Поведение насекомых: что общего с позвоночными и в чем их уникальность

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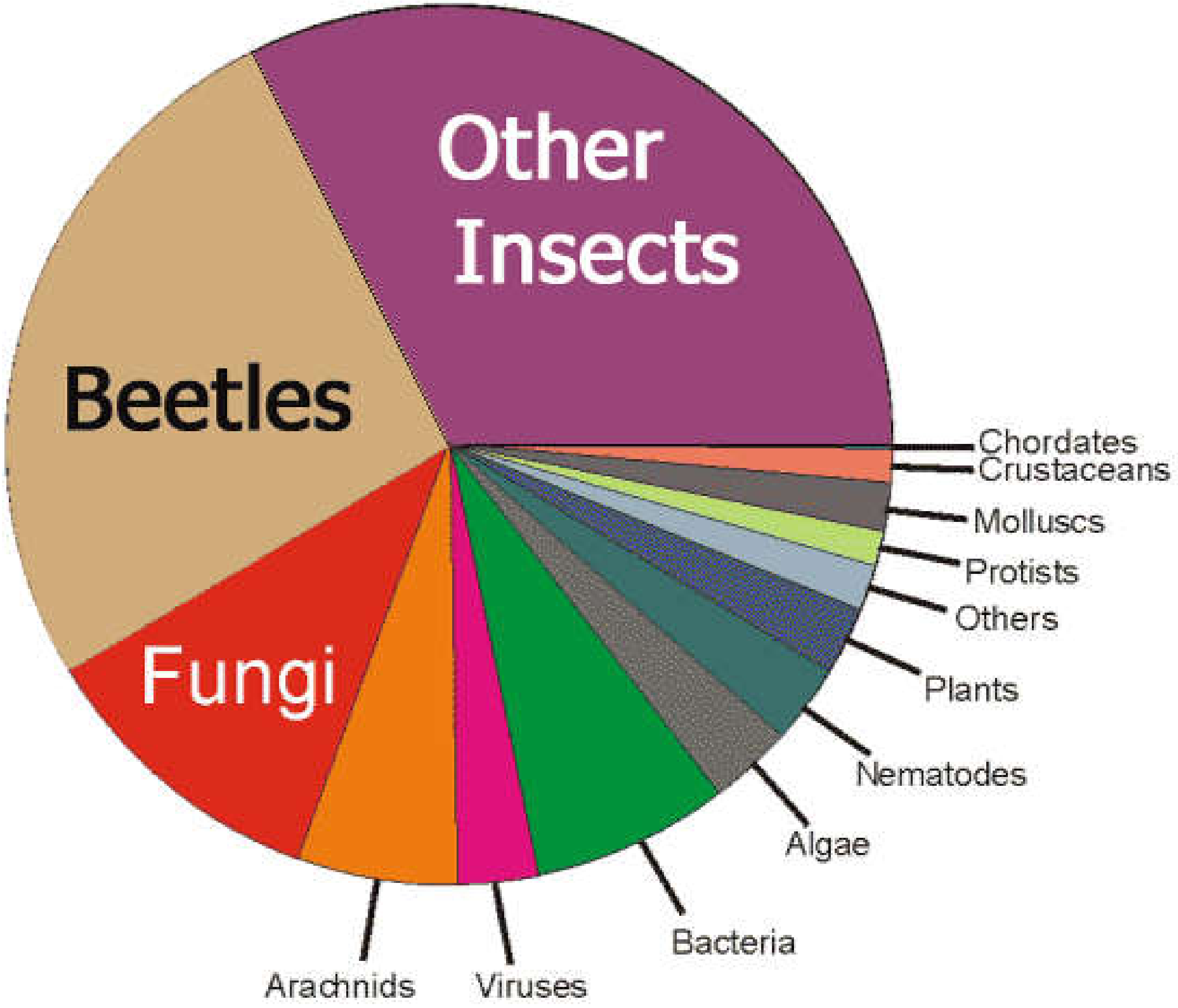
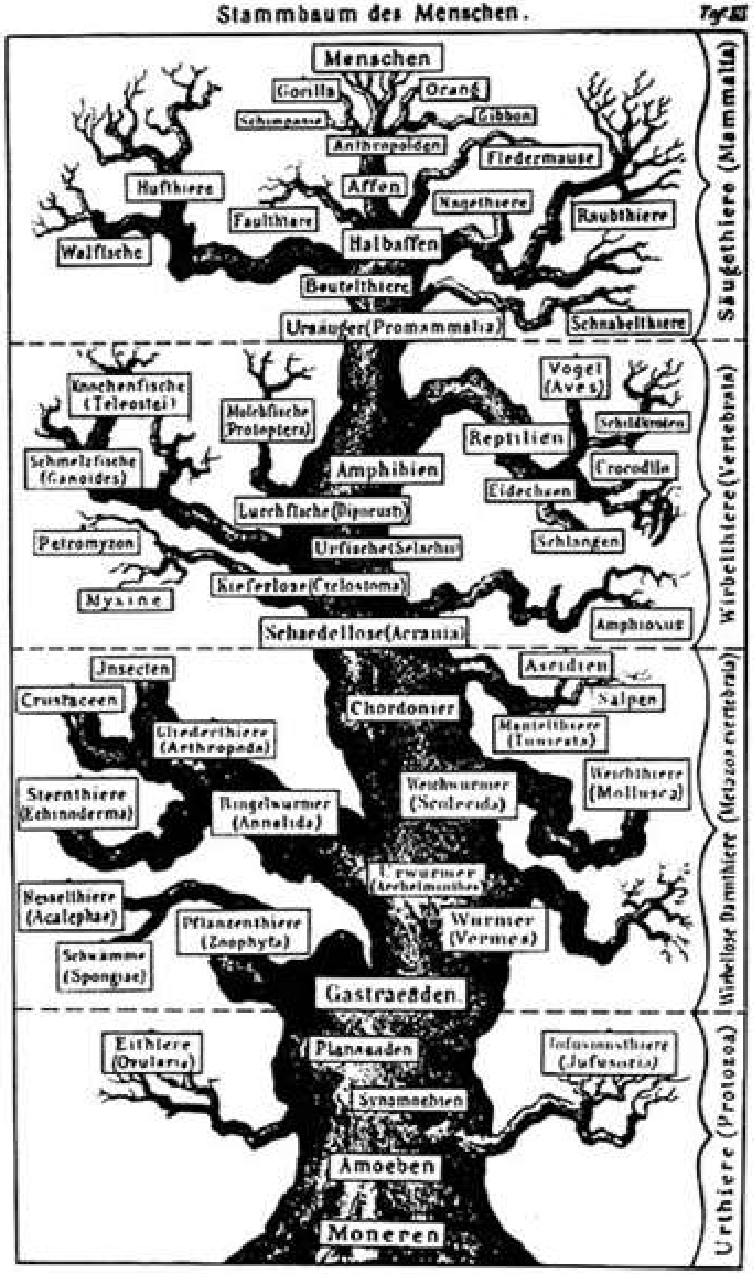
Институт систематики и экологии животных СО РАН

