COURSE BOOK

Introduction to Natural Sciences: Biology

Academic year 2020–2021

МИНИСТЕРСТВО ОБРАЗОВАНИЯ И НАУКИ РФ
НАЦИОНАЛЬНЫЙ ИССЛЕДОВАТЕЛЬСКИЙ ТОМСКИЙ ГОСУДАРСТВЕННЫЙ УНИВЕРСИТЕТ
САЕ ИНСТИТУТ «УМНЫЕ МАТЕРИАЛЫ И ТЕХНОЛОГИИ»

INTRODUCTION TO NATURAL SCIENCES: BIOLOGY
COURSE BOOK
ВВЕДЕНИЕ В ЕСТЕСТВЕННЫЕ НАУКИ: БИОЛОГИЯ

Методическое руководство по курсу «Введение в естественные науки: биология» для студентов автономной образовательной программы бакалавриата «Tomsk International Science Program» по направлению подготовки 27.03.05 Инноватика

Томск 2020

РАССМОТРЕНО И УТВЕРЖДЕНО методической комиссией САЕ Институт «Умные материалы и технологии»
Протокол № 1 от «7» сентября 2020 г.
Председатель МК И.А. Курзина

Методическое руководство составлено в соответствии с тематикой семинарских занятий и программой курса «Введение в естественные науки: биология» для студентов автономной образовательной программы бакалавриата «Tomsk International Science Program» (TISP) по направлению подготовки 27.03.05 Инноватика. Особое внимание уделено основам клеточного строения и функционированию живых организмов благодаря протекающим в них молекулярным процессам, а также эволюционным адаптациям классов живых организмов. Методическое руководство содержит кейсы для семинарских занятий, методические указания к их решению, а также их оценки с использованием рейтингового контроля. Для студентов и слушателей курсов TISP, а также для студентов биологических специальностей.

СОСТАВИТЕЛИ: Е.А. Соломина, М.Н. Шурупова, Р.Т. Багиров

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1. GENERAL INFORMATION

1.1. Learning outcomes

LO1 Define different forms of life
LO2 Explain evolutionary mechanisms of random events and selection pressure and their effects on protein evolution
LO3 Describe the macromolecules of life (nucleic acid, proteins, fats and sugars) and explain how their structure relates to their function
LO4 Explain how organelles (Golgi apparatus, mitochondria) contribute to cell homeostasis (structure-function relationships)
LO5 Explain how evolution has led to biodiversity
LO6 Identify characteristics of organisms the main phyla within the six-kingdom classification of life
LO7 Explain how abiotic (physical and chemical) and biotic (living) factors influence life in the ecosystems

1.2. Overview

This course, which prepares you for more advanced courses in biology and allied subjects, surveys the fundamental principles of biology with an emphasis on evolution. Topics covered include cell and molecular biology, genetics, evolution, biodiversity and ecology.

1.3. Tutorials

In the 14 planned tutorial meetings, students will be guided by experienced tutors. PBL-training will be integrated with the tutorial groups, but will also be introduced in a dedicated lecture. In this course, special emphasis is placed on the different roles in the tutorial group (moderator, minutes secretary, participant and tutor). Main goal of the PBL training is that students know their responsibilities and learn to provide and receive feedback. Additionally, they will learn to manage their own portfolio. In each tutorial group the students will construct a ‘growing concept map’, in which the previous case is central to the extensions made to the concept map, to facilitate understanding of the connections between the various cases.

1.4. Additional assignment

During each tutorial group meeting one of the learning goals will be presented by one of the students. Students will be asked to stand in front of the group and present by only using the whiteboard and short notes. This student and the learning goal will be selected in the previous meeting, in order to give him/her the chance to be more specific in the preparation. In the following courses, students will present uninstructed during tutorial group meetings. Using a pre-structured feedback form the student evaluates his/ her own presentation (which should be included in the self-evaluation at the end of the course).

1.5. Lectures

Lectures will give an overview of each theme. Lectures will be planned after the tutorial group meetings to prevent interference with the brainstorming session. Lectures will summarize shortly what should be known from secondary school, but will predominantly add more depth to the existing knowledge.

1.6. Study material

Required literature

• *Books*

In this course we will make use of one course textbook, and several additional sources. The course book is Biology by Neil Campbell, 7th edition. This is a very good basic book, and we will be covering quite a large amount of the book throughout the course.

Other good sources of information are Biology: by Rye C. et. al., (OpenStax). These books cover the required content. I would not advise purchasing these books. Tutors have electronic versions of them.

