陈光霁 2023.07.26

Hematophagy (Bloodsucking) in animals



Hematophagy (Bloodsucking) Feeding on blood of another <u>living</u> organism

Bloodsucking Creatures:



insects (eg. mosquitoes)



arachnids (eg. tick[蜱虫])

15,000 blood-feeding species representing at least 6 evolutionary events



nematode worms



fish (eg. candiru[卷须寄生鲇])





leeches



Vampire Bats

• 30,000 bloodsuckers out of the roughly 1.5 or 1.6 million species of animals that have been described is a very, very small number.

 The first known hematophages (blood) feeders) were the *protomosquitoes*, of which there is fossil evidence from 220 million years ago (Schutt 2008).

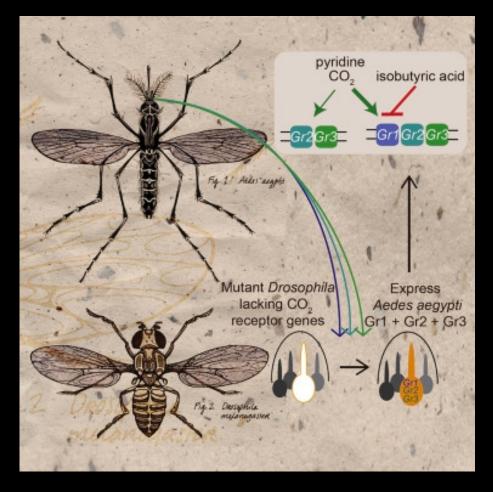


Two Ancient Mosquito Species

Adaptations for Hematophagy

Blood feeders need to

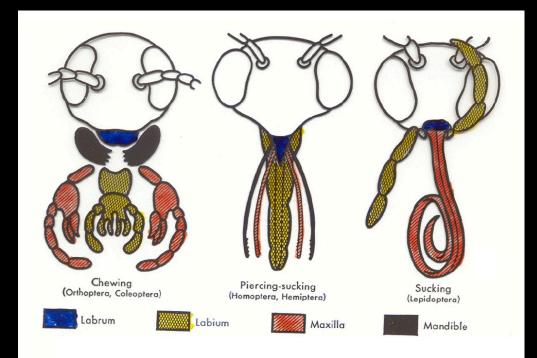
- (i) find a host on which to feed
 - ecto- or endoparasites [外寄生或内寄生]
 - a combination of visual, olfactory, and temperature cues to find their hosts
- (ii) attach to the host in order to feed
- (iii) access the blood of their host
 - piercing/sucking or ripping/tearing
- (iv) **<u>digest</u>** the blood meal
 - comprised of protein and water ightarrow
 - accumulation of nitrogenous waste products ightarrow
 - poisonous due to iron toxicity



Carbon Dioxide Receptor Subunits to Odor Detection



ecto- or endoparasites (eg. lice in the hair)

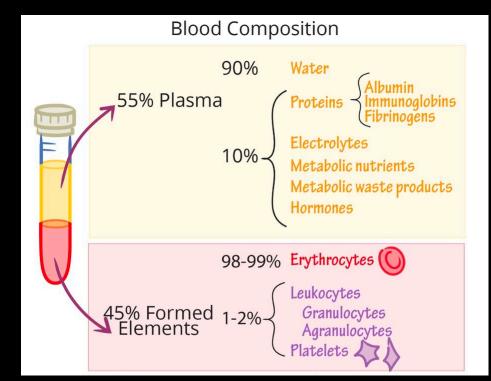


piercing/sucking

Why Do Bloodsucking Animals Feast on Blood?

- Ecological niche?
 - Since those bigger animals no longer served as \bullet viable prey, these animals evolved to favor a mutation — bloodsucking — that still allowed them to feast without having to catch, subdue and kill their food.

- Nutritional benefits ?
 - Blood is a rich source of protein, iron, and other \bullet essential nutrients that are necessary for the survival and reproduction of these animals.

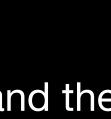


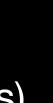




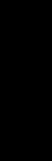
- Nutritional disadvantage?
 - Obligate sanguivory requires adaptation to
 - very low levels of some nutrients (essential amino acids and the vitamin B complex)
 - Iron concentration
 - nitrogenous waste products (renal disease-like symptoms).













Vampire snail



Vampire Bats

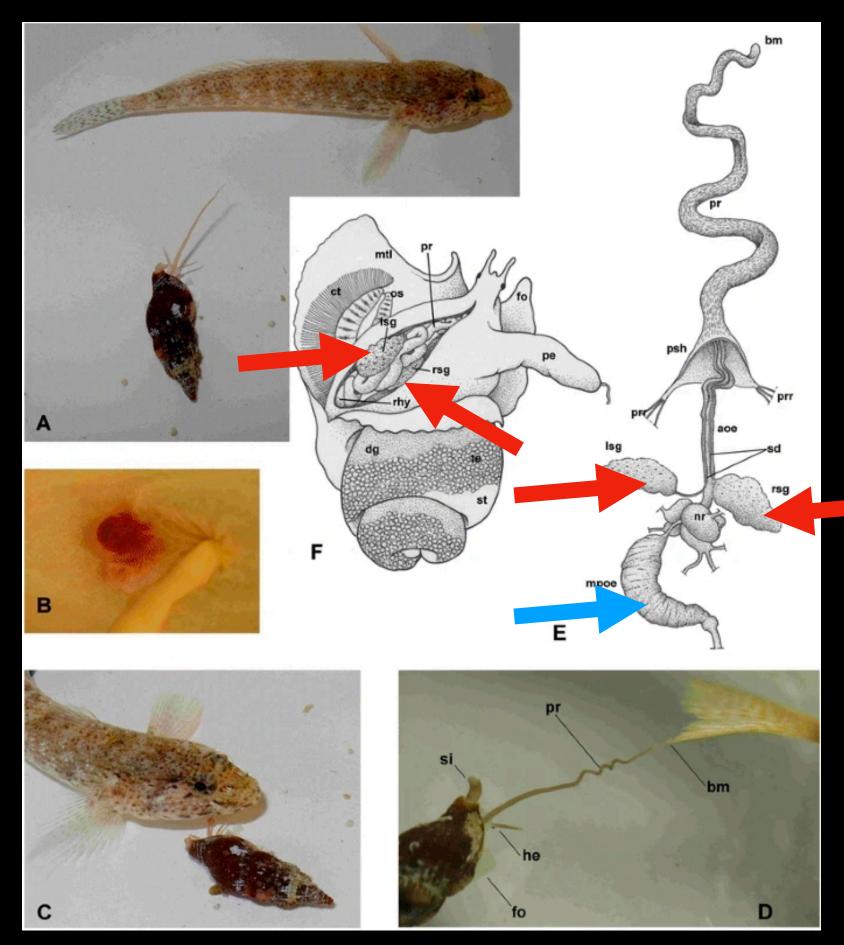


Leeches



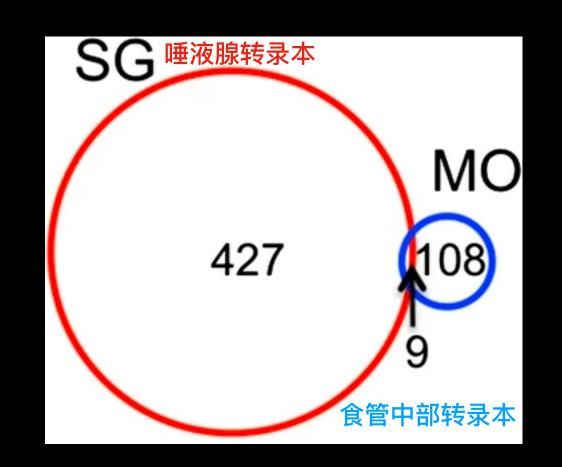
Vampire finch

Vampire snail Colubraria reticulata (Mollusca, Gastropoda)



Vampire snail (Colubraria reticulata)

RNA-seq of mid-oesophagous[食管中部], salivary glands[唾液腺] and whole body.



Colubraria reticulata secretes chemicals that disrupts the process of blood clotting and wound healing.

- 1. Anesthetics [麻醉剂]

Modica, M.V. et al. (2015) BMC Genomics

• ShK, Turripeptide, ADA, and CAP-ShK. 2. Anticoagulants [抗凝血剂] • PS1, Meprin, and Kunitz. 3. ACE [血管紧张素转换酶] increase blood pressure



Colubrariidae [布纹螺科] The trait of feeding on blood is likely shared by the entire family.





Vampire snail



Vampire Bats



Leeches



Vampire finch

Bloodsucking



East Asian Leech (Hirudo nipponia, 日本医蛭)