Новосибирский государственный университет

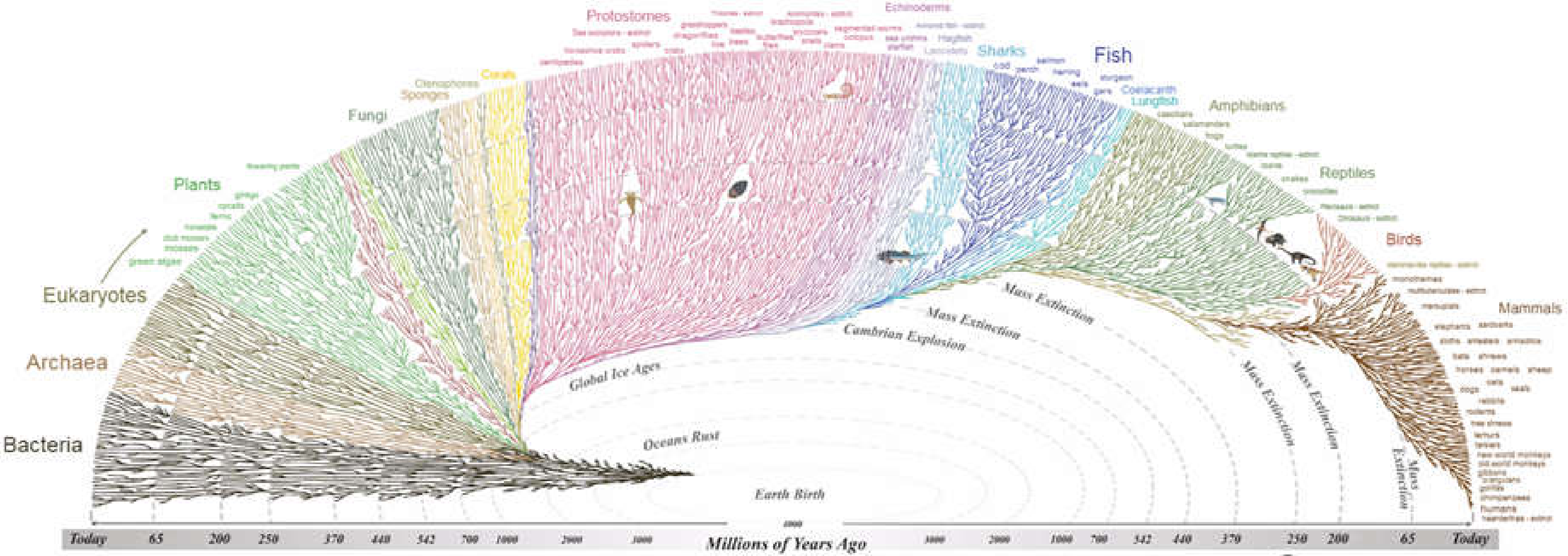
Species Biodiversity



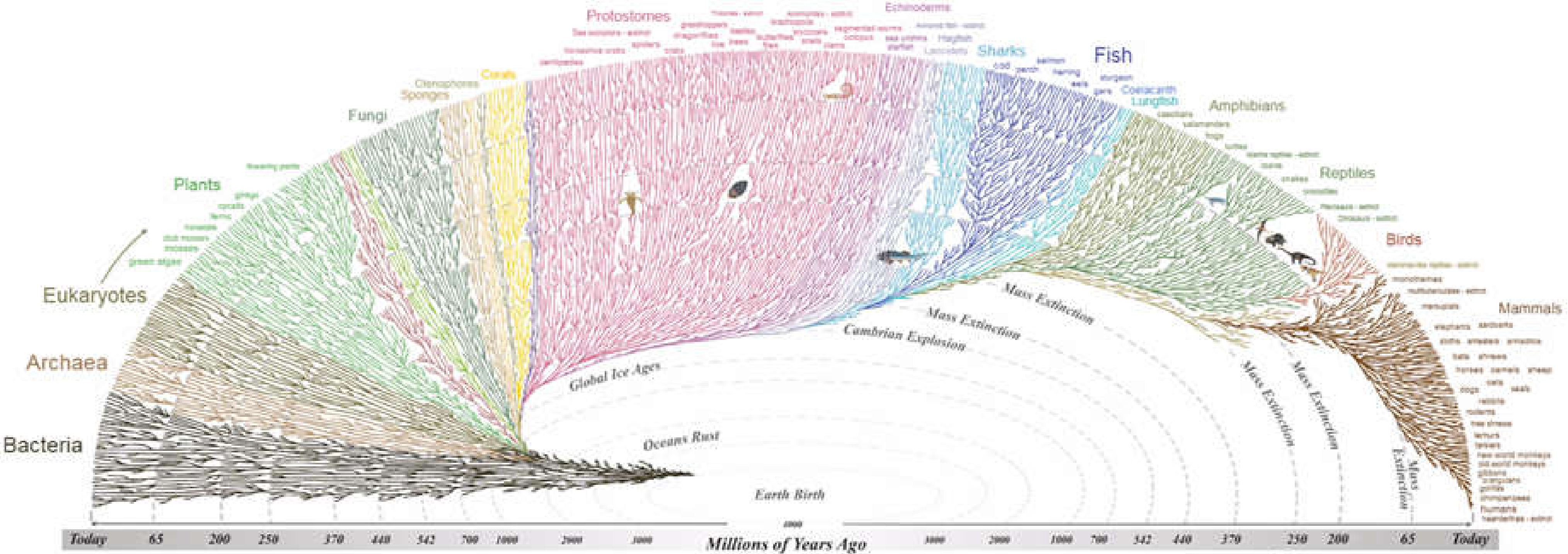
Родословное древо человека из книги Э.Геккеля “Антропогения”



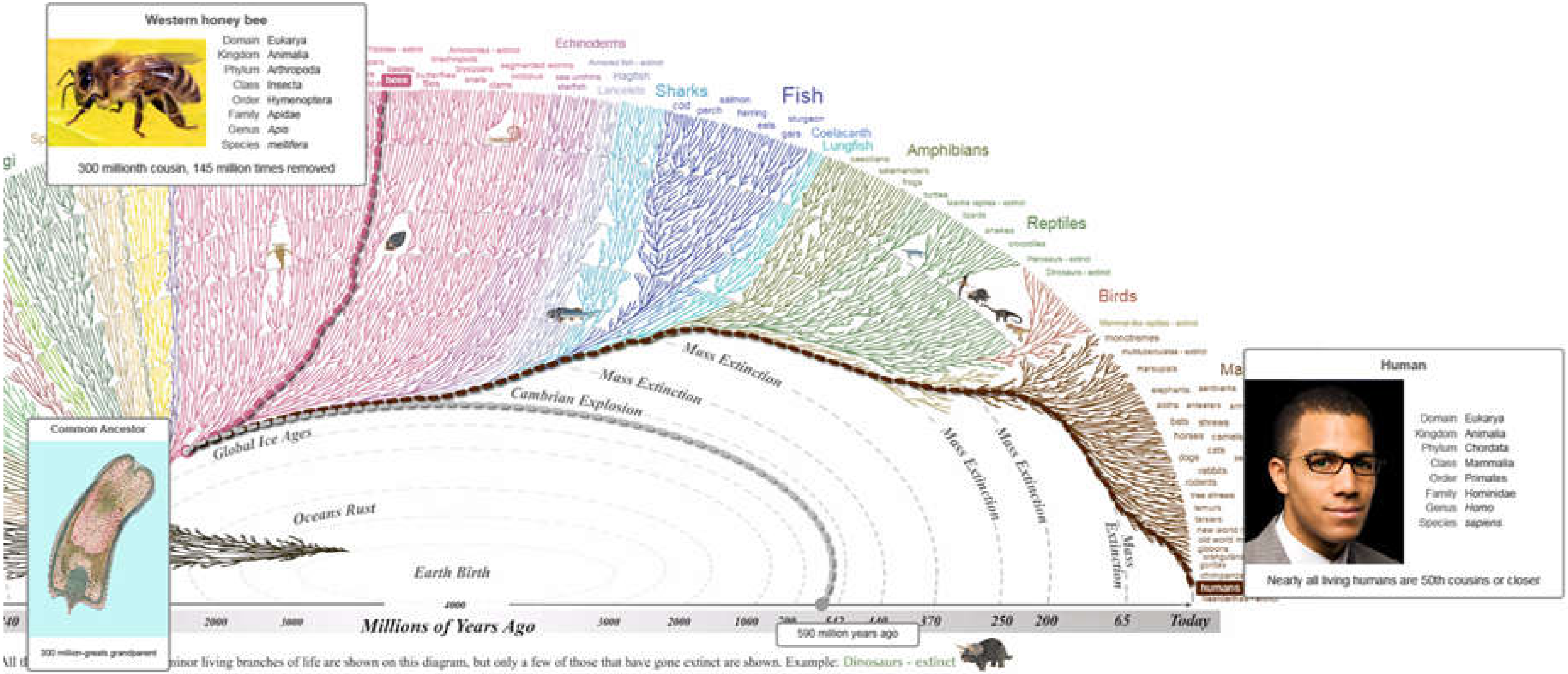
The Tree of Life Web Project
http://tolweb.org



All the major and many of the minor living branches of life are shown on this diagram, but only a few of those that have gone extinct are shown. Example: Dinosaurs - extinct 



All the major and many of the minor living branches of life are shown on this diagram, but only a few of those that have gone extinct are shown. Example: Dinosaurs - extinct 



Western honey bee

Domain Eukarya
Kingdom Animalia
Phylum Arthropoda
Class Insecta
Order Hymenoptera
Family Apidae
Genus Apis
Species mellifera

300 millionth cousin, 145 million times removed

Common Ancestor

300 million-greats grandparent

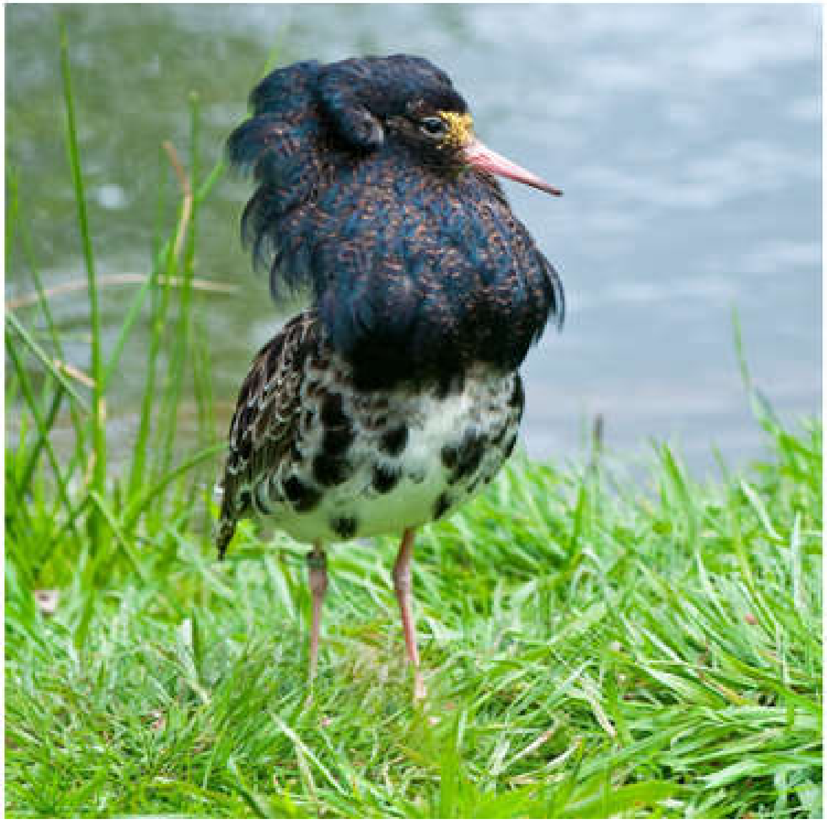
Human

Domain Eukarya
Kingdom Animalia
Phylum Chordata
Class Mammalia
Order Primates
Family Hominidae
Genus *Homo*
Species sapiens

