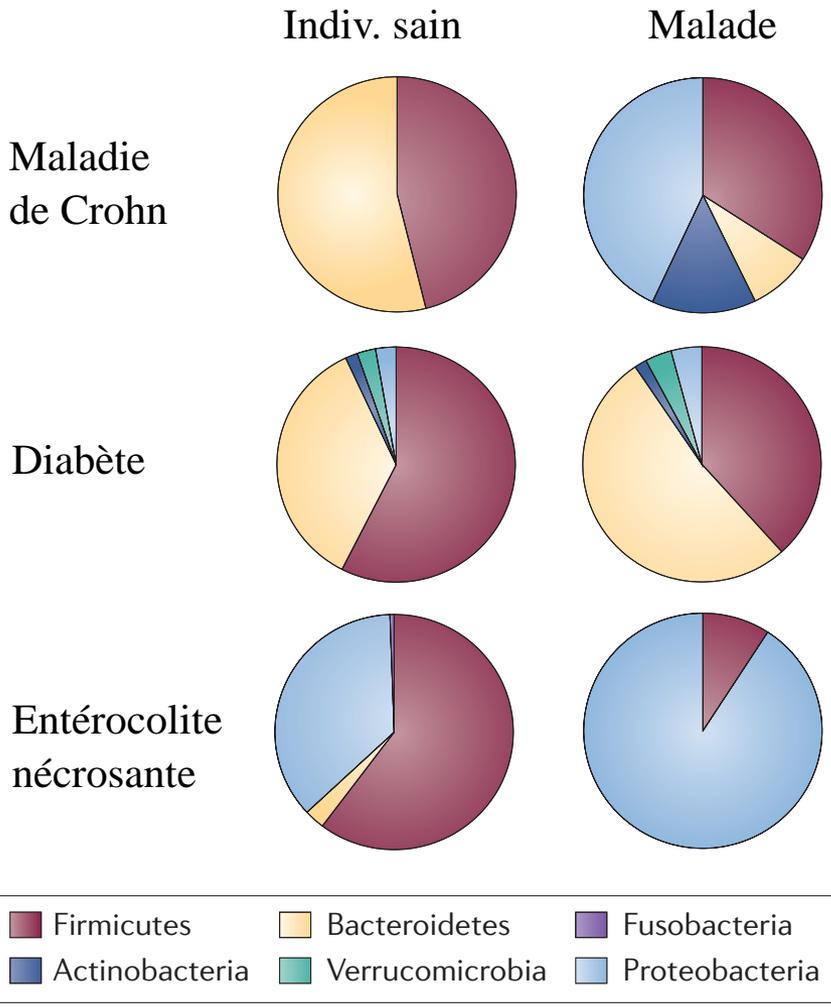
MICROBIOTE ET IMMUNITÉ

Maladies :

- du métabolisme (diabète, obésité...)
- du système immunitaire (asthme, allergie, maladies auto-immunes...)
- du système nerveux (autisme, Parkinson, Alzheimer...)