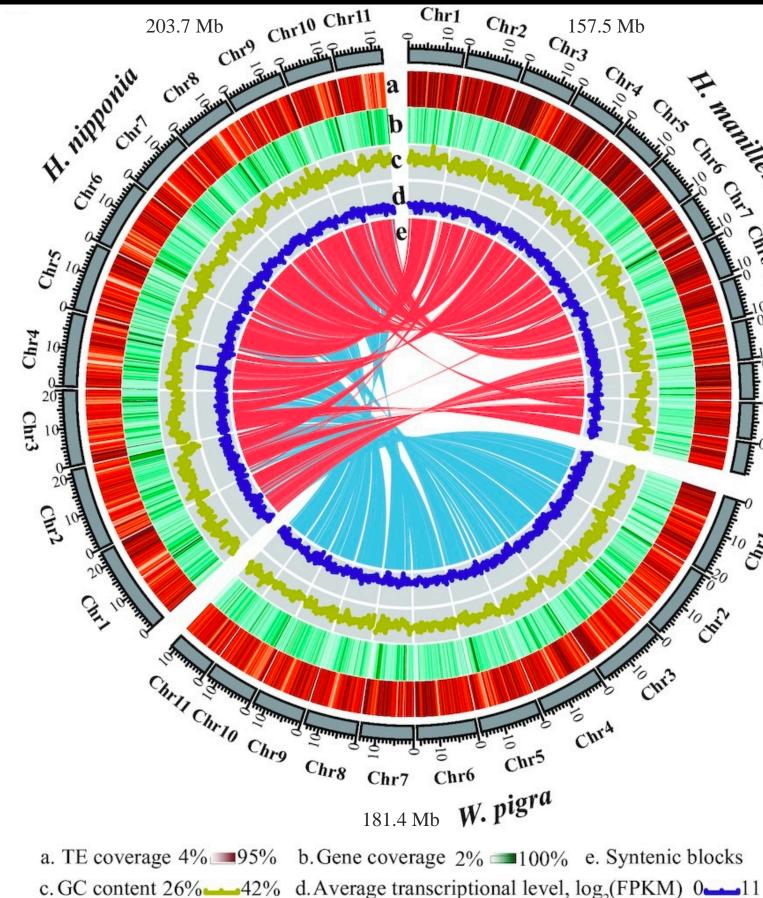


Hirudinaria manillensis 欧洲医蛭

Nonbloodsucking

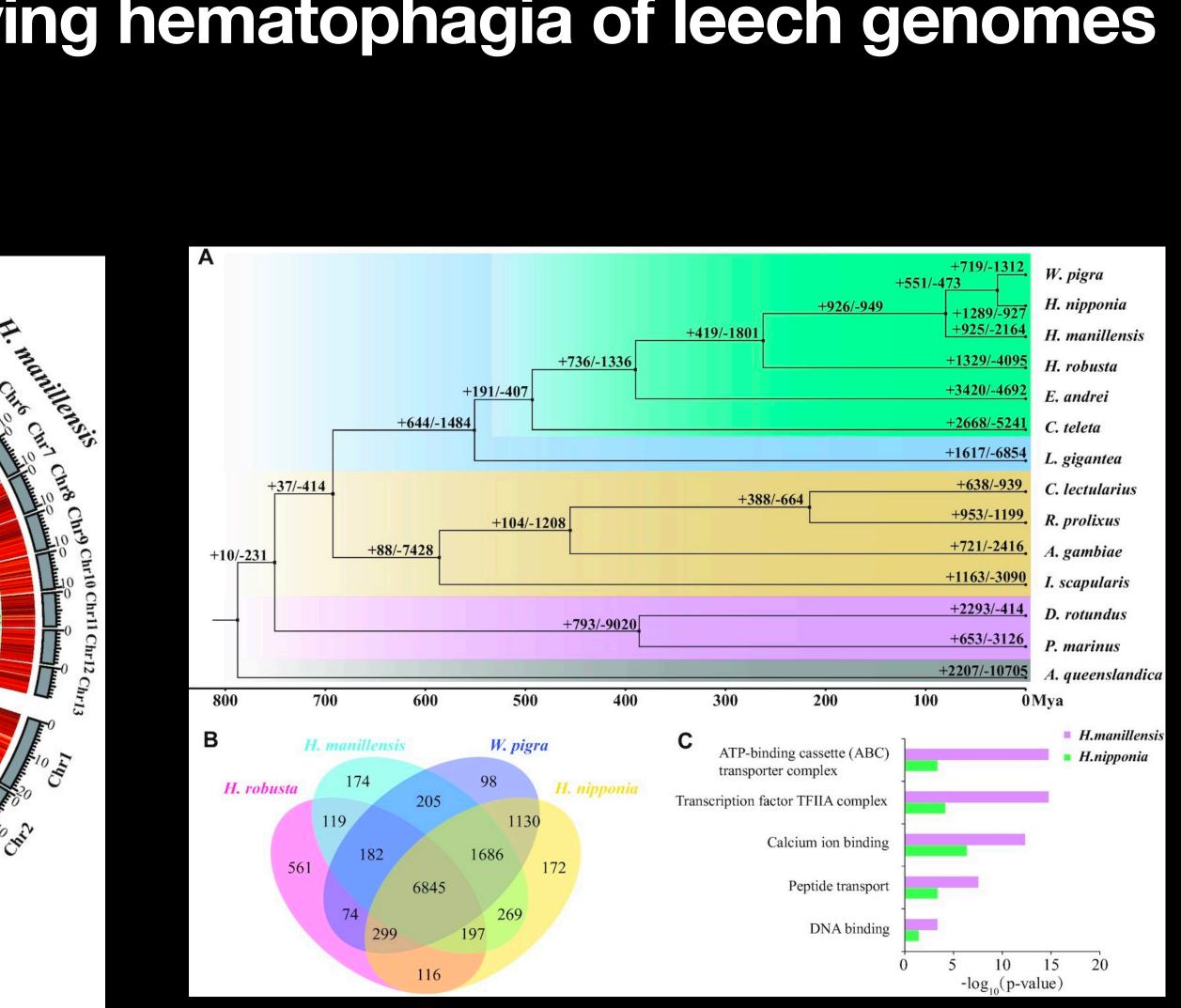


Whitmania pigra 宽体金线蛭



Comparative genomic analysis of the 3 leech species.

Zheng J. et al. (2023) GigaScience.



- GO of <u>expanded gene families in both bloodsucking</u> leech species
 - 1. ATP-binding cassette transporter complex,
 - 2. transcription factor IIA complex,
 - 3. calcium ion binding functions



East Asian Leech (Hirudo nipponia, 日本医蛭)

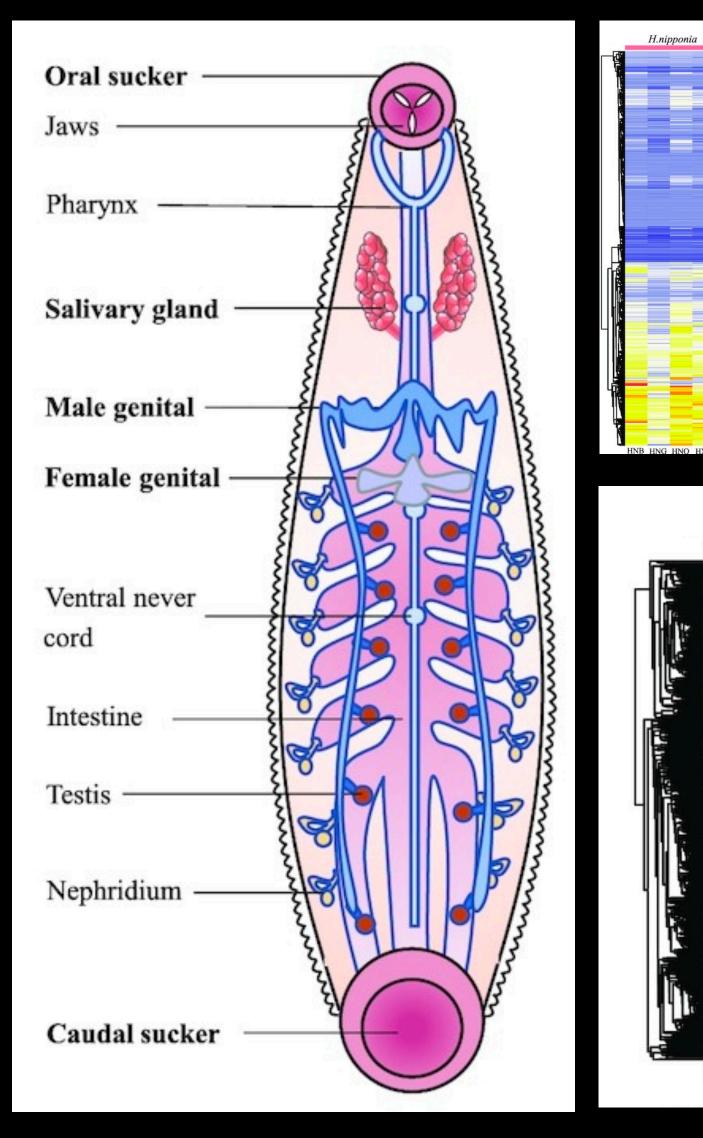


Hirudinaria manillensis 欧洲医蛭

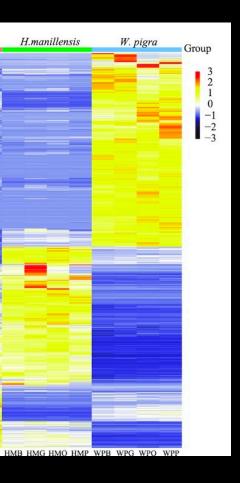
Nonbloodsucking



Whitmania pigra 宽体金线蛭



Zheng J. et al. (2023) GigaScience.



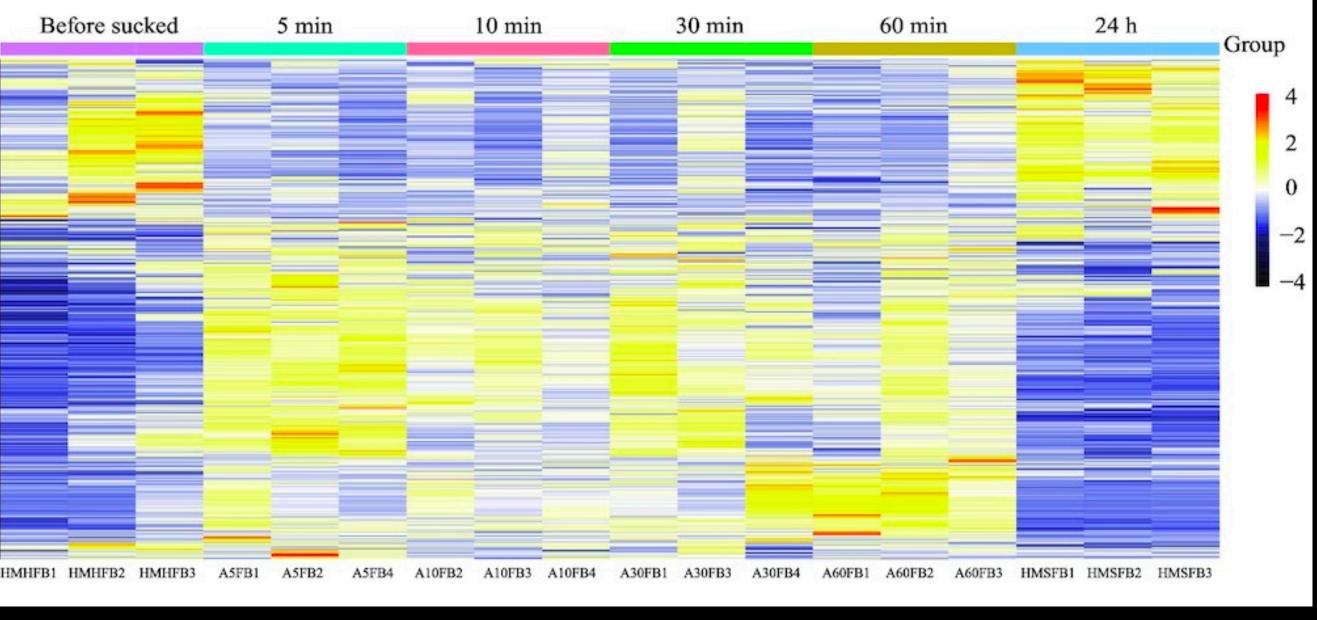
Tissue of different body parts:

- B: Body
- G: Genital gland
- O: Oral sucker
- P: Posterior sucker

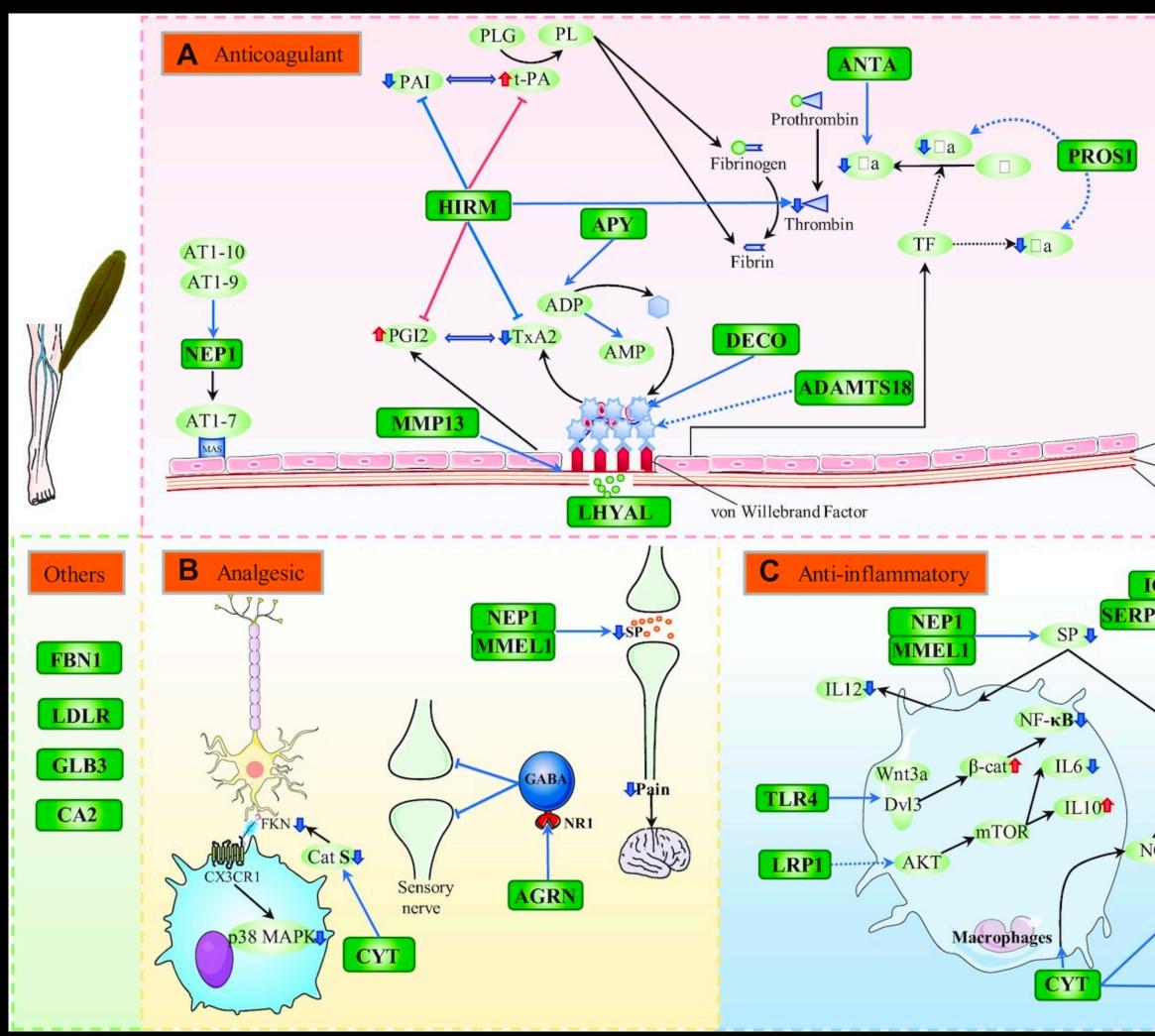
• 2 bloodsucking leeches shared similar expression patterns

Transcriptome dynamics during bloodsucking in *H. manillensis*

• DEGs responded quickly after bloodsucking and continuously changed in the following 60 min, restored after 24 hours







Zheng J. et al. (2023) GigaScience.

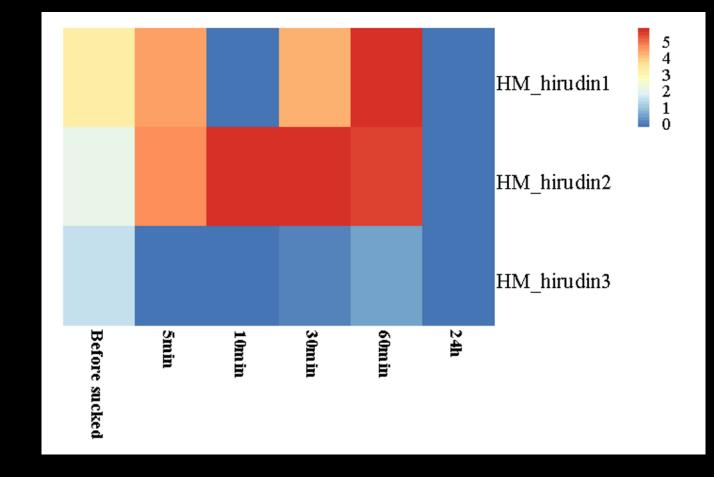
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Indirect action	1
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IL17 IFN-y	1
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/	1
01	1
Cat C	
Cat G	
Cat L	1
	1
→PBMC → IL101	

Leeches avoid detection by hosts during the bloodsucking:

- A. inhibition of blood coagulation <u>抑制血液凝固</u>
- B. alleviation of pain 减轻疼痛
- C. suppression of inflammation 抑制炎症

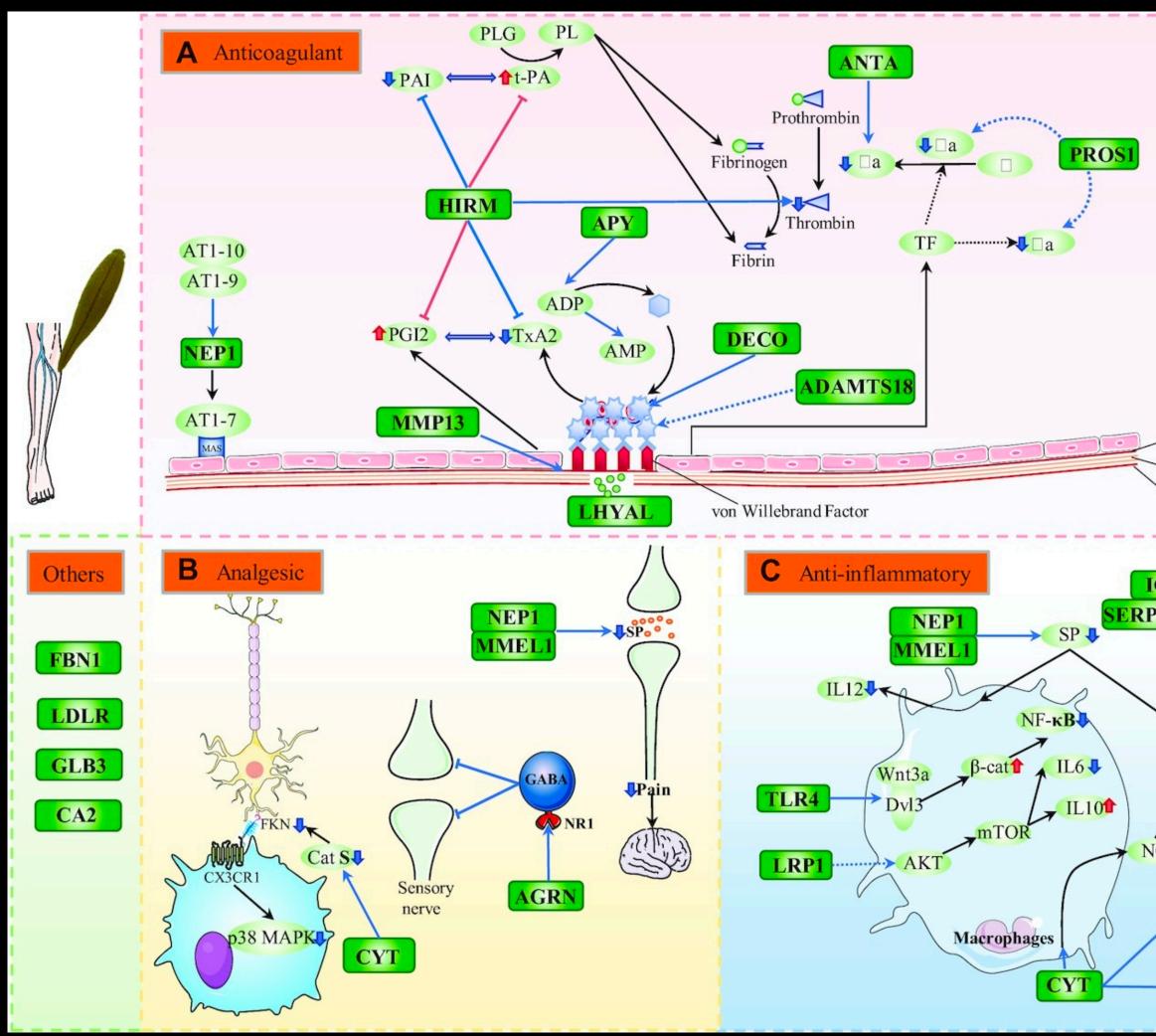
HIRM (hirudin 水蛭素) in <u>H. manillensis</u>