• *Articles*

Some tasks require also some specific readings that are not covered sufficiently in Handbooks. Therefore we will provide a selection of interesting articles via Moodle. Although textbooks are very valuable in providing a proper basic academic knowledge, articles provide an essential and indispensable addition.

Searching for your own literature

One important feature of PBL, is to let students select their own literature to a great extent. Throughout the course, I expect that you supplement the given literature with your own choice. In searching for literature, I would however like to urge you to carefully consider the selection you make. Literature ought to be trustworthy, of sufficient academic level, credible, relevant to the subject at hand and referenced when used. Some good sources are: Research Library of Tomsk State University Library, https://www.nature.com/, https://www.cell.com/, https://www.nationalgeographic.com/ etc.

Moodle

Please check Moodle on a daily basis. There, study material such as PDF-copies of lectures and additional literature will be offered to the students. In addition, this is where changes to the schedule will be announced. Additional information concerning the content of the assignments and tasks will also be provided at Moodle

1.7. Assessment

Summative assessment

Students will be assessed in two different manners. Students will have to make an oral presentation and to complete a written exam. At the beginning of the course, students will receive additional information concerning the assessments.

1. *Oral presentation.*

Each student will have to give an oral presentation that summary one case.

*The grade of the presentation will count for **30 %** towards your final grade.*

2. *Exam.*

The exam will consist of 9 open questions, one per case. The exam will test both factual knowledge and insight into the material. The content of the **cases** as well as the **lectures** are part of the exam.

*The grade of the exam will count for **70 %** towards your final grade.*

Formative assessment

- In order to be able to take the exam, student have to obtain not less than 170 points during the course, which include attendance of tutorials and lectures, active participation during tutorial, using correct terminology and additional sources for post-discussion;
- The group process and the functioning of the tutor will be evaluated at mid-term and at the end of the course by both students and tutors.
- The performance of the discussion leader and the scribe will be shortly evaluated at the end of each session.
- Peers and tutors will provide formative feedback on the presentation of one learning goal by individual students at every session.
- Peers and tutors will provide formative feedback on the final oral presentation of one case.

1.8. Attendance, Additional Assignments and Resit Policy

This course has an 85 % attendance requirement. Students must attend a minimum of 12 of the 14 tutorial meetings. If you cannot attend an individual session, please contact your tutor and e-mail your assignment (e.g. preparation for the PBL case) to your tutor and course coordinator. Students who have attended 11 meetings may apply for a compensation assignment according to MSC procedures. Please note that additional assignments are only granted when students have a valid reason for missing all meetings. Students who attend 10 meetings or less will fail the course.

When a student fails the course he or she is entitled to a resit on the exam if, and only if, they made a reasonable effort to pass the course. This means that if you do not show up for the exam, or do not hand in your essay, you are not allowed to take the resit.

1.9. Staff

Course coordinator

Solomina Yevgeniya, PhD Maastrich University, methodologist Tomsk State University, evgeniyasea27@gmail.com

Tutors

Taisiya Kletskina kletskina_taisiya@mail.ru
Margarita Shurupova rita.shurupova@inbox.ru
Ruslan Bagirov rbaghirov@yandex.ru
Yevgeniya Solomina evgeniyasea27@gmail.com

Lecturers

Dean Paes d.paes@maastrichtuniversity.nl

Wilfred Germeraad w.germeraad@maastrichtuniversity.nl
Terry Callaghan

1.10. Questions

If you have questions about the timetable, registration for trainings and practicals, education and examination rules, exam dates, exam results etc. you can contact 1st year coordinator: Taisiya kletskina_taisiya@mail.ru

For questions about the content of the course or the exam you can contact the coordinator of this course: Yevgeniya evgeniyasea27@gmail.com

2. CASES

Case 1. What is life?

Many origins-of-life theories focus on explaining the emergence of a “privileged function” – a specific aspect of modern-day earthly biology that is assumed to have been present at its emergence. Often, these privileged functions are also implicitly assumed to be more fundamental to life in that once the privileged function is established, the rest of life’s functions should naturally emerge. In RNA or Clay Worlds, the privileged function is replication. In Metabolism-First Worlds, the privileged function is metabolism. In Thermal Vent Worlds, the privileged function is energy harvesting from chemical gradients. In Membrane Worlds, the privileged function is compartmentalization. But does these functions actually were present at life’s beginnings? Based on phylogenetic studies, our knowledge of Earth’s earliest life forms ceases at the Last Universal Common Ancestor (LUCA). Such studies have shed light on LUCA’s nature – most likely a cellular being with a chemiosmotic metabolism whose genetics were written in DNA/RNA. However, LUCA was almost certainly not the original life form on Earth. But how do scientists distinguish living forms from non living ones?