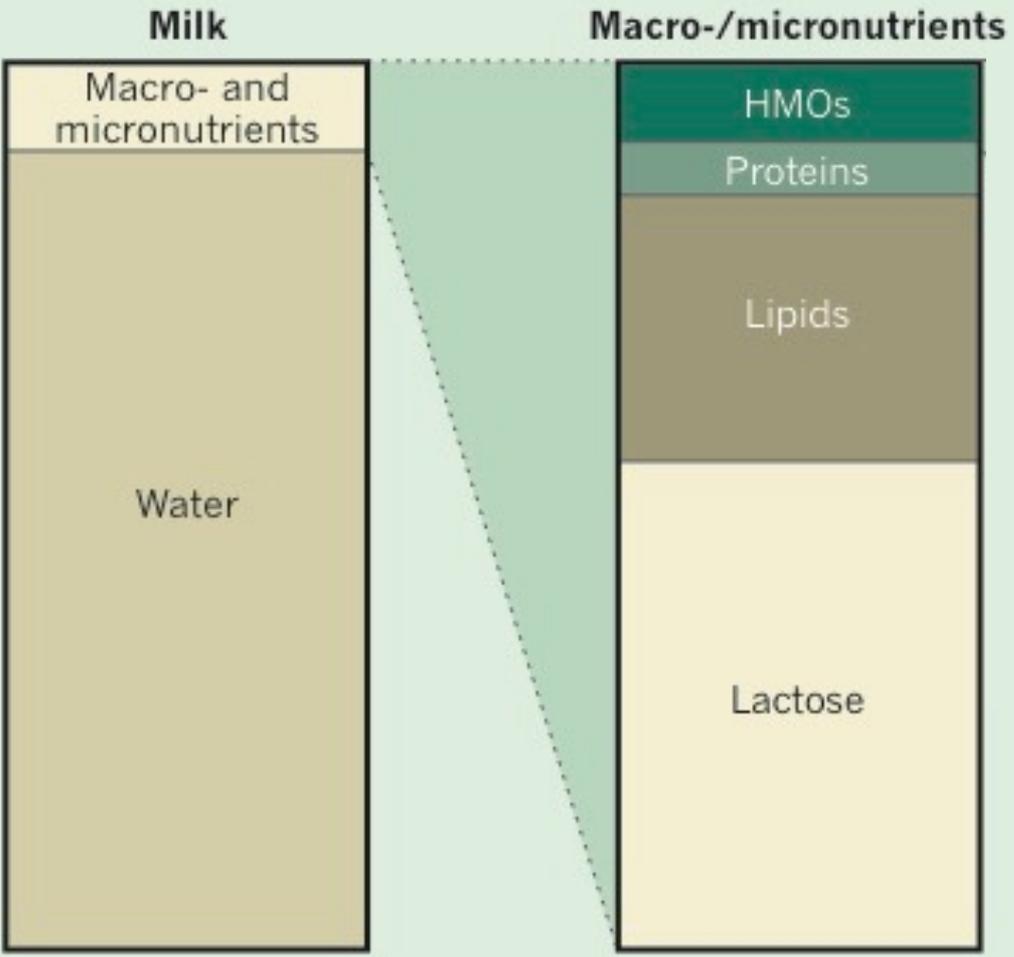


MICROBIOTE ET IMMUNITÉ



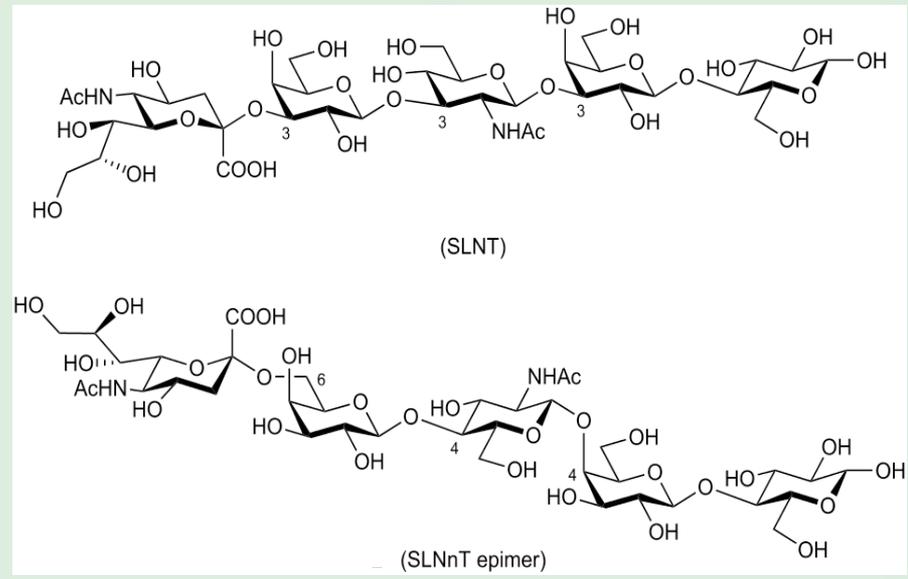
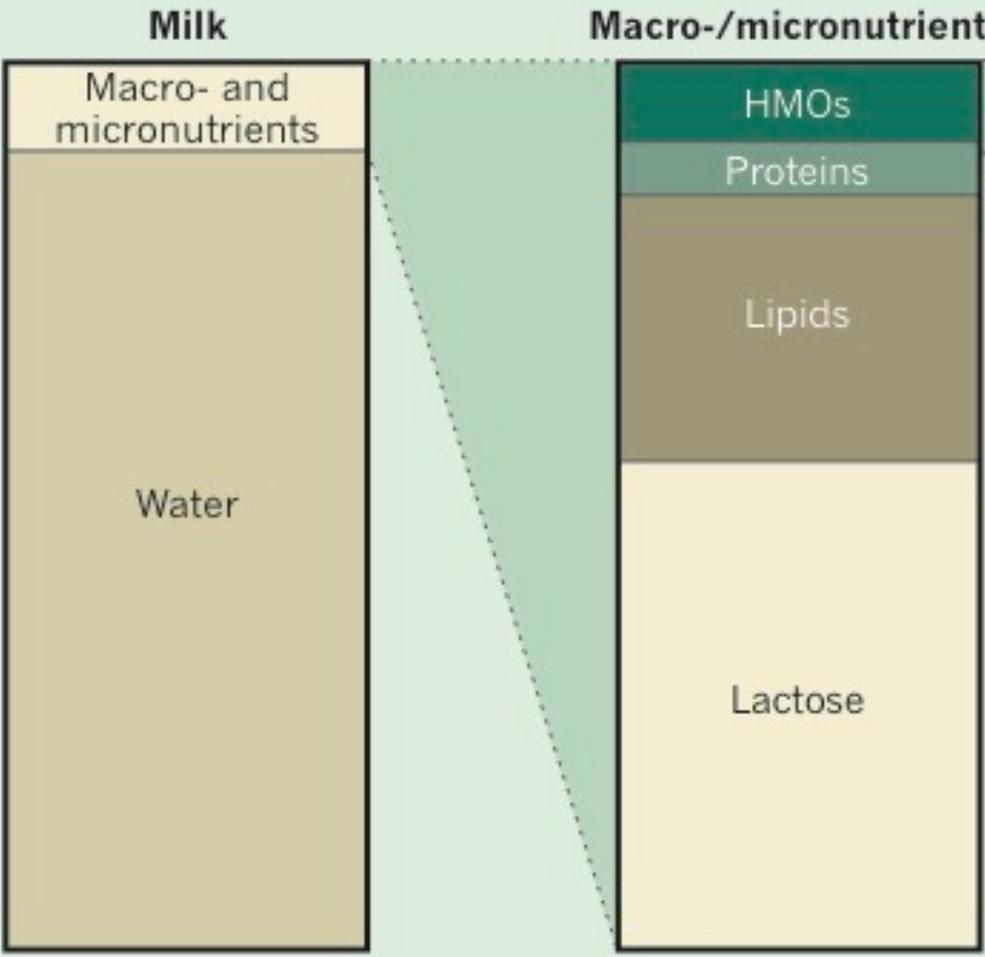