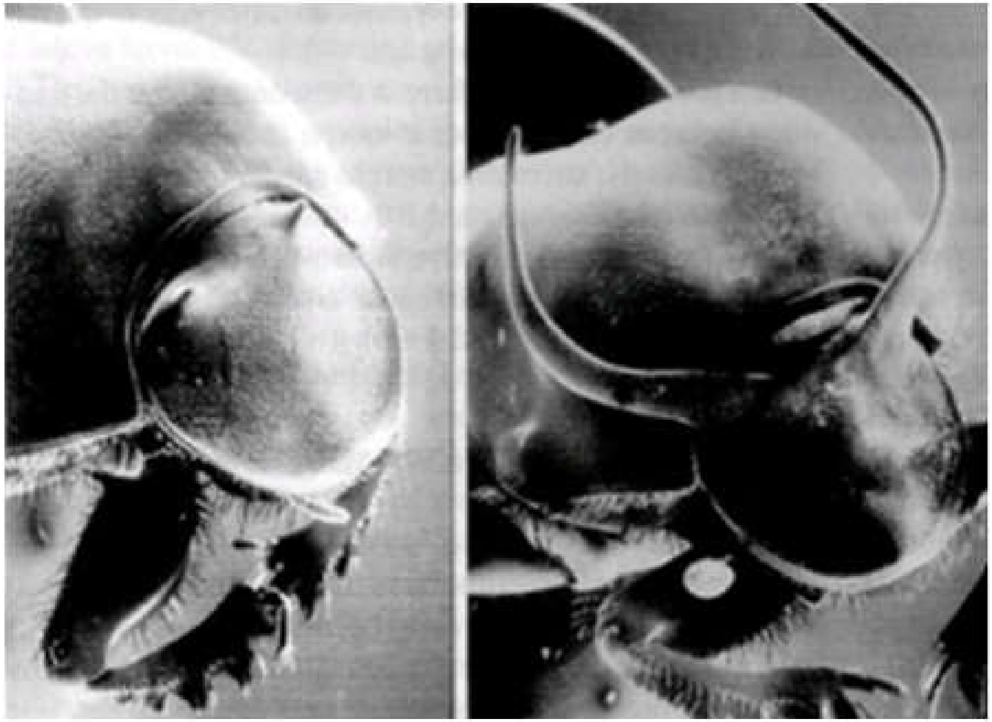
Nearly all living humans are 50th cousins or closer

All t minor living branches of life are shown on this diagram, but only a few of those that have gone extinct are shown. Example: Dinosaurs - extinct

Инстинктивное поведение



Küpper, Clemens, et al. "A supergene determines highly divergent male reproductive morphs in the ruff." *Nature genetics* 48.1 (2016): 79.



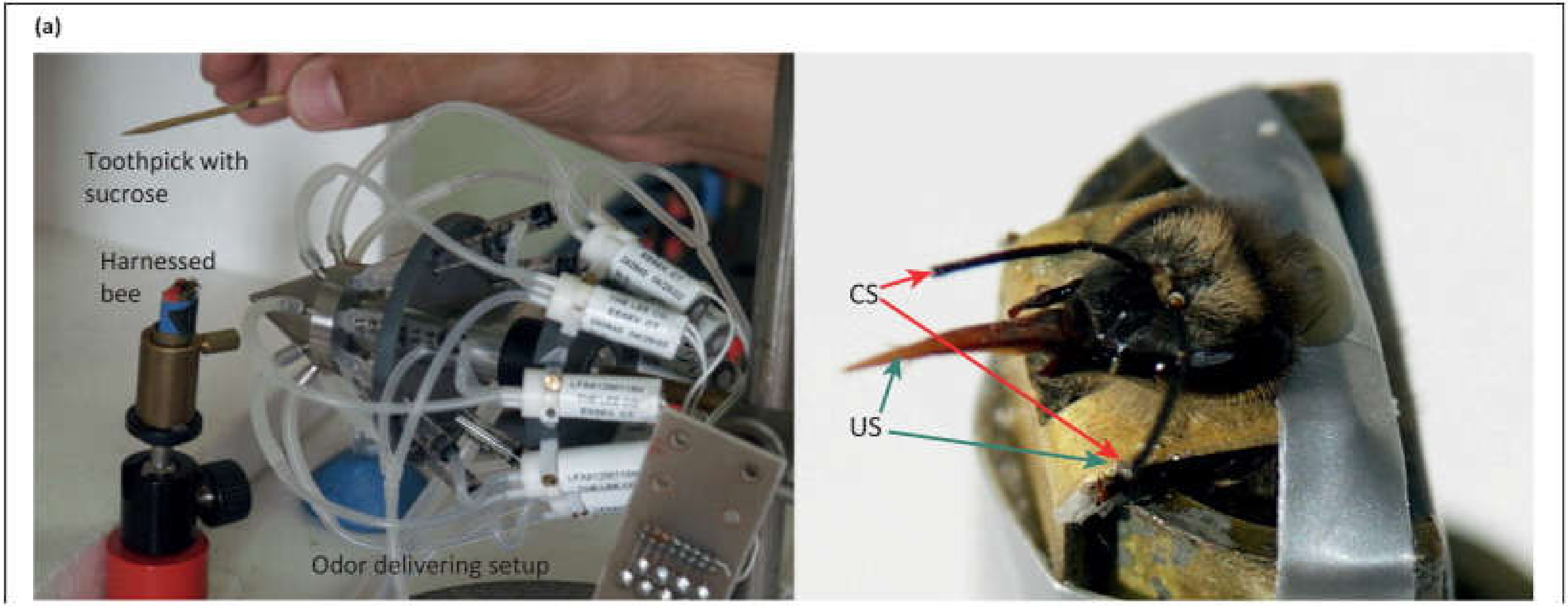
Onthophagus taurus

Simmons, L. W., and J. S. Kotiaho. "The effects of reproduction on courtship, fertility and longevity within and between alternative male mating tactics of the horned beetle, Onthophagus binodis." *Journal of evolutionary biology* 20.2 (2007): 488-495.