References:

1. Biology, 7th edition by Campbell N.A., Reece J.B., Chapter 5 “The Structure and Function of Macromolecules”. Pp. 68–89.

2. Bartlett S., Wong M.L. Defining Lyfe in the Universe: From Three Privileged Functions to Four Pillars, Life. 2020, doi:10.3390/life10040042

3. Chemical Evolution and the Origin of Life, Chapter 1 "Historical Survey". Pp. 3–16; Chapter 4 "Chemical Evolution”, "The Miller–Urey Model Experiments". P. 87.

Case 2. Prokaryote or Eukaryote?

A cell is the smallest unit of a living thing. A living thing, whether made of one cell (like bacteria) or many cells (like a human), is called an organism. Thus, cells are the basic building blocks of all organisms. There are only two kinds of organisms on the Earth: prokaryotes and eukaryotes. Only the predominantly single-celled organisms of the domains Bacteria and Archaea are classified as prokaryotes. Cells of animals, plants, fungi, and protists are all eukaryotes and are made up of eukaryotic cells. Although eukaryotes are considered to have evolved from prokaryotes, there were no previously known intermediate forms between them. The differences in their cellular structures are so vast that the problem of how eukaryotes could have evolved from prokaryotes is one of the greatest enigmas in biology. You work as a researcher at Marine Biodiversity Research Program. The goal of your research team is to identify an evolutionary path between prokaryotes and eukaryotes.

There are two major hypotheses regarding the origin of eukaryotes. According to the endosymbiotic theory, a large, amoeboid, heterotrophic, anaerobic prokaryote engulfed aerobic bacteria, some of which were not digested but instead stabilized as endosymbionts, which became integrated into the host cell as mitochondria. According to the autogenesis theory, the structures and functions of eukaryotic cells developed gradually from simple rudiments in prokaryotic cells. There is still considerable debate about how eukaryotes originated.

Your research group has recently discovered a unique organism from the deep sea off the coast of Japan. By using electron microscopy (fig. 1) you determined that the

organism is 10 μm long and 3 μm in diameter, having > 100 times the volume of *Escherichia coli*. It has a large 'nucleoid', consisting of naked DNA fibers, with a single nucleoid membrane and endosymbionts that resemble bacteria, but no mitochondria. You named this unique microorganism *Parakaryon myojinensis.*

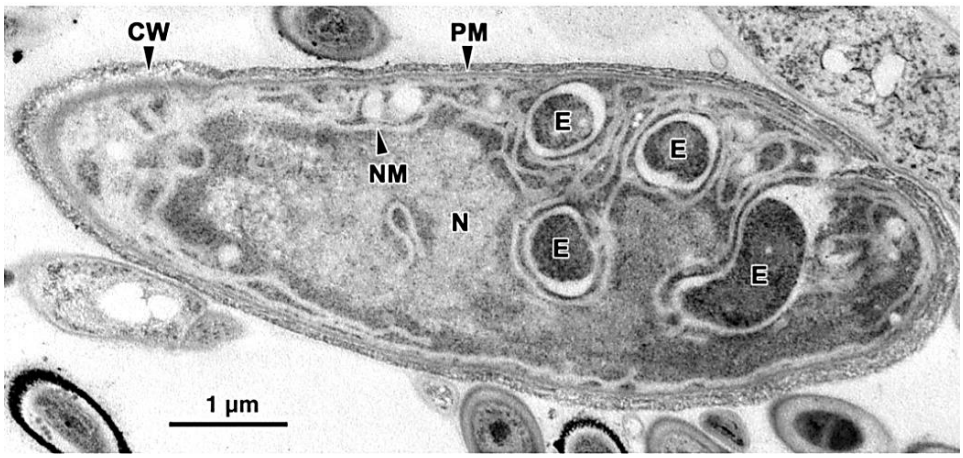


Fig. 1. An ultrathin section of *Parakaryon myojinensis*. The large irregular nucleoid (N) with single nucleoid membrane (NM), the presence of endosymbionts (E) and the absence of mitochondria. Also labeled are the cell wall (CW) and plasma membrane (PM)

Three-dimensional structural reconstruction provided information about the numbers and sizes of all cell components in *P. myojinensis* (table 1). Now try to describe and discuss the results of these findings in order to publish this data.