WHAT'S IN HUMAN MILK



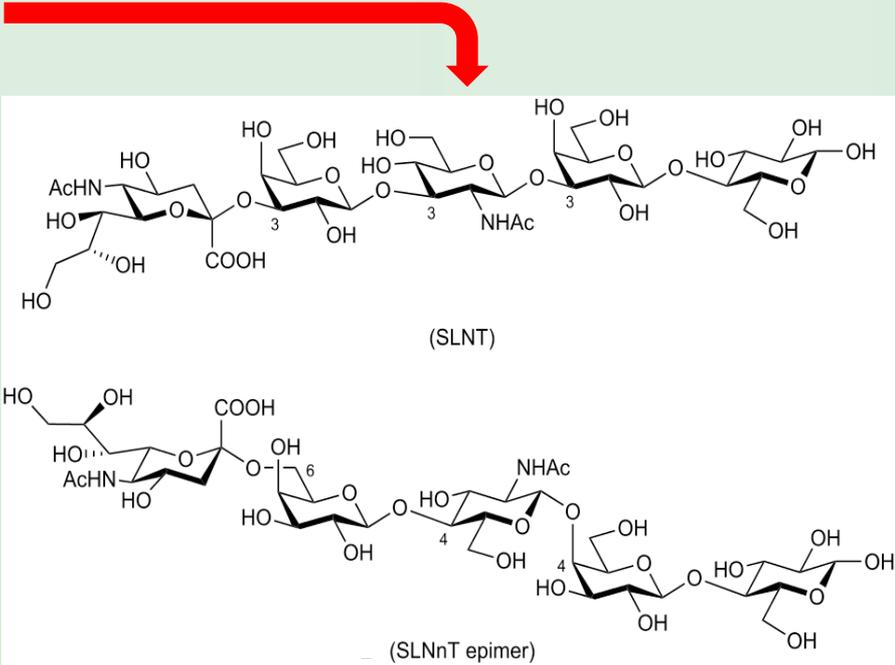
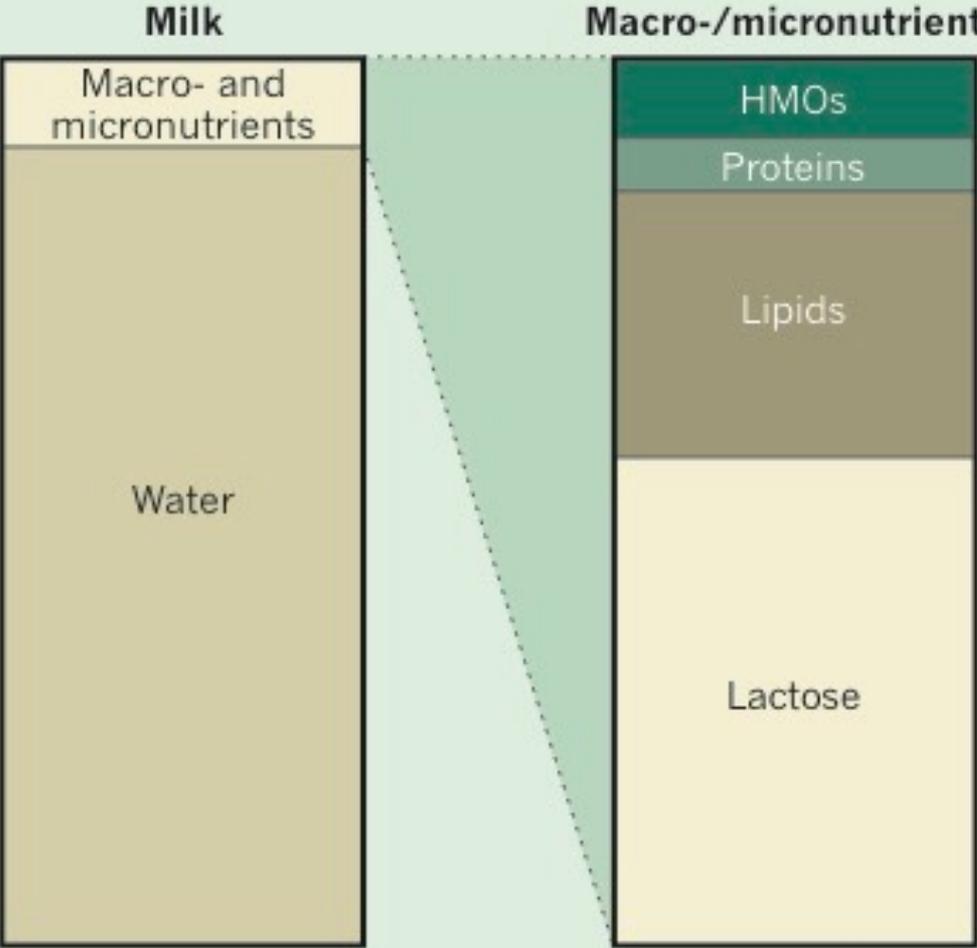
WHAT'S IN HUMAN MILK