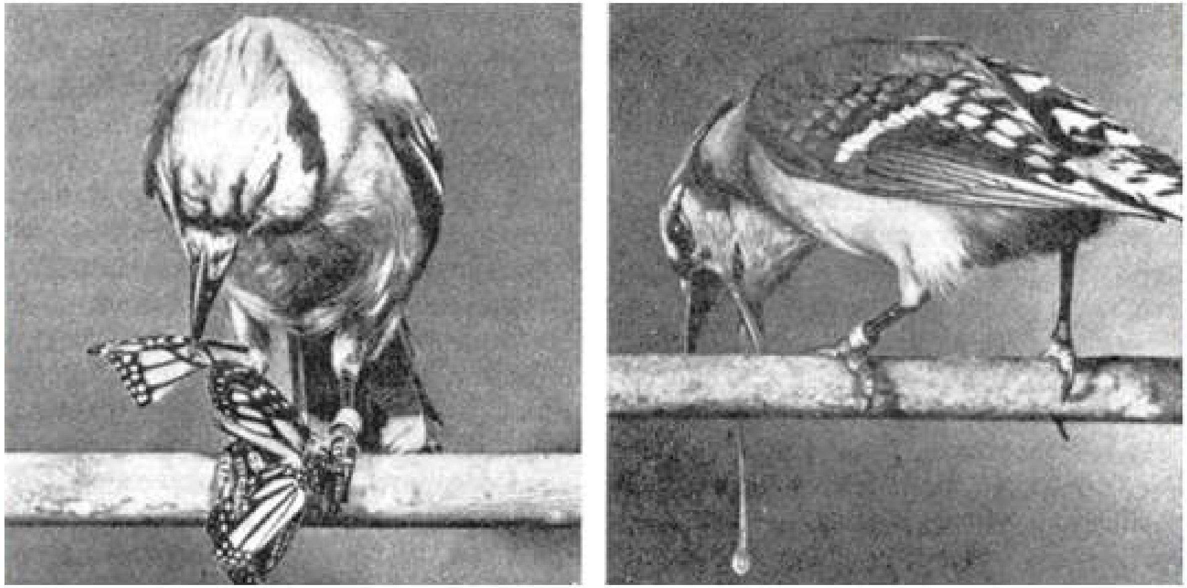
Классические условные рефлексы

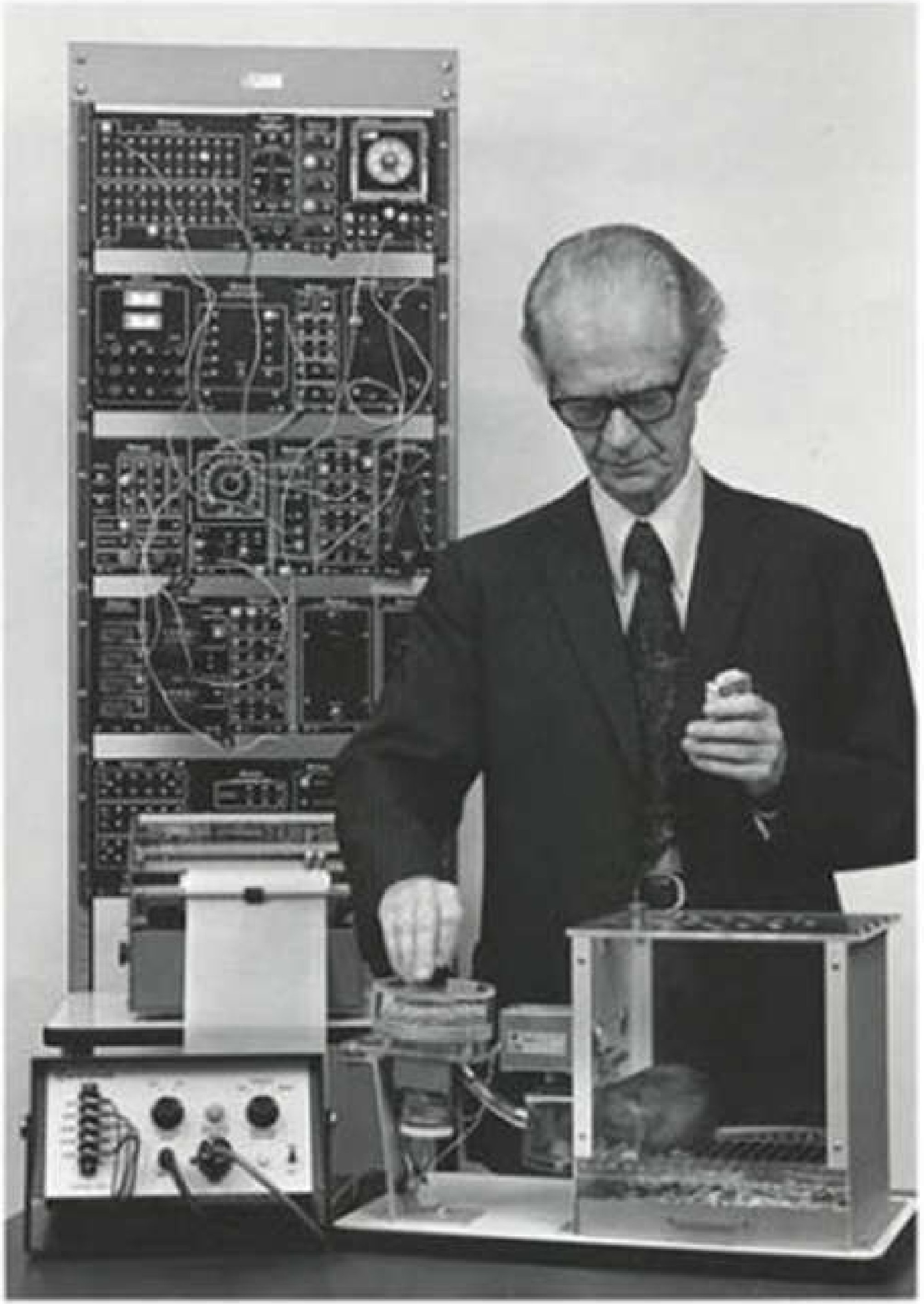
И.П. Павлов, психическая секреция

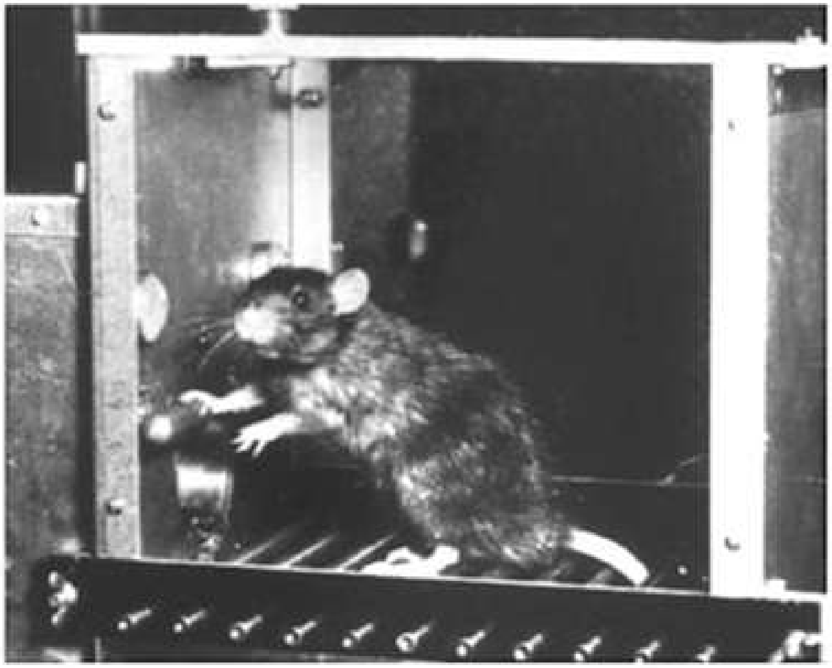
“...всякая деятельность организма есть закономерный ответ на тот или другой внешний агент.”

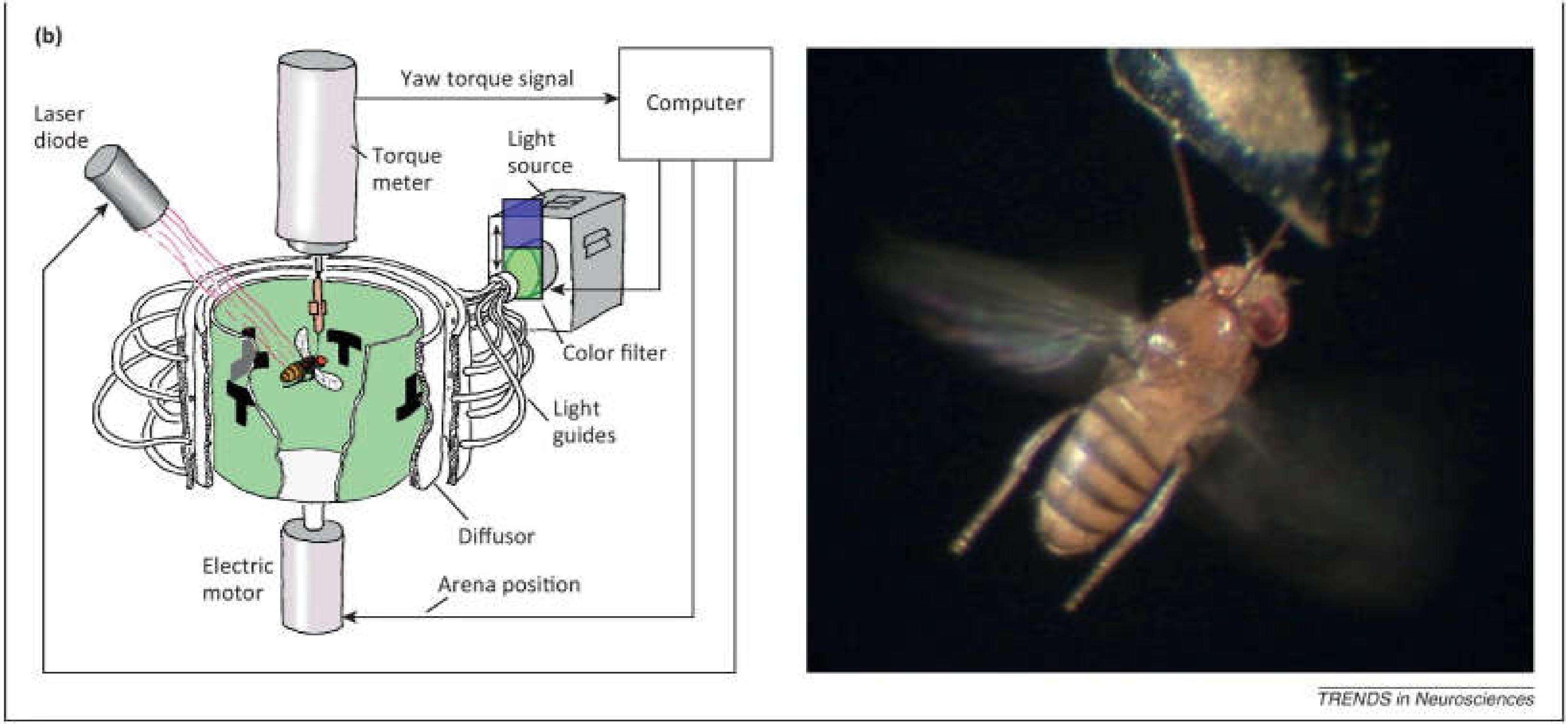


Giurfa, Martin. "Cognition with few neurons: higher-order learning in insects." *Trends in neurosciences* 36.5 (2013): 285-294.





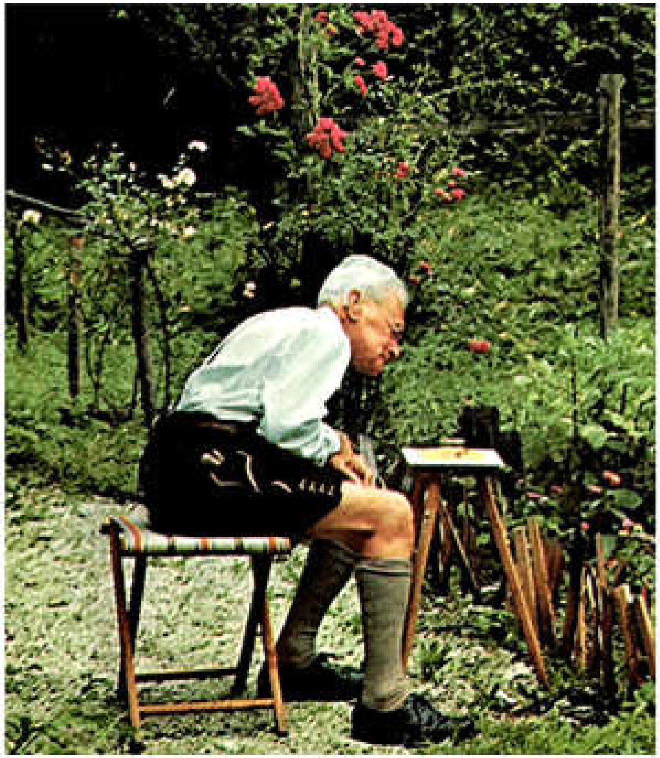




Brembs, Björn, and Martin Heisenberg. "The operant and the classical in conditioned orientation of Drosophila melanogaster at the flight simulator." *Learning & Memory* 7.2 (2000): 104-115.