increased with the time of physiological coagulation



水蛭素(hirudin)是一种天然抗凝剂,因为它具有特异性的抗凝血酶作用,有助于治疗血栓。



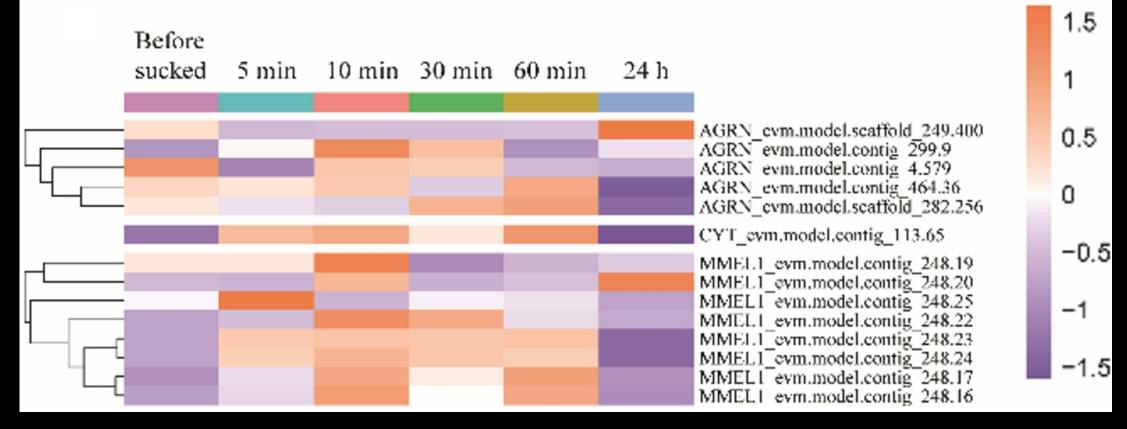


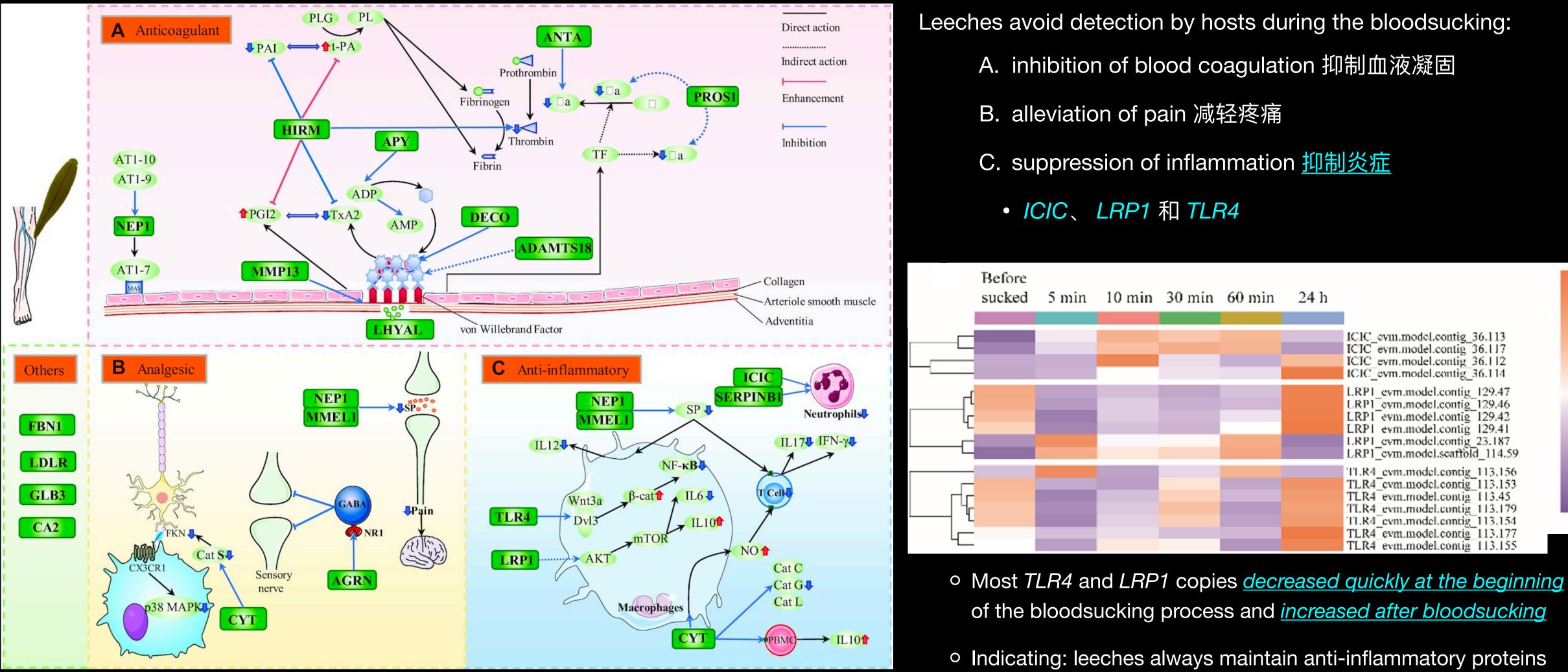
Zheng J. et al. (2023) GigaScience.

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01	Cat C Cat G
	Cat C Cat G
	Cat C Cat G Cat G

Leeches avoid detection by hosts during the bloodsucking:

- A. inhibition of blood coagulation 抑制血液凝固
- B. alleviation of pain <u>减轻疼痛</u>
 - AGRN、CYT 和 MMEL1
- C. suppression of inflammation 抑制炎症

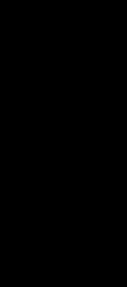




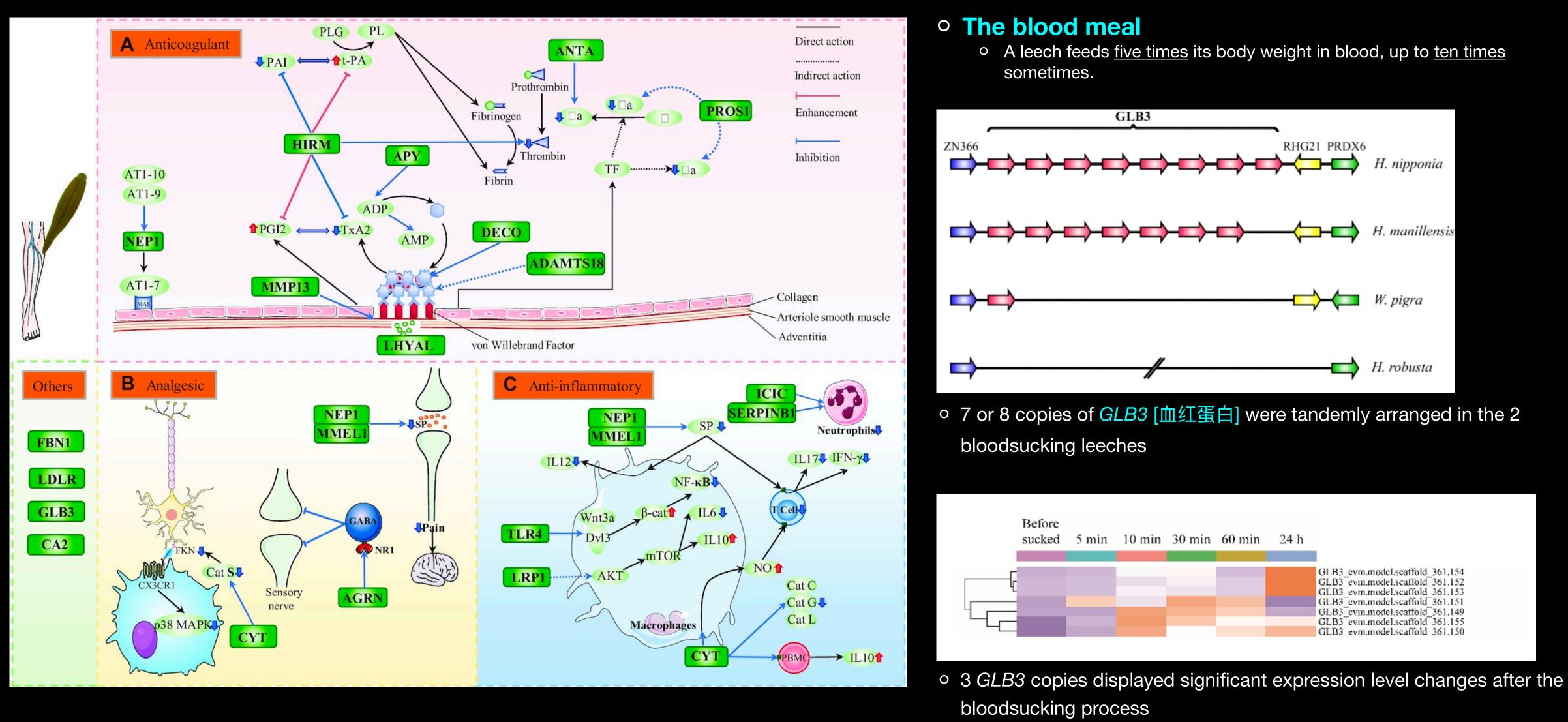
Zheng J. et al. (2023) GigaScience.

Direct action
Indirect action
—
Enhancement
H
Inhibition

- for swift release into the prey body



1.5 0.5 0 -0.5-1 -1.5



Zheng J. et al. (2023) GigaScience.