Human Milk Oligosaccharides (HMOs)



WHAT'S IN HUMAN MILK

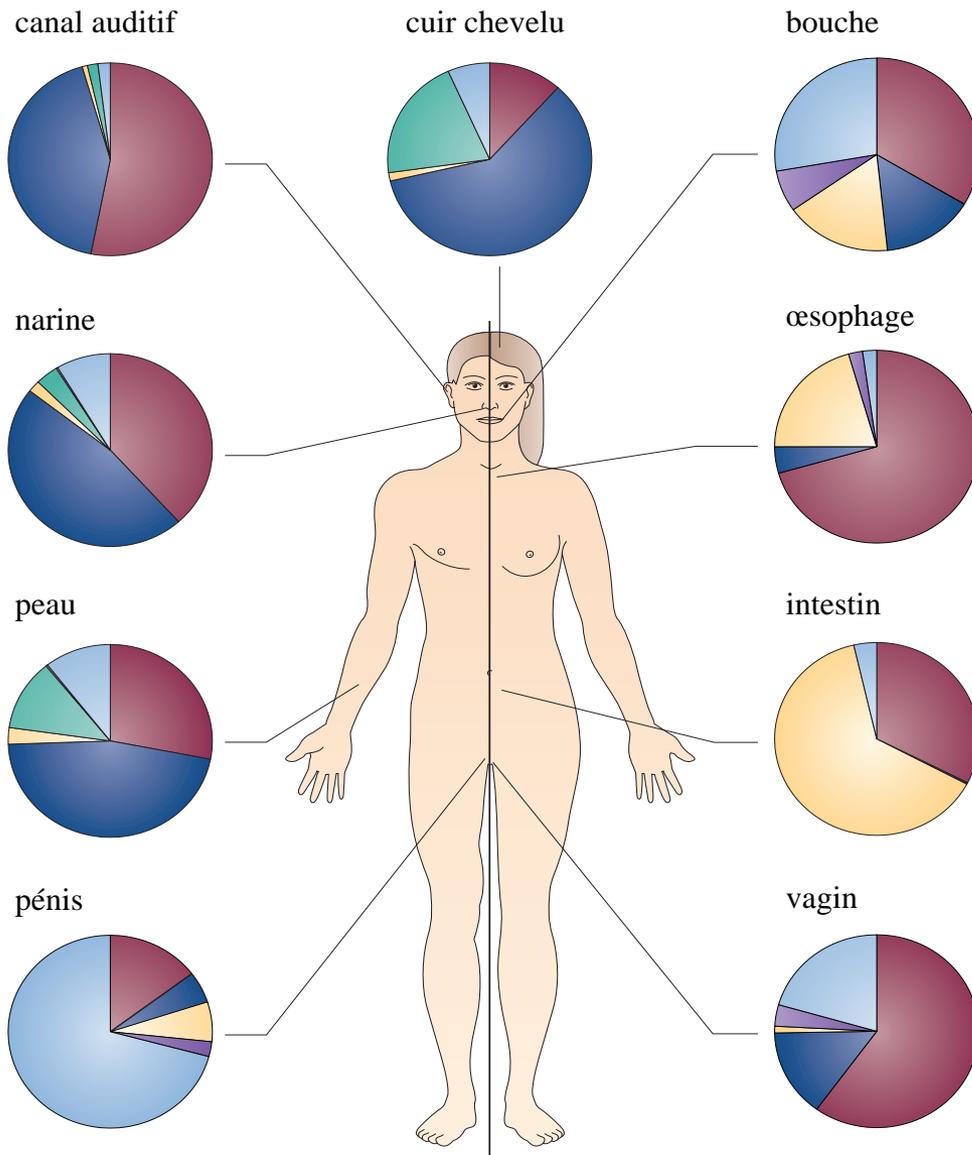
Human Milk Oligosaccharides (HMOs)