Жанна Ильинична Резникова в лаборатории Г.А. Мазохина-Поршнякова

Карл фон Фриш, язык танца медоносной пчелы



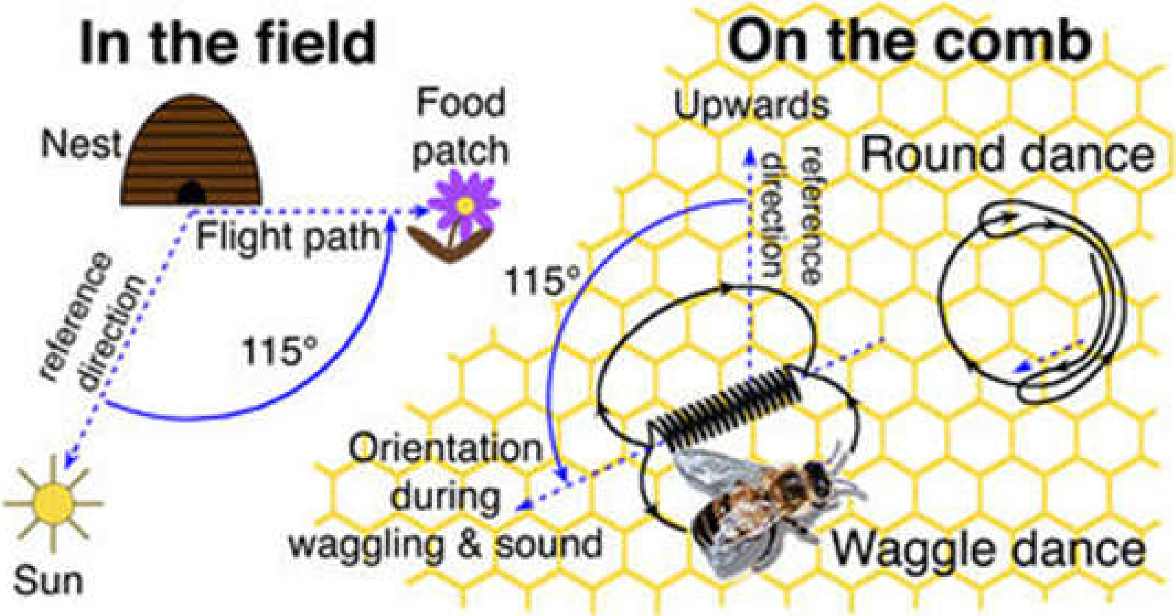


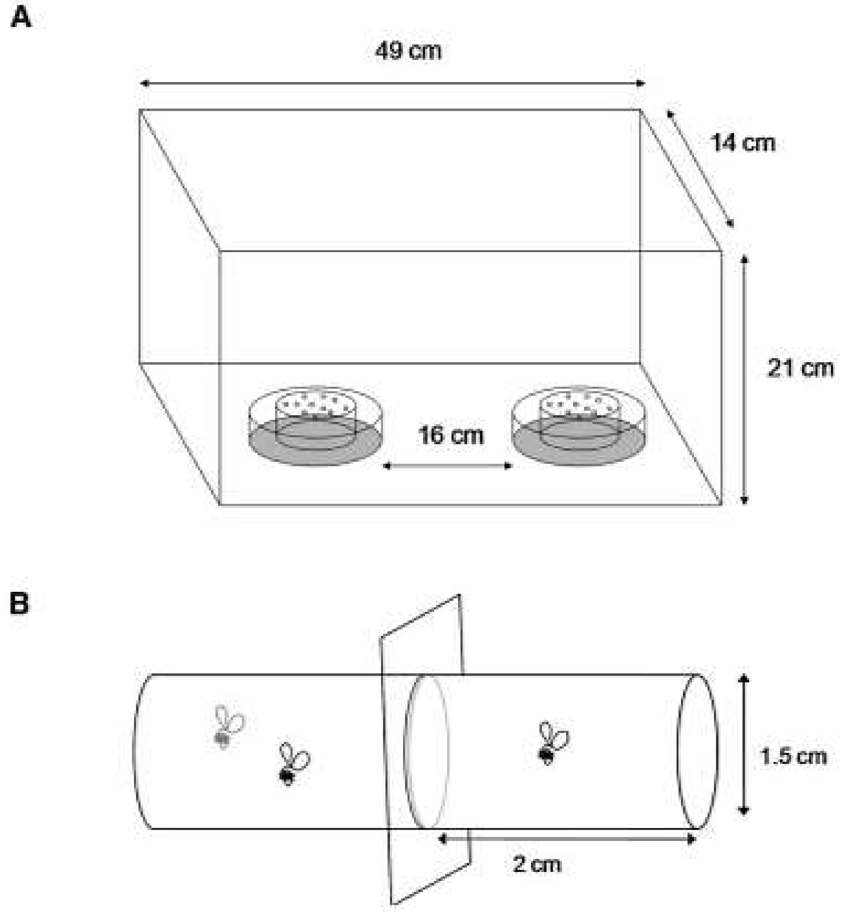
Фото Т.А. Новгородовой

И муравьям есть что сообщить

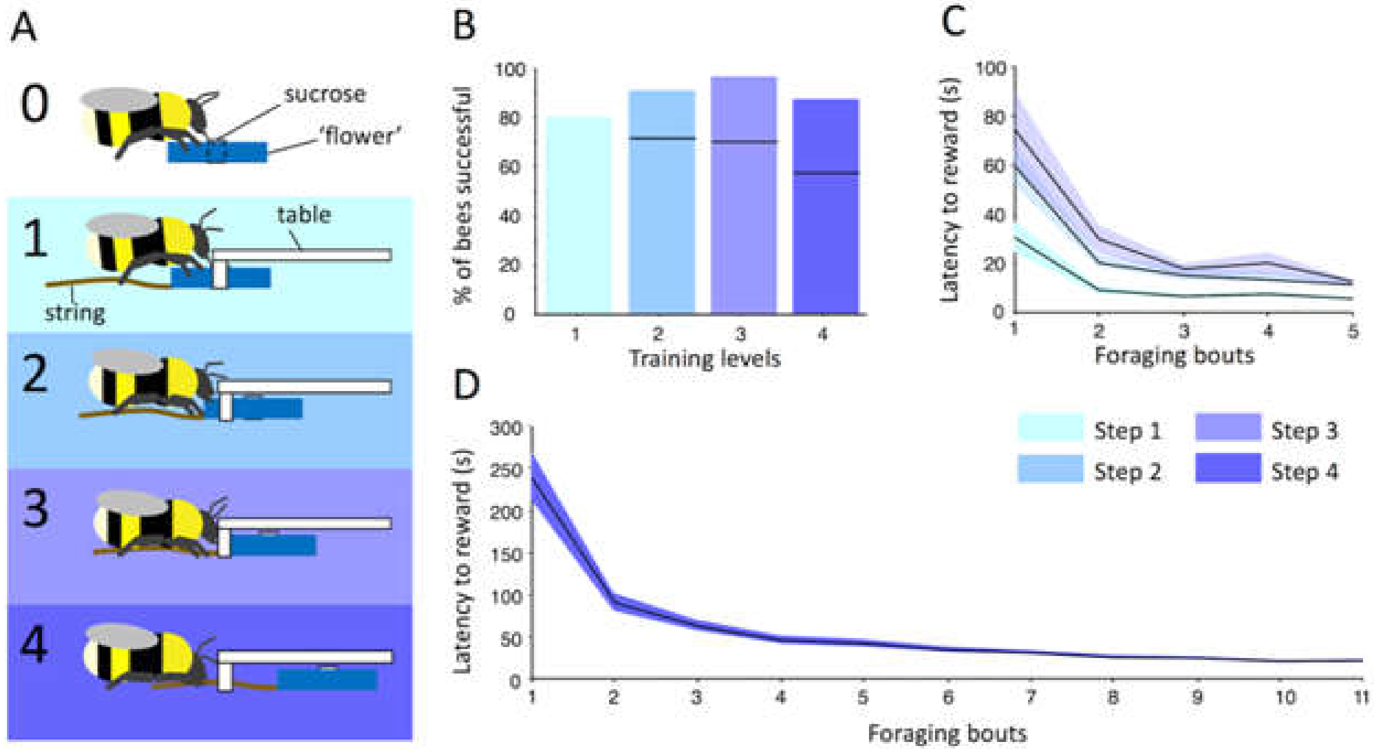
Фото Ж.И. Резниковой

Как использовать общественную информацию

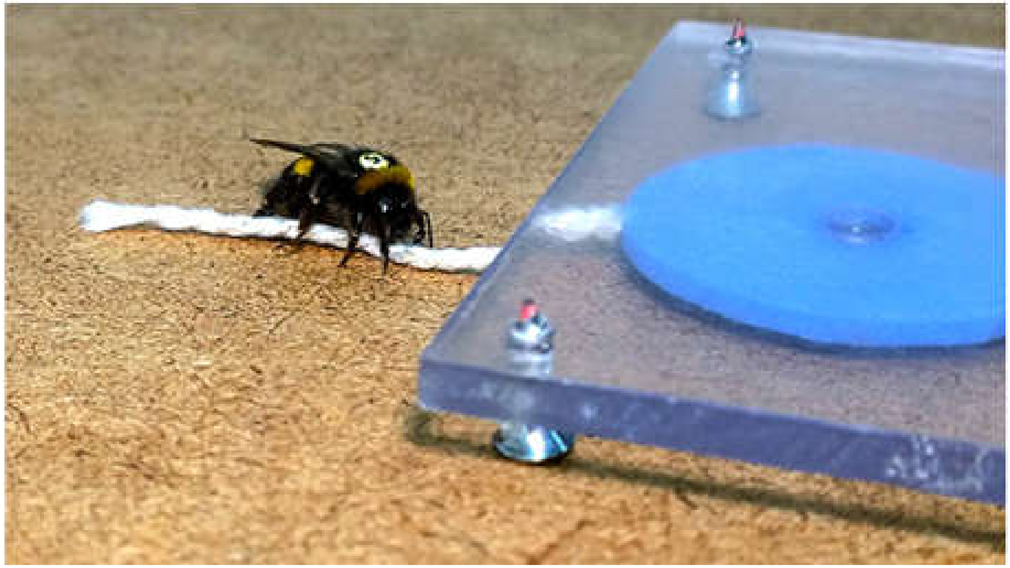
при выборе полового партнера?