Table 1

The numbers and sizes of all cell components in *P. myojinensis*

Cell/components	Number	Length × diameter
Cell	1	10.3 × 3.1 μm
Cell wall	1	
Cytoplasm	1	
Nucleoid	1	9.0 × 2.1 μm
Cytosol	1	
Plasma membrane	1	
Cytomembranes	n. d.	
Ribosomes	n. d.	
Endosymbionts	3	
Endosymbiont 1		10.4 × 0.7 μm
Endosymbiont 2		1.7 × 0.4 μm
Endosymbiont 3		0.8 × 0.4 μm
Phagosome space	3	
Vacuoles	102	236 nm (average diameter)
Small granulated electron-transparent materials	150	155 nm (average diameter)

n. d. = not determined.

References:

1. Biology, 7th edition by Campbell N.A., Reece J.B., Chapter 6 "The Cell". Pp. 94–99.

2. Yamaguchi M. Prokaryote or eukaryote? A unique microorganism from the deep sea // Journal of Electron Microscopy. 61(6): 423–431 (2012), doi: 10.1093/jmicro/dfs062

3. For a perspective on cell size, try the HowBig interactive web-site. URL: https://www.cellsalive.com/howbig.htm

Case 3. The cells inside

You already know, that any organism consists of a single cell or a group of cells. And all cells contain certain organelles like nucleus, ribosomes, centrioles etc. All plant cells additionally have cell wall composed of the polysaccharides cellulose, hemicelluloses and pectin, while fungi possess cell walls made of the chitin. Plant and bacterial cells contain different types of plastids like green chloroplasts and colorful chromoplasts. But animal cells do not have them. Why cells can be so different? And why some organism, like bacteria need only a single cell to live and reproduce, while human's organism contains 30,000,000,000,000 and need to meet other sex for reproduction?

References:

1. Biology, 7th edition by Campbell N.A., Reece J.B., Chapter 6 "The Cell". Pp. 102–120.

2. Biology by Rye C. et. al., (OpenStax), Unit 2. Chapter 4. Cell Structure. Pp. 103–109.

Pre-reading for the Case 4

They say that music is a universal language… and that every human being, regardless of their native tongue, can appreciate notes and chords, songs and symphonies. Te notes on a page are translated into sounds and songs by the musical instruments we use to play them.

There is another universal language: DNA, hidden deep within our cells, is the language of life. No matter how different two human beings are on the outside, their cells contain the exact same DNA building blocks: nucleotides containing the bases cytosine (C), thymine (T), adenine (A), or guanine (G). Human beings have about three billion of these building blocks across 23 pairs of chromosomes. Chromosomes are just long strands of nucleotides packaged up with protein. We can think of these nucleotides as notes, and the order in which they are arranged helps create the symphony that makes us human.

A unit of DNA information (i.e., "a gene") is used as a template to build mRNA which, in turn, is used as a set of directions to put together amino acids and synthesize a polypeptide. Transcription is often described as consisting of three phases: initiation, elongation and termination. Transcription initiation involves an enzyme called RNA polymerase that binds to a region of DNA (the "promotor" region) just upstream of a particular gene. Elongation consists of RNA polymerase separating the two strands of DNA followed by the creation of an mRNA molecule. Tis "messenger RNA" is made when RNA polymerase covalently attaches RNA nucleotides together using one of the separated DNA strands as a template. Finally, RNA polymerase reaches the end of the gene and, with the help of various accessory proteins, it falls of of the gene and the free mRNA is released.

In eukaryotic cells, once the mRNA is produced it is processed in a few special ways. "Caps" and "tails" are added to the ends, and little bits of extra (non-coding) RNA called introns are spliced out so that a continuous (mature) mRNA molecule is made from segments of coding DNA called exons. Ten this mature mRNA leaves the nucleus and special protein-making machines called ribosomes jump on the mRNA floating around in the cytoplasm and the process of translation begins.

Translation also has three steps with the same names as the steps involved in transcription: initiation, elongation and termination. While the purpose of transcription is to produce RNA by "reading" the DNA, the purpose of translation is to produce protein by "reading" the RNA; a molecular machine called the ribosome performs this task. Initiation

of translation begins when the small ribosomal subunit searches for a special mRNA start site (the nucleotides AUG). It waits for a complementary transfer RNA molecule to bring in the amino acid methionine. Elongation of translation occurs as the ribosome “reads” an mRNA molecule in three nucleotide “words” called codons (AUG is one of them) and waits for the appropriate tRNA to bring in the right amino acid. Each codon will specify the addition of one amino acid and only that amino acid will be allowed into a growing protein chain. Finally, termination happens when a ribosome reaches a stop codon in its reading frame. Once it reaches a stop codon, a release factor will help the whole complex dissociate, freeing our newly created protein so that it can go of and do its job in the cell.