... des prébiotiques !

6

... en une voie vers
l'interdépendance...

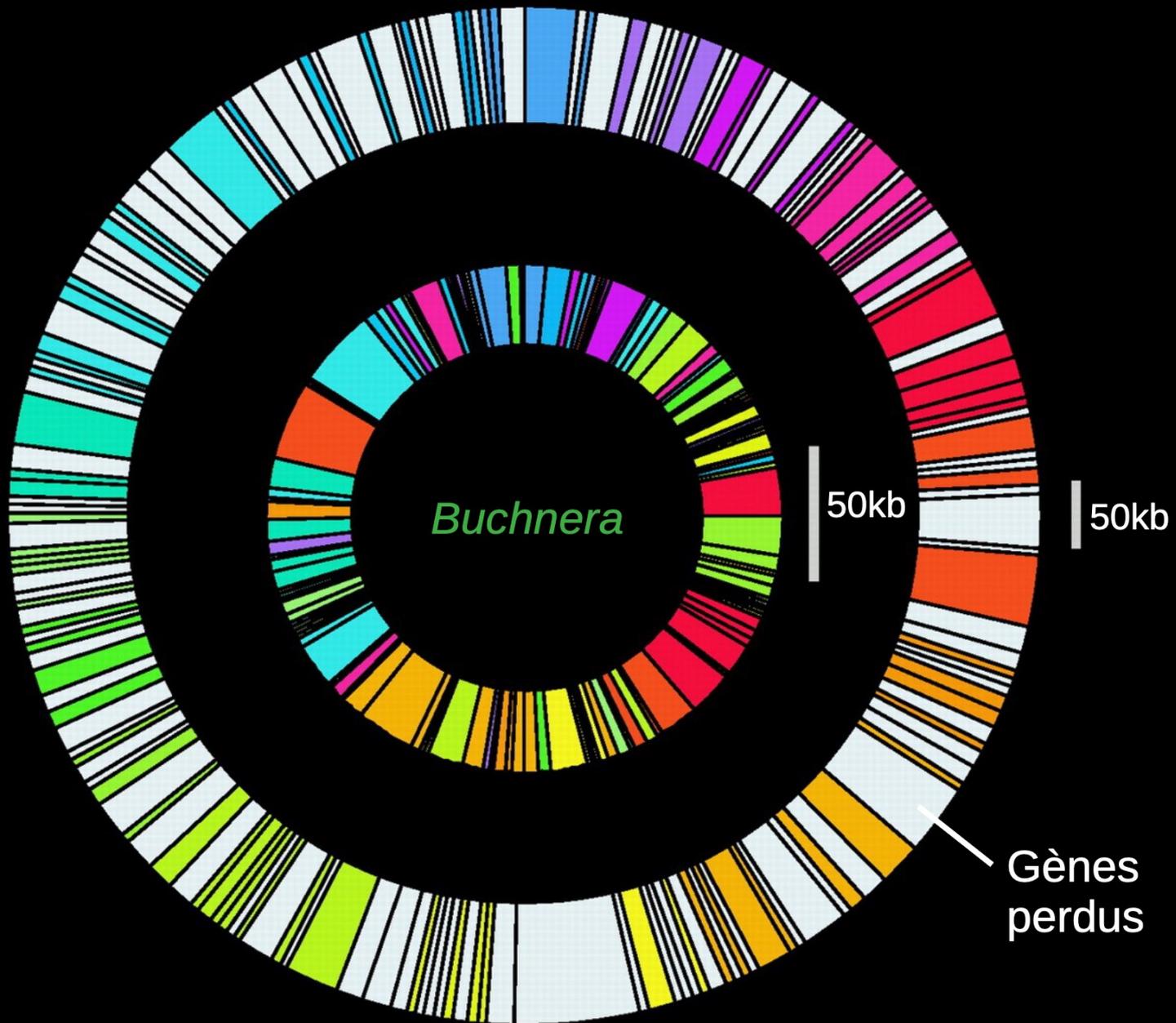


10 000 milliards de bactéries dans l'intestin