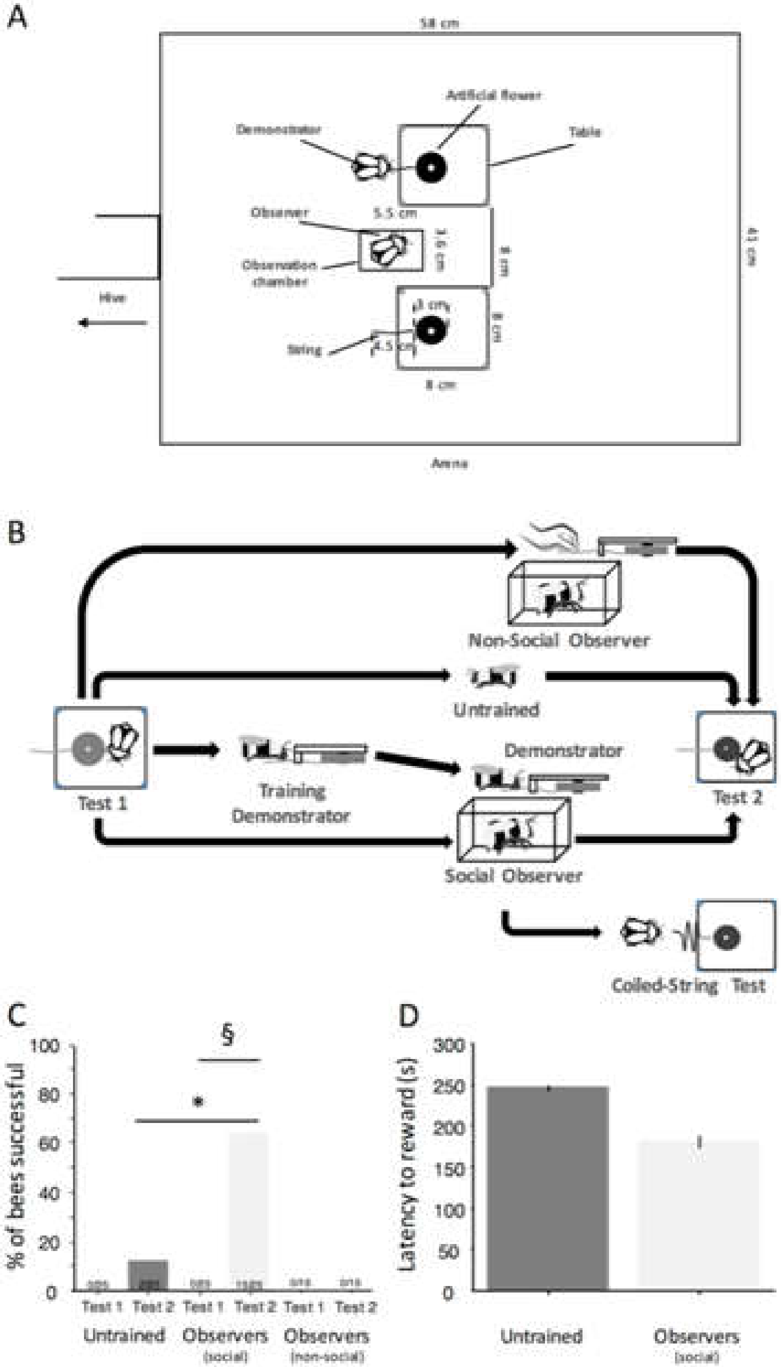


Mery F., Varela S. A. M., Danchin E., Blanchet S., Parejo D., Coolen I., Wagner R. H.
2009. Public versus personal information for mate copying in an invertebrate. Curr. Biol. 19, 730–73410.1016/j.cub.2009.02.064



Alem, Sylvain, et al. "Associative mechanisms allow for social learning and cultural transmission of string pulling in an insect." *PLoS biology* 14.10 (2016): e1002564.




A
58 cm
Artificial flower
Demonstrator
Table
Observer
5.5 cm
3.6 cm
8 cm
41 cm
Observation chamber
Hive
3 cm
8 cm
String
4.5 cm
8 cm
Arena
B
Non-Social Observer
Untrained
Test 1
Training Demonstrator
Demonstrator
Test 2
Social Observer
Coiled-String Test
C
§
*
100
80
60
40
20
0
% of bees successful
Test 1
Test 2
Test 1
Test 2
Test 1
Test 2
Untrained
Observers (social)
Observers (non-social)
D
300
250
200
150
100
50
0
Latency to reward (s)
Untrained
Observers (social)

Сто коров,

Двести бобров,

Четыреста двадцать

Ученых комаров

Покажут сорок

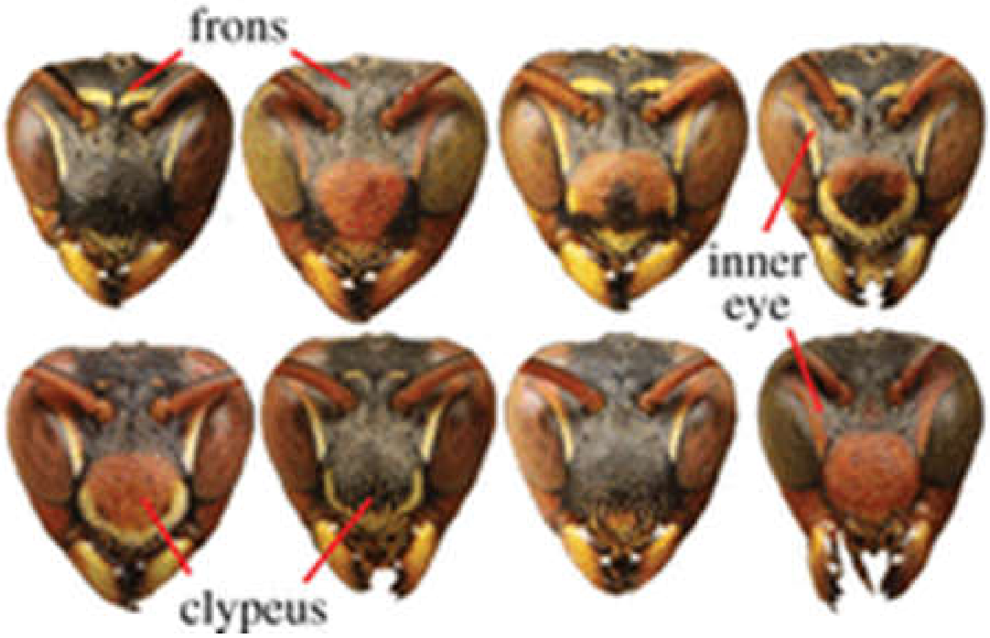
Удивительных

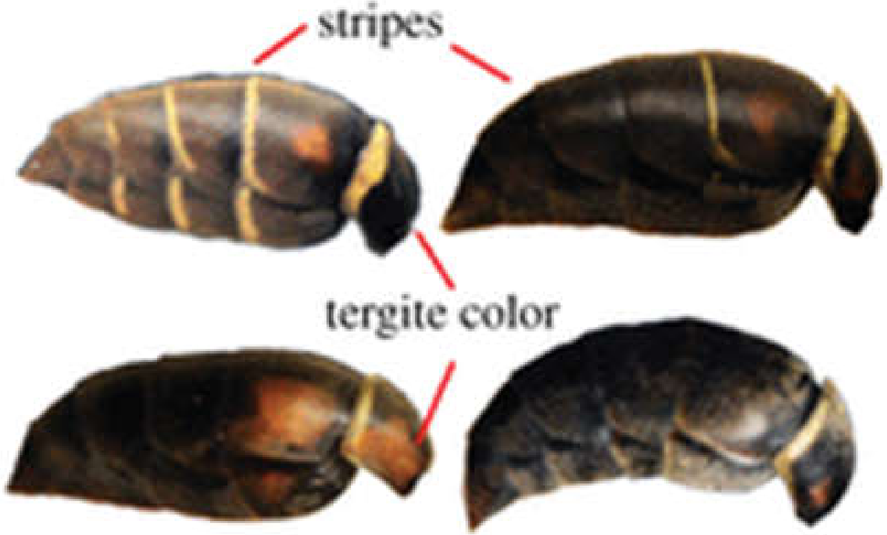
Номеров.

Д. Хармс

Loukola, Olli J., et al. "Bumblebees show cognitive flexibility by improving on an observed complex behavior." *Science* 355.6327 (2017): 833-836.

Распознают своих





Sheehan, Michael J., Juanita Choo, and Elizabeth A. Tibbetts. "Heritable variation in colour patterns mediating individual recognition." *Royal Society Open Science*4.2 (2017): 161008.