Vampire snail



Vampire Bats



Leeches



Vampire finch

Fruit eaters Cynopterus sphinx Blood feeders Megaerops niphanae Insect eaters Thoopterus nigrescens Macroglossus minimus M.sobrinus Pteropodidae Dobsonia viridis (Old World Rousettus leschenaultii fruit bats) Eonyeteris spelaea Epomophorus wahlberg Pteropus vampyrus P. giganteus P. rufus P. poliocephalus Acerodon celebensis Rhinolophus lepidus R. hipposideros R.ferrumequinum Hipposideros pratti Rhinolophoidea H. armiger H. lankadiva — Megaderma lyra M. spasma Rhinopoma microphyllum Glossophaga soricina Leptonycteris nivalis Anoura geoffroyi Brachyphylla cavernarum Artibeus jamaicensis Sturnira lilium Carollia perspicillata Desmodus rotundus Diaemus youngi Noctilionoidea Diphylla ecaudata Macrotus californicus Pteronotus parnellii ? personatus Mormoops megalophylla Noctilio leporinus Furipterus horrens Thyroptera tricolor Mystacina tuberculata Myotis lucifugus M. mystacinus M. myotis Plecotus auritus P. rafinesquii Pipistrellus subflavus P. pipistrellus Vespertilionoidea Nyctalus noctula Miniopteridae Eptesicus fuscus Miniopterus magnate M. schreibersi M. fuligulosus Molossus molossus Tadarida brasiliensis Natalus stramineus Balantiopteryx io Taphozous saccolaimus Emballonuroidea Nycteris thebaica

Blood feeding习性只出现在三种蝙蝠:



hairy-legged vampire bat (Diphylla ecaudata, 毛腿吸血蝠)

modified from Fig 2 of Huabin Zhao. et. al. (2011) Molecular Biology and Evolution



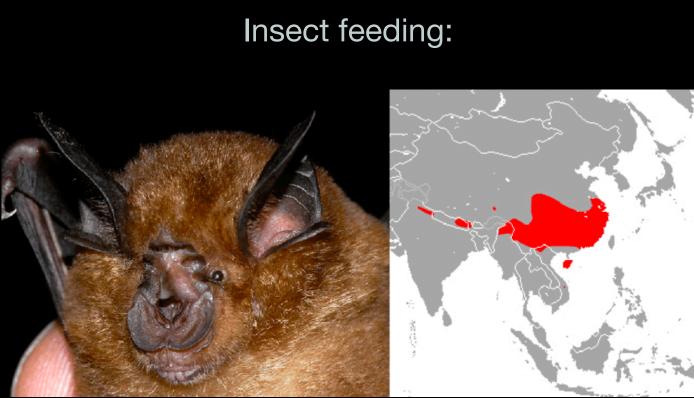
Fruit feeding:



greater short-nosed fruit bat (Cynopterus sphinx, 短吻果蝠)

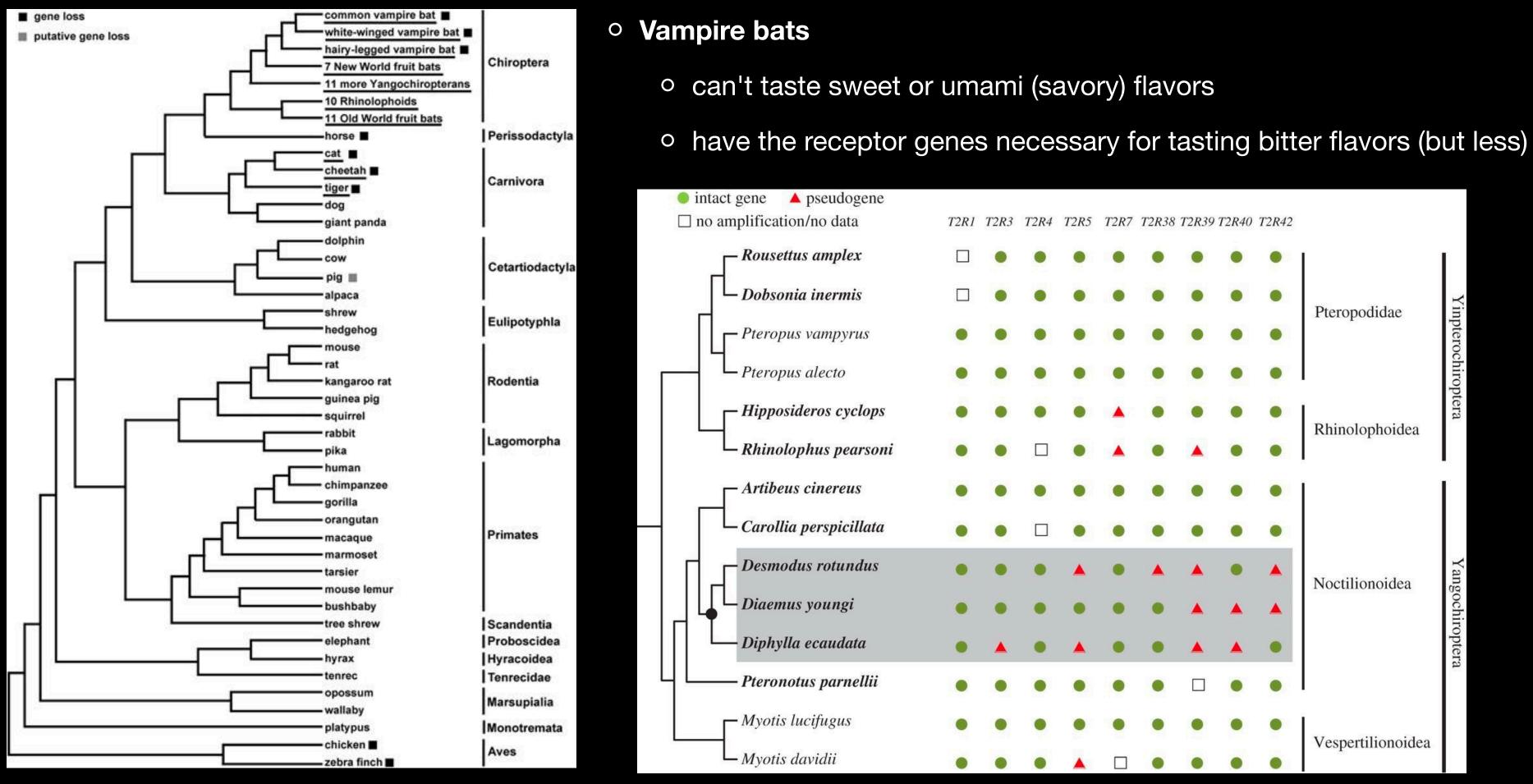


Pallas's long-tongued bat (Glossophaga soricina, 鼩形长舌蝠)



Chinese rufous horseshoe bat (Rhinolophus sinicus, 中华菊头蝠)





Tas1r2 [sweet taste] loss in 3 vampire bats

Hong Wei and Zhao Huabin. (2014) Proc. R. Soc. B.

Vampire bats have more bitter taste receptor (T2R) pseudogenes.



common vampire bat (Desmodus rotundus, 吸血蝠)



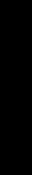
white-winged vampire bat (Diaemus youngi, 白翼吸血蝠)

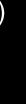


hairy-legged vampire bat (Diphylla ecaudata, 毛腿吸血蝠)



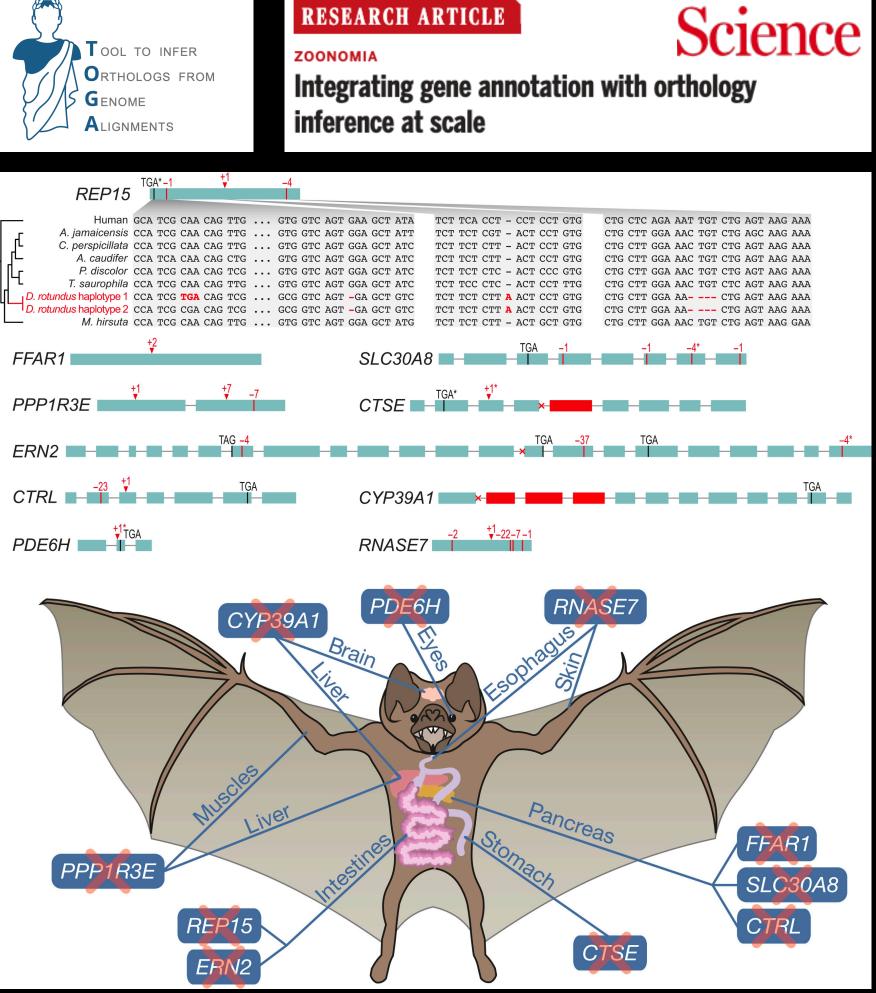








Species	Bat family						
Pteropus vampyrus Pteropus alecto Macroglossus sobrinus Rousettus aegyptiacus Eidolon dupreanum	Pteropodidae						
Rhinolophus ferrumequinum Rhinolophus sinicus	Rhinolophidae						
Hipposideros armiger	Hipposideridae						
Myotis lucifugus Myotis brandtii Myotis myotis Pipistrellus kuhlii Eptesicus fuscus Aeorestes cinereus Miniopterus natalensis	Vespertilionidae						
Molossus molossus Tadarida brasiliensis	Molossidae						
Noctilio leporinus	Noctilionidae						
Mormoops blainvillei Pteronotus mesoamericanus	Mormoopidae						
Artibeus jamaicensis Carollia perspicillata Anoura caudifer Phyllostomus discolor Tonatia saurophila Desmodus rotundus Micronycteris hirsuta	Phyllostomidae						
Haplotype 1 Hap	lotype 2						



559 scaffolds <2.7 Mb 78.6 Mb = 3.7% of assembly

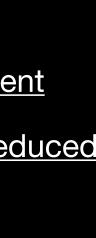
417 scaffolds <6.3 Mb

64.4 Mb = 3.26% of assembly

Moritz Blumer et al. (2022) Sci. Adv.