1 000 milliards sur la peau

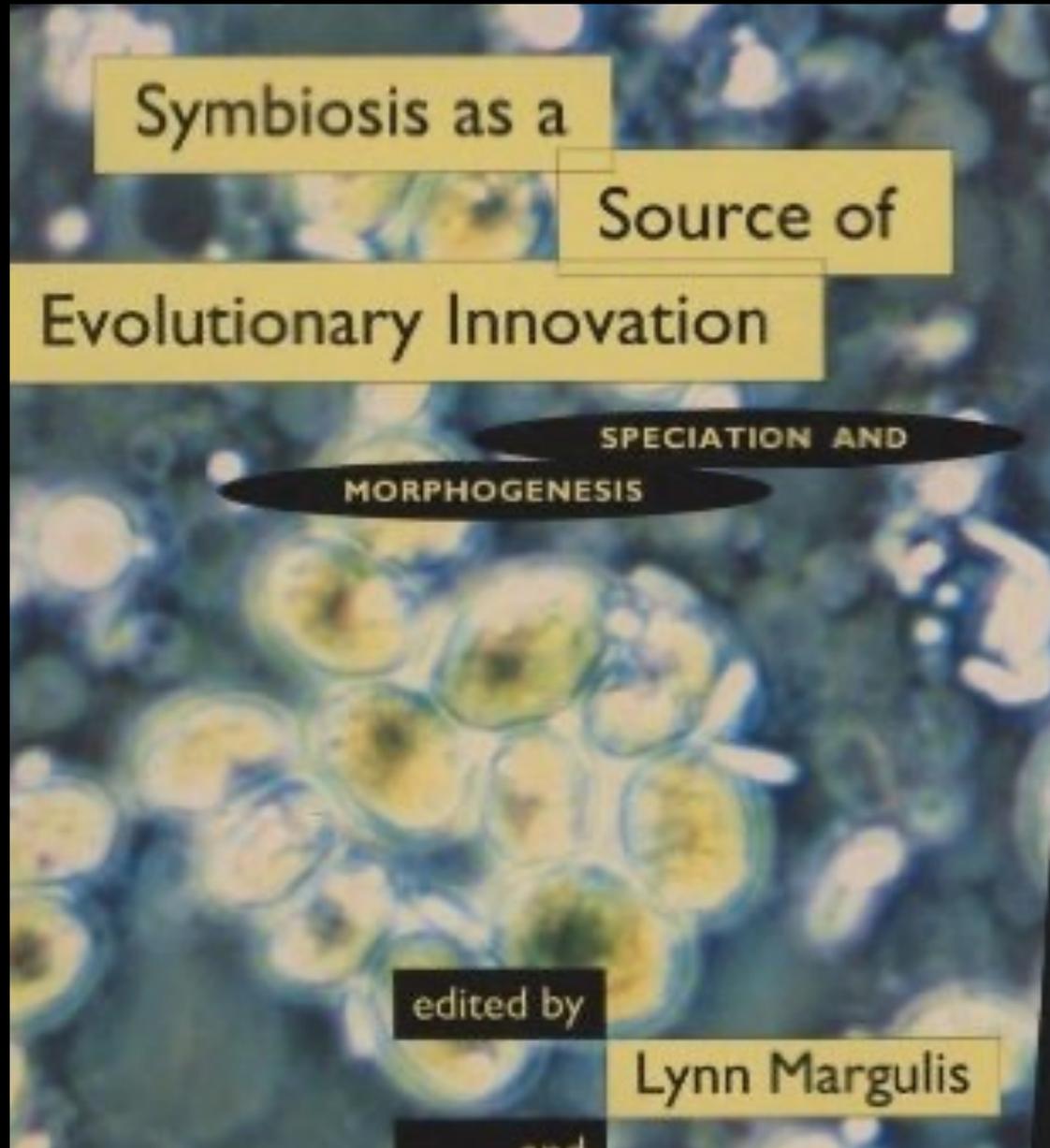
100 milliards ailleurs

... contre 10 000 milliards de cellules humaines