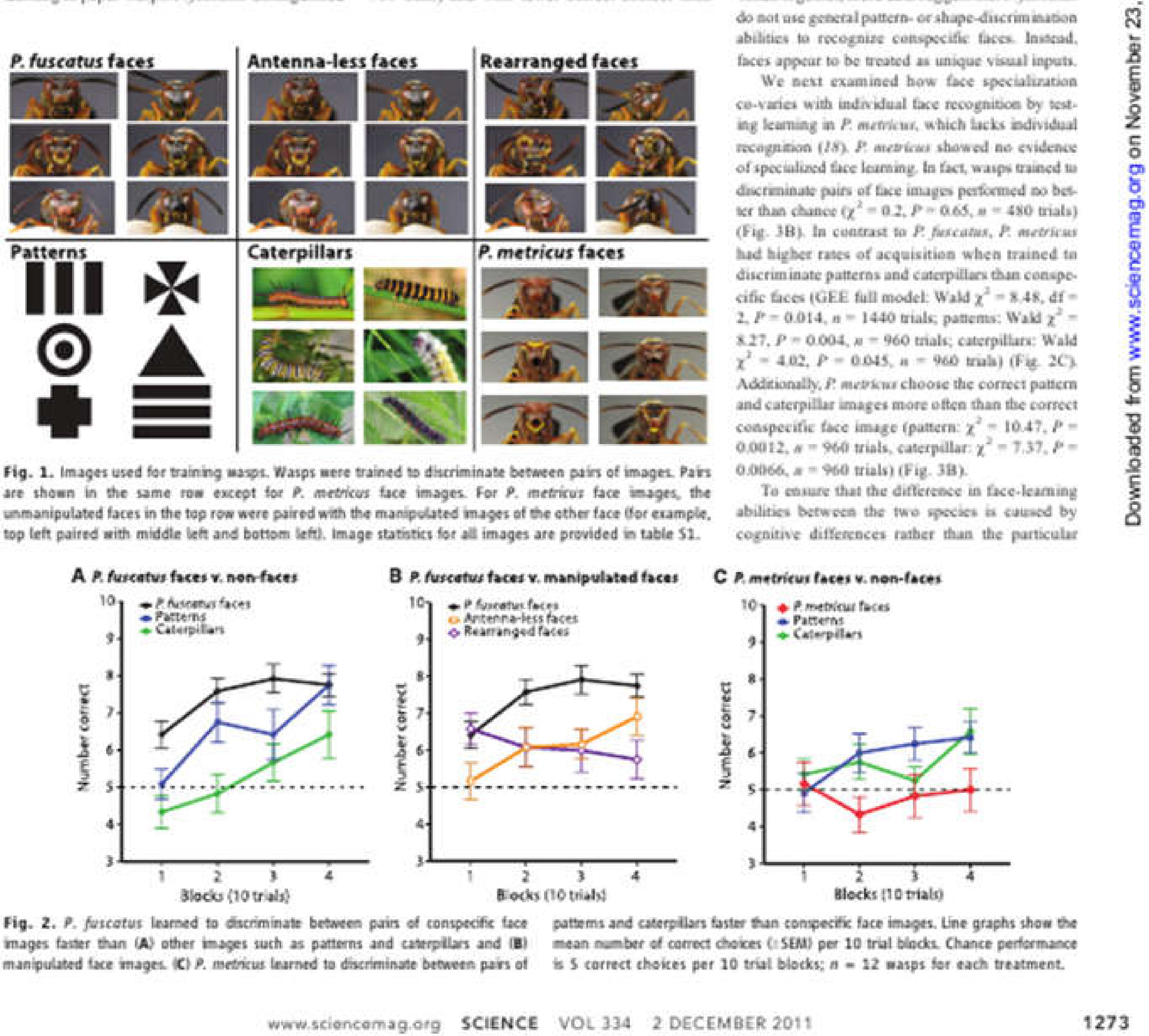


Fig. 1. Images used for training wasps. Wasps were trained to discriminate between pairs of images. Pairs are shown in the same row except for *P. metricus* face images. For *P. metricus* face images, the unmanipulated faces in the top row were paired with the manipulated images of the other face (for example, top left paired with middle left and bottom left). Image statistics for all images are provided in table S1.

do not use general pattern- or shape-discrimination abilities to recognize conspecific faces. Instead, faces appear to be treated as unique visual inputs.

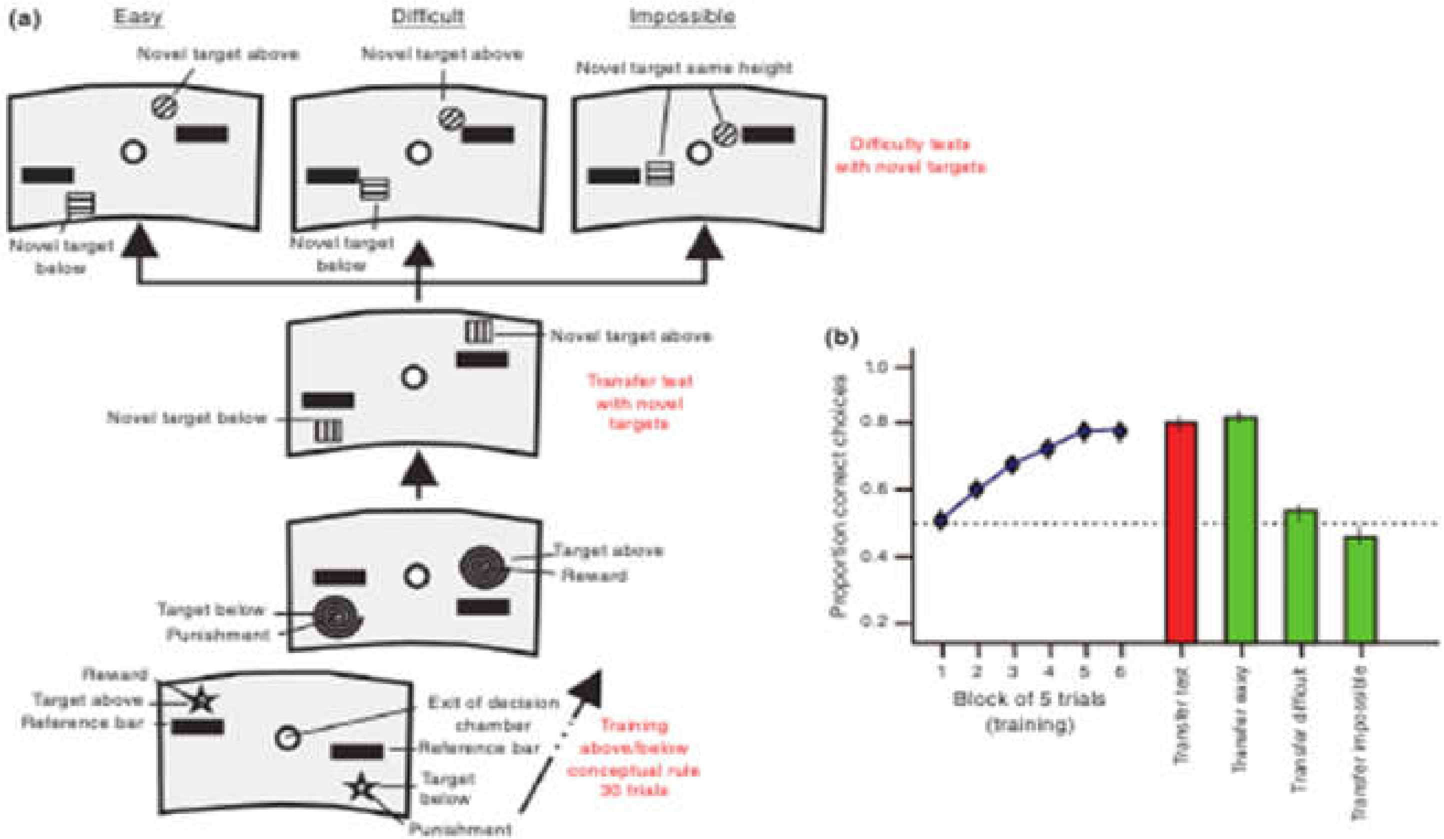
We next examined how face specialization co-varies with individual face recognition by testing learning in *P. metricus*, which lacks individual recognition (*18*). *P. metricus* showed no evidence of specialized face learning. In fact, wasps trained to discriminate pairs of face images performed no better than chance ($\chi^2 = 0.2$, $P = 0.65$, $n = 480$ trials) (Fig. 3B). In contrast to *P. fuscatus*, *P. metricus* had higher rates of acquisition when trained to discriminate patterns and caterpillars than conspecific faces (GEE full model: Wald $\chi^2 = 8.48$, df = 2, $P = 0.014$, $n = 1440$ trials; patterns: Wald $\chi^2 = 8.27$, $P = 0.004$, $n = 960$ trials; caterpillars: Wald $\chi^2 = 4.02$, $P = 0.045$, $n = 960$ trials) (Fig. 2C). Additionally, *P. metricus* choose the correct pattern and caterpillar images more often than the correct conspecific face image (pattern: $\chi^2 = 10.47$, $P = 0.0012$, $n = 960$ trials, caterpillar: $\chi^2 = 7.37$, $P = 0.0066$, $n = 960$ trials) (Fig. 3B).

To ensure that the difference in face-learning abilities between the two species is caused by cognitive differences rather than the particular

Fig. 2. *P. fuscatus* learned to discriminate between pairs of conspecific face images faster than (**A**) other images such as patterns and caterpillars and (**B**) manipulated face images. (**C**) *P. metricus* learned to discriminate between pairs of patterns and caterpillars faster than conspecific face images. Line graphs show the mean number of correct choices (±SEM) per 10 trial blocks. Chance performance is 5 correct choices per 10 trial blocks; $n = 12$ wasps for each treatment.

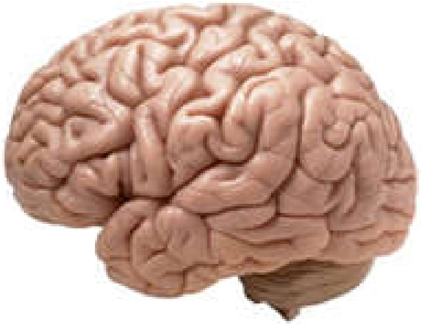
Sheehan, Michael J., and Elizabeth A. Tibbetts. "Specialized face learning is associated with individual recognition in paper wasps." *science* 334.6060 (2011): 1272-1275.

Метапознание у насекомых?

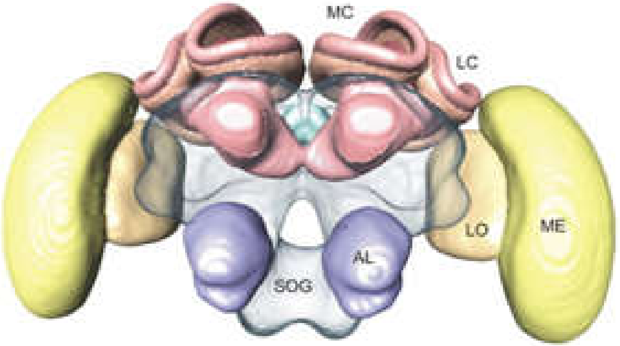


Perry CJ, Barron AB. Honey bees selectively avoid difficult choices. Proc Natl Acad Sci USA 2013, 110:19155–19159.