• 13 vampire bat-specific gene losses:

- 1. sweet taste receptor gene
 - TAS1R2
- 2. bitter taste receptor genes
 - TAS2R5
 - TAS2R42
- 3. 10 genes new reported
 - Loss of CYP39A1 and advanced social <u>behavior</u>
 - Loss of *ERN2* and low dietary fat content
 - Losses of FFAR1 and SLC30A8 and reduced insulin secretion
 - Loss of REP15 and enhanced iron excretion
 - <u>.</u>





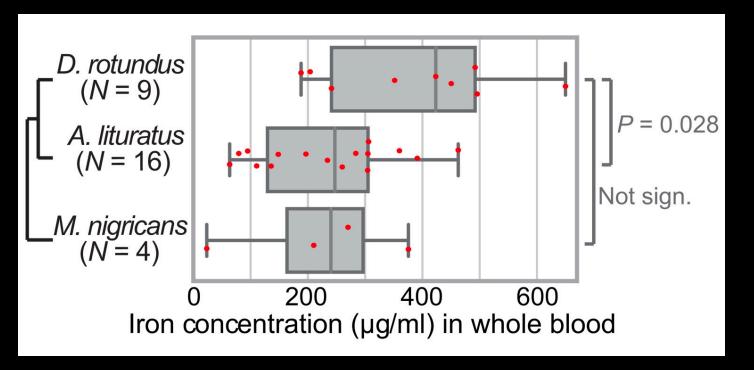
Gene-inactivating mutations, indicating that potential transcripts cannot be translated into a full-length protein.

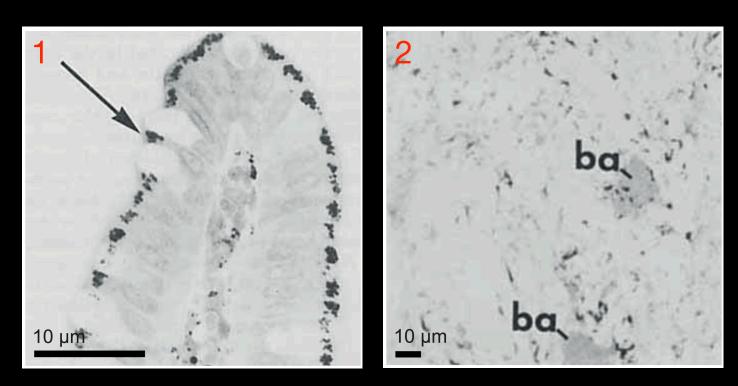
The loss of *REP15*

• involved in regulating cellular iron uptake

1		REP15		4* -1		+	1		-4 														
Ē		Human	GCA	TCG	CAA	CAG	TTG		GTG	GTC	AGT	GAA	GCT	ATA		тст	TCA	CCT	- 1	ССТ	ССТ	GTG	
	Г	A. jamaicensis	CCA	TCG	CAA	CAG	TTG	• • •	GTG	GTC	AGT	GGA	GCT	ATT	1	тст	тст	CGT		ACT	ССТ	GTG	
_ r_ _ r_ [\[ր	C. perspicillata	CCA	TCG	CAA	CAG	TTG	• • •	GTG	GTC	AGT	GGA	GCT	ATC		тст	тст	CTT		АСТ	ССТ	GTG	
	ட	A. caudifer	CCA	TCA	CAA	CAG	CTG	• • •	GTG	GTC	AGT	GGA	GCT	ATC		тст	TCT	\mathbf{CTT}		ACT	ССТ	GTG	
		P. discolor	CCA	TCG	CAA	CAG	TCG	• • •	GTG	GTC	AGT	GGA	GCT	ATC	1	тст	TCT	CTC		ACT	CCC	GTG	
		T. saurophila	CCA	TCG	CAA	CAG	TTG	• • •	GTG	GTC	AGT	GGA	GCT	ATC	1	тст	TCC	CTC		ACT	ССТ	TTG	
l ll	D.	rotundus haplotype 1	CCA	TCG	TGA	CAG	TCG	• • •	GCG	GTC	AGT	-GA	GCT	GTC		тст	TCT	\mathbf{CTT}	A	ACT	ССТ	GTG	
1	$\neg D$.	rotundus haplotype 2	CCA	TCG	CGA	CAG	TCG	• • •	GCG	GTC	AGT	-GA	GCT	GTC	1	тст	TCT	\mathbf{CTT}	A .	ACT	ССТ	GTG	
		M. hirsuta	CCA	TCG	CAA	CAG	TTG	• • •	GTG	GTC	AGT	GGA	GCT	ATG		TCT	TCT	CTT		ACT	GCT	GTG	

Gene-inactivating mutations of REP15: 1 base A insertion & 4 base lost



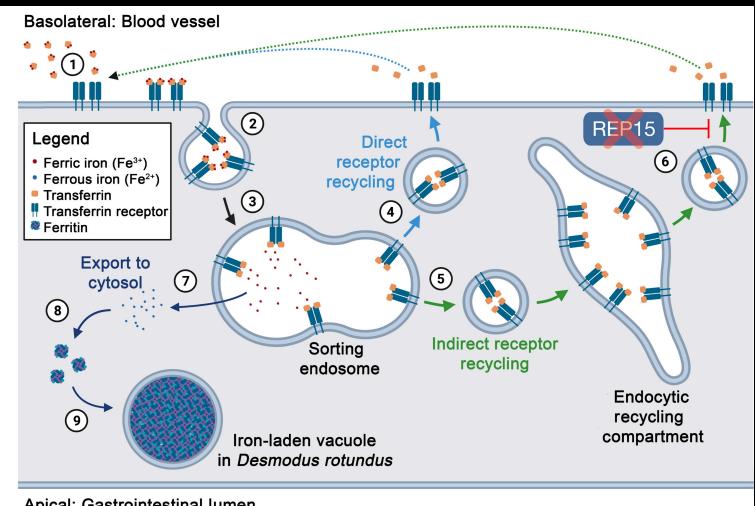


Vampire bats had higher blood iron levels

Moritz Blumer et al. (2022) Sci. Adv.

CTG CTC AGA AAT TGT CTG AGT AAG AAA CTG CTT GGA AAC TGT CTG AGC AAG AAA CTG CTT GGA AAC TGT CTG AGT AAG AAA CTG CTT GGA AAC TGT CTG AGT AAG AAA CTG CTT GGA AAC TGT CTG AGT AAG AAA CTG CTT GGA AAC TGT CTC AGT AAG AAA CTG CTT GGA AA- --- CTG AGT AAG AAA CTG CTT GGA AA- --- CTG AGT AAG AAA CTG CTT GGA AAC TGT CTG AGT AAG GAA

Mechanism to reduce systemic iron levels D. Morton, W. A. Wimsatt. (1980) Anat. Rec.



Apical: Gastrointestinal lumen

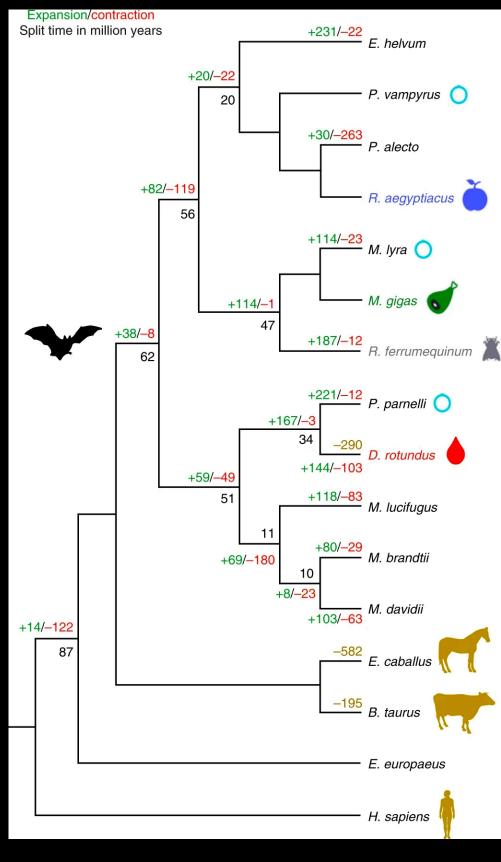
the loss of REP15 in D. rotundus enhances iron accumulation in gastrointestinal tract cells.