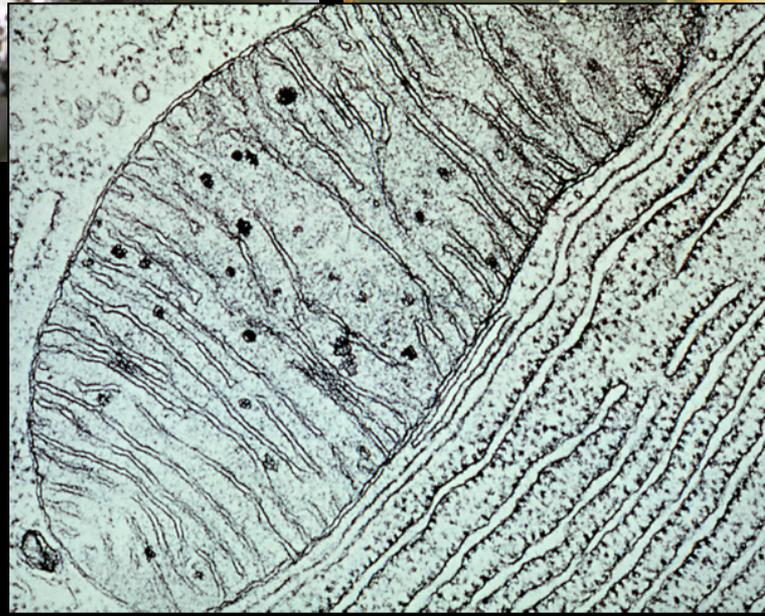
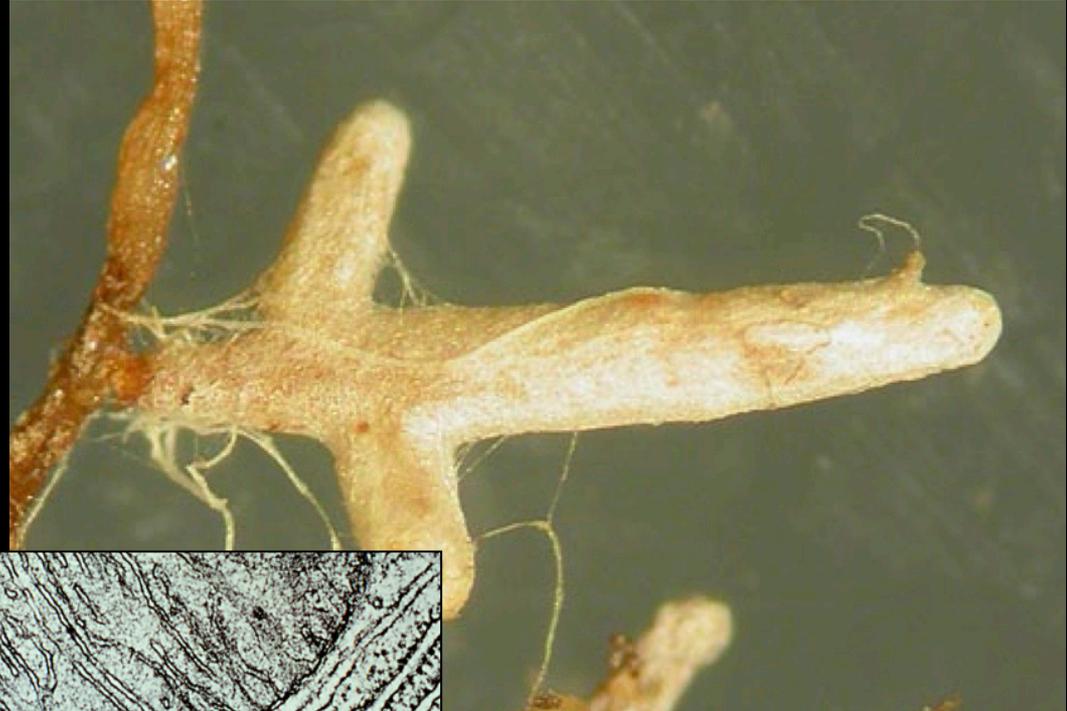
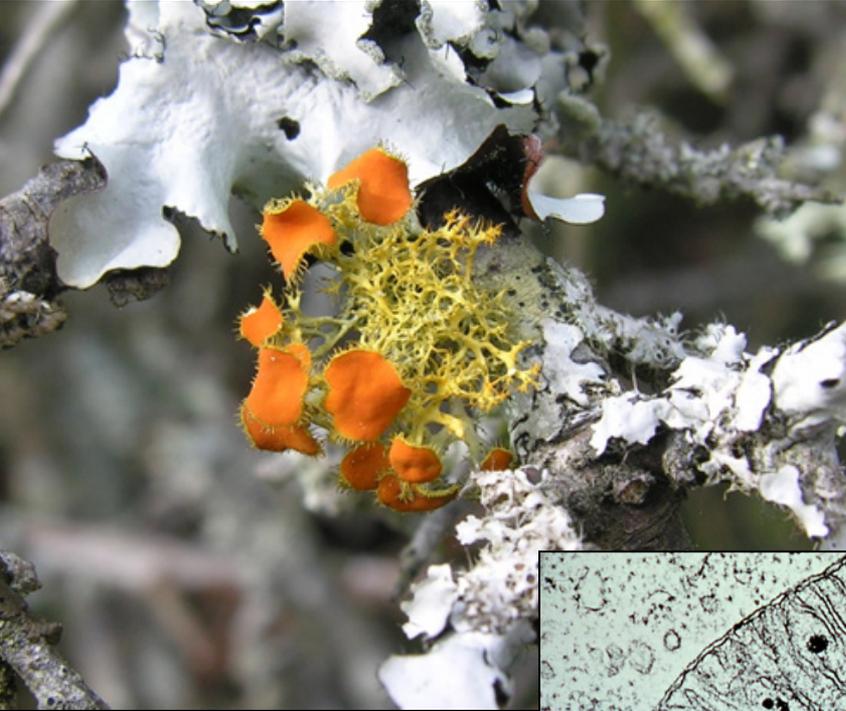