Мозг кашалота
до 9 кг
200 млн. нейронов



Мозг человека
1,24-1,45 кг
85 млн. нейронов

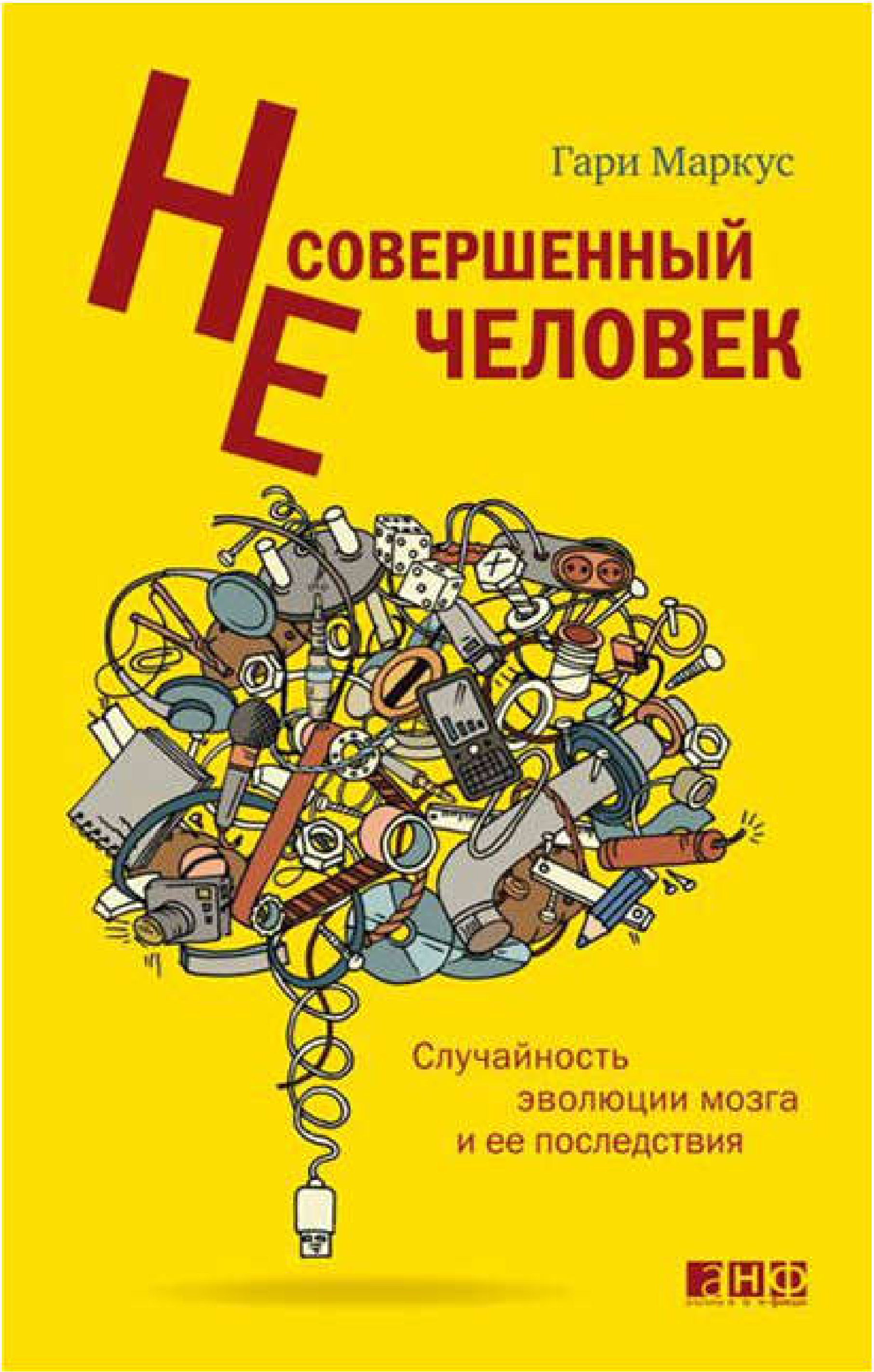


Мозг пчелы
1 мг
1 млн. нейронов

Insects possess a nervous system that is incredibly complex and differentiated, and whose fineness attains ultramicroscopic levels. Comparing the visual and cerebroid ganglia of a bee or a dragonfly with those of a fish or an amphibian yields an extraordinary surprise. The excellence of the psychic machinery does not increase with zoological hierarchy; on the contrary, one realizes that in fishes and amphibians, the nervous centers have suffered an unexpected simplification. Certainly, the grey substance has considerably increased in mass, but when one compares its structure with that of the brain of Apidaea or Libellulidae, it appears as excessively coarse and rudimentary. It is like pretending to match the rough merit of a wall clock with that of a pocket watch, a marvel of fineness, delicacy and precision. As usually, the genius of life shines more in the construction of smaller than larger master pieces’

S. Ramon Cajal

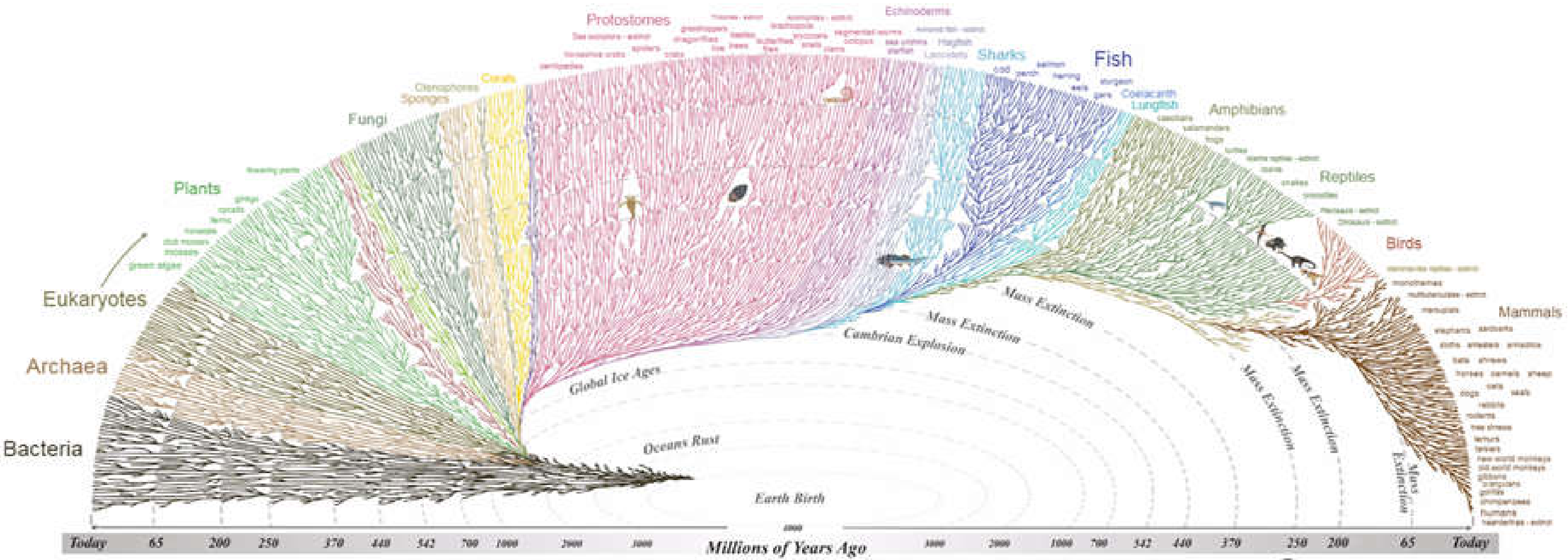
Ramón y Cajal S, Sánchez D. Contribución al Conocimiento de los Centros Nerviosos de los Insectos. Madrid: Imprenta de Hijos de Nicolás Moya; 1915



Гари Маркус

НЕсовершенный
человек

Случайность
эволюции мозга
и ее последствия



All the major and many of the minor living branches of life are shown on this diagram, but only a few of those that have gone extinct are shown. Example: Dinosaurs - extinct

PHOTO: PAUL STAROSTA/GETTY IMAGES

HYPOTHESIS

Epigenetics and the evolution of instincts

Instincts may evolve from learning and share the same cellular and molecular mechanisms

By **Gene E. Robinson**[1] *and* **Andrew B. Barron**[2]

An animal mind is not born as an empty canvas: Bottlenose dolphins know how to swim and honey bees know how to dance without ever having learned these skills. Little is known about how animals acquire the instincts that enable such innate behavior. Instincts are widely held to be ancestral to learned behavior. Some have been elegantly analyzed at the cellular and molecular levels, but general principles do not exist. Based on recent research, we argue instead that instincts evolve from learning and are therefore served by the same general principles that explain learning.

Consider individuals in an ancestral population that use behavioral plasticity to respond adaptively to their environment (*1*, *2*). If this adaptive response increases fitness, then natural selection should favor animals that manifest the trait earlier in development or with less practice (*3*). Selection acting to adjust the timing and extent of plasticity can thus produce an instinct. The selective forces would depend on the environment. In certain environments, behavioral plasticity might be favored, but in other environments, more stereotyped behavior might prove superior (*1*, *3*). This process need not result in the programming of every single detail of an instinct; all that is needed is an initial behavioral bias followed by a process of experience-dependent refinement (*4*), driven by predictable patterns of environmental reinforcement.

This hypothesis is consistent with the "plasticity first" model of evolution, which states that plasticity can precede and facilitate evolutionary adaptation (*1*). The plausibility of this model has increased dramatically with the advent of behavioral genomics. We now know that the genome responds dynamically to a range of behaviorally relevant stimuli, often with massive changes in brain gene expression (*2*). Plasticity-first models have been used to explain various phenomena, including the evolution of personality differences in stickleback fish, behavioral diversification in Darwin's finches, and rapid anatomical and behavioral evolution in primates (*2*, *5*).

Also, it is possible that some instincts evolved via the more traditional "mutation first" model of evolution. In this case, mutations cause changes in the timing of the development of neural circuitry, for example, from postnatal to prenatal. In either case, once evolved, the effectiveness of innate components of a behavior can be enhanced by the evolution of more complex forms of learning as these components become increasingly refined by natural selection. Learned and instinctive components of behavior are intertwined and should therefore be regulated by the same general neural mechanisms.

Evidence from neuroscience supports the idea of a unified model of behavior. For example, recent results from bees and flies show that both innate and learned olfactory responses are governed by the same neural circuits (*6*). Similarly, in rodents, the neural circuits organizing innate and learned fear

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[1] *Carl R. Woese Institute for Genomic Biology, Department of Entomology, and Neuroscience Program, University of Illinois at Urbana-Champaign, Urbana, IL 61801, USA.* [2] *Department of Biological Sciences, Macquarie University, Sydney NSW 2109, Australia. Email: generobi@illinois.edu; andrew.barron@mq.edu.au*

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