- 胃肠道上皮细胞的液泡中富集铁
- 2. 胃肠道细胞脱落到肠腔

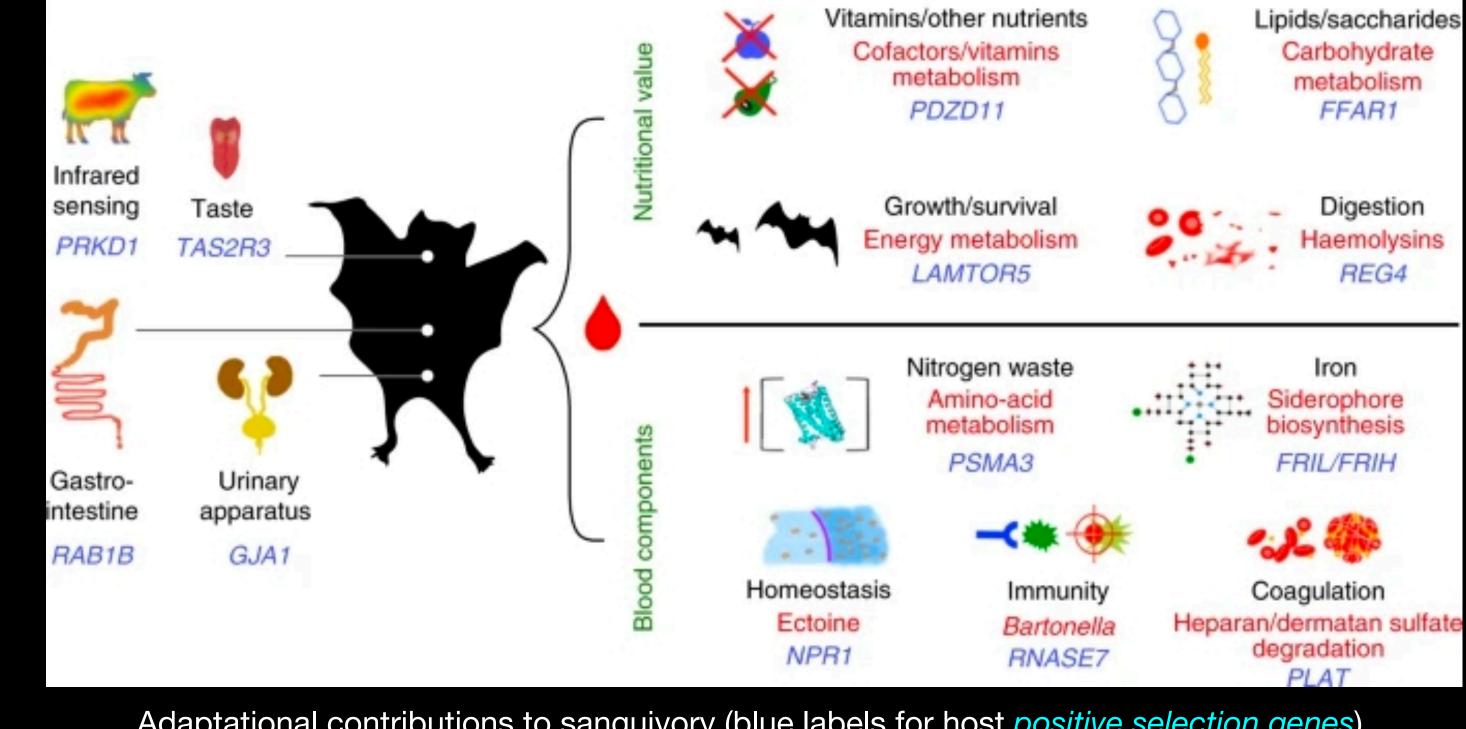


Adaptational contributions to sanguivory in vampire bat

Adaptations



Gene expansion & contraction

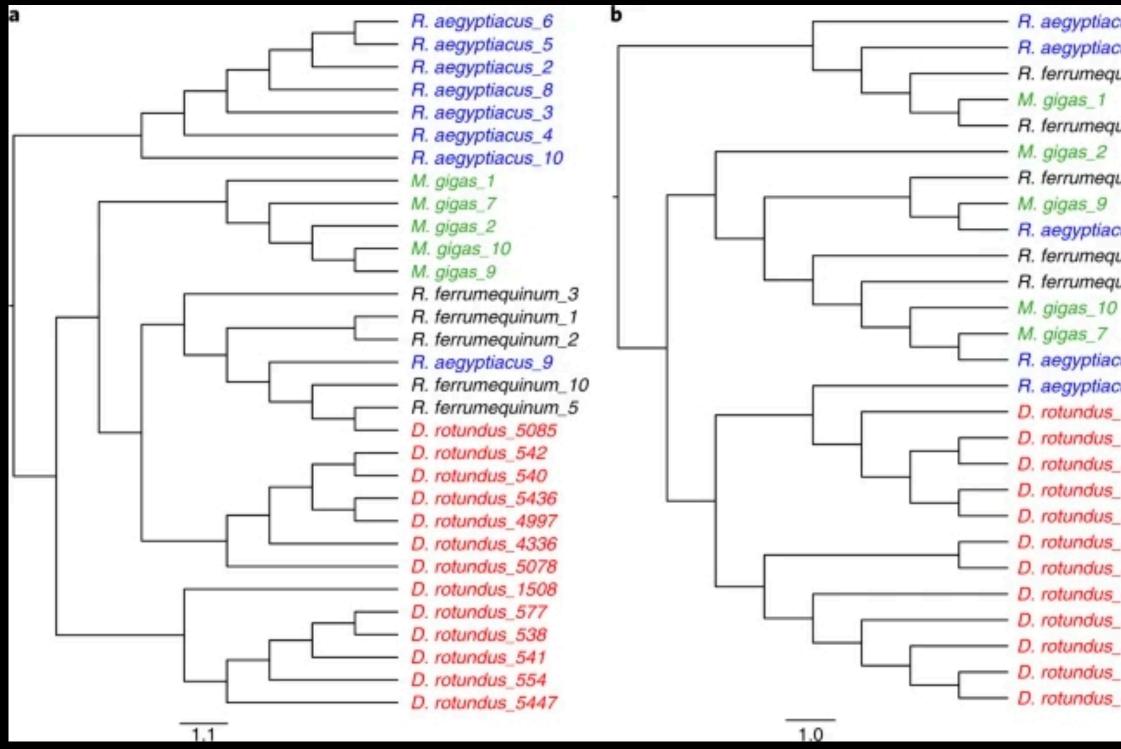


Zepeda Mendoza et al. (2018) Nat. Ecol. Evol.

Adaptational contributions to sanguivory (blue labels for host positive selection genes)

Adaptational contributions to sanguivory in vampire bat

Gut microbiome

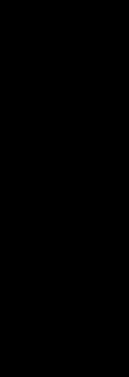


gut microbiome harbours a set of functions **specialized to its extreme diet**.

Zepeda Mendoza et al. (2018) Nat. Ecol. Evol.

- R. aegyptiacus_3 R. aegyptiacus_9 R. ferrumequinum 3 R. ferrumequinum 2 R. ferrumequinum 1 R. aegyptiacus_5 R. ferrumequinum 10 R. ferrumequinum 5 R. aegyptiacus_4 R. aegyptiacus_2 D. rotundus 541 D. rotundus_540 D. rotundus 542 D. rotundus_538 D. rotundus 577 D. rotundus_554 D. rotundus_5436 D. rotundus_4997 D. rotundus_5078 D. rotundus_5447 D. rotundus 1508 D. rotundus_4336
- *D. rotundus* (sanguivorous [吸血食性], red),
- R. ferrumequinum (insectivorous [食虫食性], black),
- M. gigas (carnivorous [食肉食性], green),
- *R. aegyptiacus* (frugivorous [食果食性], blue).
- a. Euclidean distance dendrogram of the *microbial presence/absence* identifications at the species taxonomical level.
- **b.** Euclidean distance dendrogram from the UniProt-identified <u>abundance</u> *functions* from the normalized samples.

• This suggests that the functional profile is less influenced by phylogeny than the taxonomic profile, and that the common vampire bat



- Anesthetics [麻醉剂]
- Anticoagulants [抗凝血剂]
- ACE [血管紧张素转换酶]



Vampire snail

Adaptations?

- Lost Genes
 - Enhanced iron excretion
 - low dietary fat content
 - Advanced social behavior
 - Reduced insulin secretion
- Gut microbiome



Vampire Bats



Leeches

- inhibition of blood coagulation [抑制血液凝固]
- alleviation of pain [减轻疼痛]
- suppression of inflammation [抑制炎症]



Obligatory [专性吸血] Facultative [兼性吸血] 🗸

Vampire finch









Bloodsucking in birds



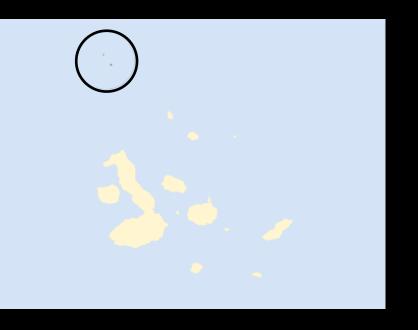
Vampire ground finch (Geospiza septentrionalis) 吸血地雀