Génome reconstitué de la bactérie ancêtre

La symbiose comme une complexification



La symbiose comme une complexification



La symbiose comme une dépendance



Selosse, Bessis & Pozo, *Trends in Microbiology* 2014 (22: 607-613)

La symbiose comme une dépendance



Selosse, Bessis & Pozo, *Trends in Microbiology* 2014 (22: 607-613)

La symbiose comme une dépendance



Selosse, Bessis & Pozo, *Trends in Microbiology* 2014 (22: 607-613)

La symbiose comme une dépendance



**Pas de
sélection**



Selosse, Bessis & Pozo, *Trends in Microbiology* 2014 (22: 607-613)

La symbiose comme une dépendance



**Contingence
neutre**



Selosse, Bessis & Pozo, *Trends in Microbiology* 2014 (22: 607-613)

La symbiose comme une dépendance



**Contingence
neutre,
souvent
irréversible**



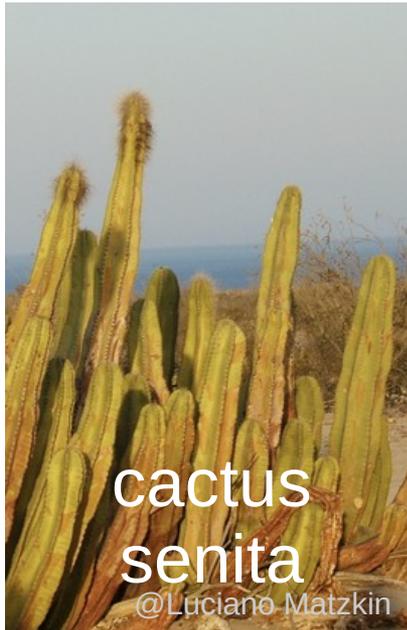
Selosse, Bessis & Pozo, *Trends in Microbiology* 2014 (22: 607-613)

La symbiose comme une dépendance



Selosse, Bessis & Pozo, *Trends in Microbiology* 2014 (22: 607-613)

La coexistence comme une dépendance



La coexistence comme une dépendance

Effet de l'interaction sur :

	<i>Espèce A</i>	<i>Espèce B</i>
Compétition	-	-
Mutualisme, symbiose	+	+
Prédation, parasitisme	+	-
Commensalisme	+	0
Amensalisme	-	0
Neutre	0	0



MARC-ANDRÉ
SELOSSE

JAMAIS SEUL

**Ces microbes qui construisent
les plantes, les animaux
et les civilisations**

postface de Francis Hallé

ACTES SUD