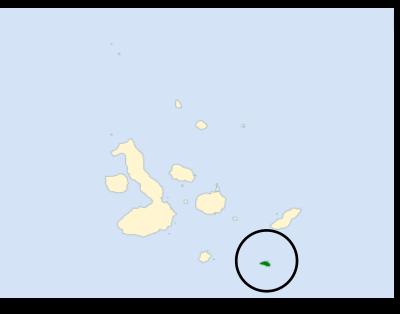


Hood mockingbird (Mimus macdonaldi) 冠嘲鸫

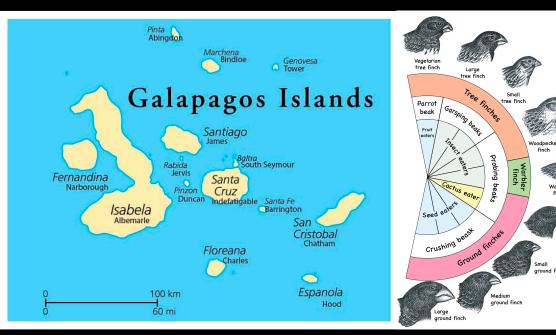


Galápagos mockingbird (Mimus parvulus) 加岛嘲鸫





Galápagos Islands







Red-billed oxpecker (Buphagus erythrorynchus) 红嘴牛椋鸟



East Africa



黄嘴牛椋鸟

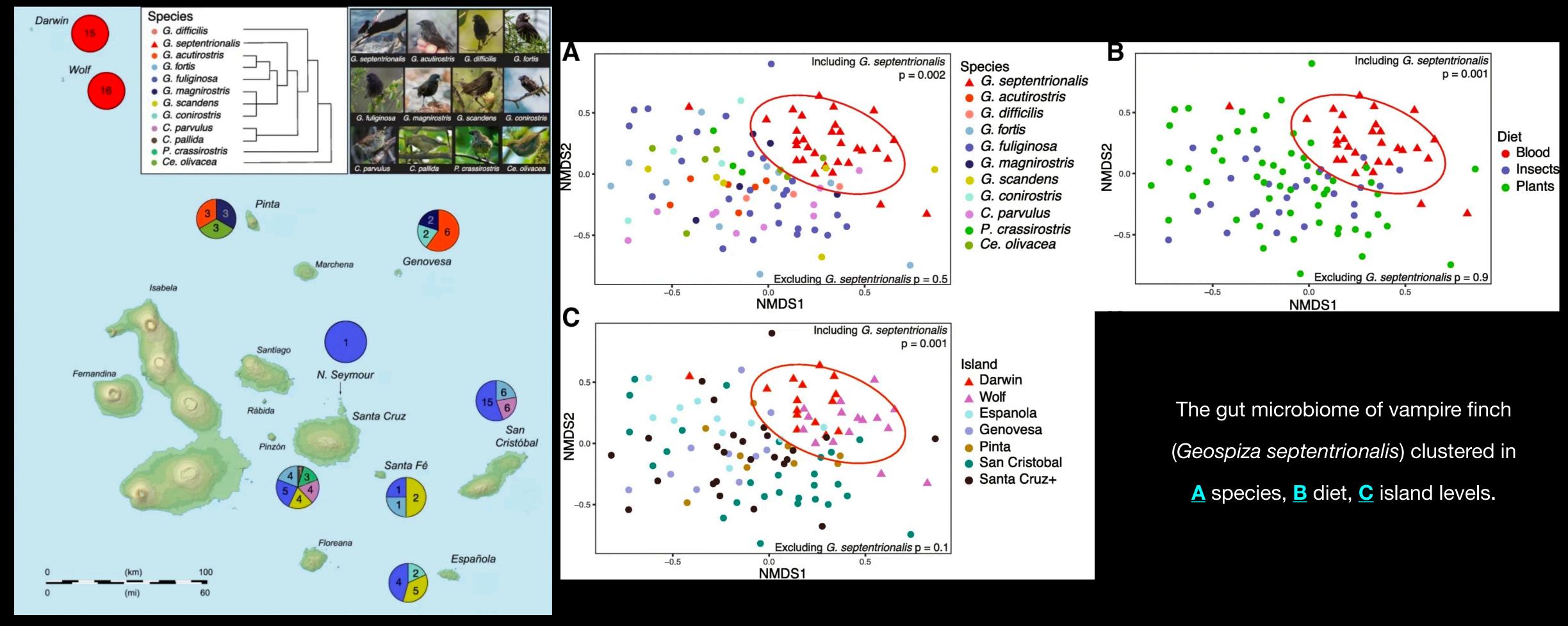


Sub-Saharan Africa



The gut microbiome of the Galápagos vampire finch

Gut microbiome



Overview of finch gut microbiome samples collected from the Galápagos Islands.

Michel, A.J. et al. (2018) Microbiome

Bloodsucking in birds



Vampire ground finch (Geospiza septentrionalis) 吸血地雀



Hood mockingbird (Mimus macdonaldi) 冠嘲鸫



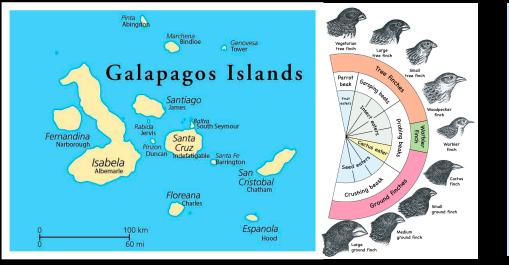
Galápagos mockingbird (Mimus parvulus) 加岛嘲鸫



Red-billed oxpecker (Buphagus erythrorynchus) 红嘴牛椋鸟



Yellow-billed oxpeckers (Buphagus africanus) 黄嘴牛椋鸟



Galápagos Islands



East Africa



Sub-Saharan Africa



Large-billed crow (Corvus macrorhynchos, 大嘴乌鸦) suck deer blood [reports from the zoo]



Tristan thrush (Turdus eremita, 特里斯坦鸫) suck penguin blood [BBC documentary]











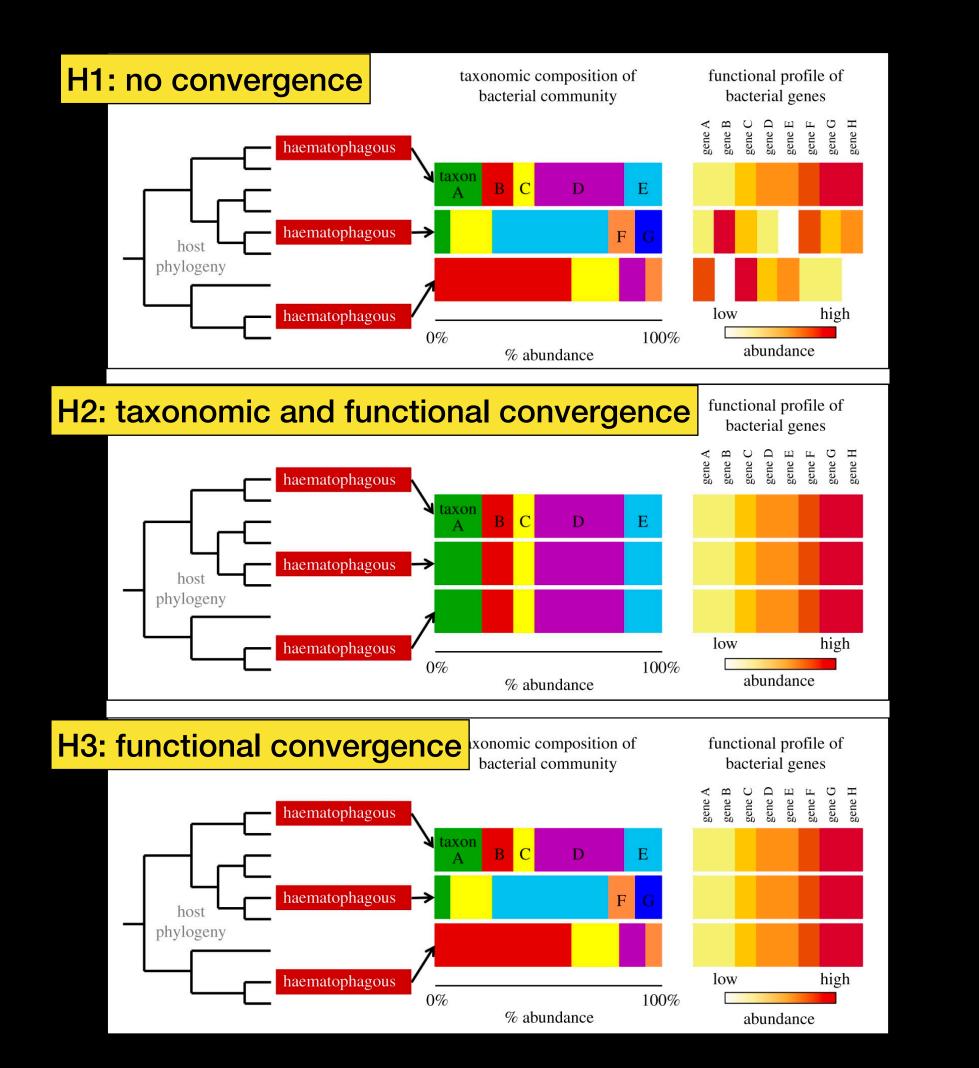


Is there convergence of gut microbes in blood-feeding vertebrates?

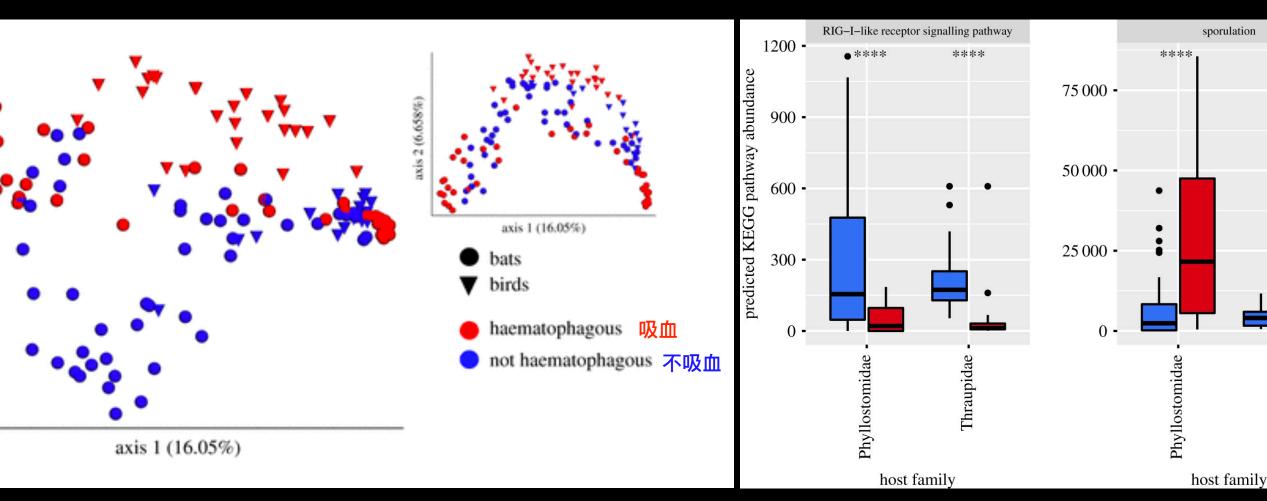
(a

(5.382

Convergence in gut microbiome?



Song, S.J. et al. (2019) Philosophical Transactions of the Royal Society B



Microbiome between haematophagous bats and birds:

- no associated at the amplicon sequence variants level
- <u>weak associated</u> at the overall community level
 - axis 3 in figure [variance 5.382%]
- more strongly converge in key taxa and predicted functions
 - Gene-I-like (RIG-I-like) receptor signalling pathway
 [基因样受体信号通路]
 - Sporulation [孢子形成]



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andique

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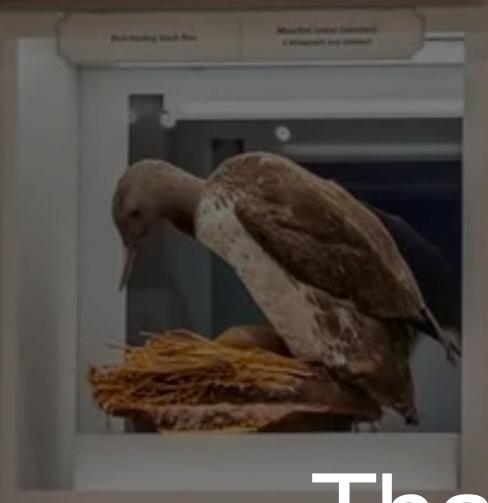
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Thanks for your listening!



A display of preserved blood-sucking specimens