In transcription, we make different forms (RNA from DNA) of the same chemical language: nucleic acids. But the next step, translation, involves a much more dramatic change. Getting back to our music analogy, think about how different it is to write notes on sheet music compared with actually playing that music. Te notes are the instructions but the song we hear is the real functional outcome, what actually moves our emotions.

Just as written notes on a page help us enjoy music, or as the Rosetta Stone helped us to translate between hieroglyphics and classic Greek, the genetic code helps us to translate from the nucleic acid language to the amino acid language. Using this code, we can read each mRNA codon and know exactly which amino acid should be inserted into a protein, the functional outcome of gene expression.

Second letter

First letter	U	C	A	G	Third letter
U	UUU Phe UUC Phe UUA Leu UUG Leu	UCU Ser UCC Ser UCA Ser UCG Ser	UAU Tyr UAC Tyr **UAA Stop** **UAG Stop**	UGU Cys UGC Cys **UGA Stop** UGG Trp	U C A G
C	CUU Leu CUC Leu CUA Leu CUG Leu	CCU Pro CCC Pro CCA Pro CCG Pro	CAU His CAC His CAA Gln CAG Gln	CGU Arg CGC Arg CGA Arg CGG Arg	U C A G
A	AUU Ile AUC Ile AUA Ile **AUG Met**	ACU Thr ACC Thr ACA Thr ACG Thr	AAU Asn AAC Asn AAA Lys AAG Lys	AGU Ser AGC Ser AGA Arg AGG Arg	U C A G
G	GUU Val GUC Val GUA Val GUG Val	GCU Ala GCC Ala GCA Ala GCG Ala	GAU Asp GAC Asp GAA Glu GAG Glu	GGU Gly GGC Gly GGA Gly GGG Gly	U C A G

What would happen if you combined our two universal languages: music and DNA? A group of researchers explored this question in a fascinating way. Rie Takahashi, Frank Pettit, and Jefrey Miller at UCLA created a program that created music from a DNA sequence (a gene) based on the protein that that gene encodes. The program transcribed and then translated a gene, producing a protein sequence. Each of the 20 main amino acids that you might find in a human protein was assigned to a specific three-note chord, so the last step of the program read the amino acid sequence of that protein to create a musical composition.

The huntingtin gene is the DNA sequence associated with Huntington disease, a very serious, inherited neurological disorder. Listen to the **audio file** of the huntingtin gene that was created with this program.

Everyone has this gene but some people unfortunately carry a variant (also known as an “allele”) that causes them to develop the symptoms of this disorder.

Case 4. The Sound of DNA.

Let's continue with our music analogy by reading a short gene, turning it into mRNA sequence (transcription), and then turning the mRNA sequence into a protein (translation), which will give us a song title. Tis will be a small protein, which is often referred to as a "peptide." There are many peptides that are important in biological systems. Some peptides are even used therapeutically as drugs or dietary substitutes. The artificial sweetener, aspartame, is a di-peptide consisting of aspartic acid (abbreviated "D" for short) and phenylalanine (abbreviated "F").

Here's the template strand of the gene: 3'-TACCTCGCAACAATGATC-5'

1. Each "letter" represents a DNA nucleotide. How many nucleotides are in this gene? _____

2. Perform the process of transcription on this gene, using the DNA sequence to build the complementary mRNA sequence (remember that RNA uses the nucleotide uracil paired with adenine instead of thymine):

5'_____3'

3. Each three-letter group is one codon. Starting with the AUG, how many codons are in this gene? _____

4. Now, perform the process of translation on this mRNA, using the mRNA sequence to construct the appropriate protein sequence using the genetic code (see Table 1, p. 2 above). This table shows amino acids using their 3- and 1-letter abbreviations, and which codons they are associated with. For this step, use the 1-letter abbreviation. If you do this correctly, you should get the title of a 2015 song from the British band Muse:

_____.

Next, you and a partner will choose different song titles (representing peptides), to create a complementary mRNA and then a DNA sequence – going in the reverse direction as above. You will then swap your DNA sequences, transcribe and translate them, and double-check that you get back the correctly spelled song title that your partner chose.

Here is a list of song titles that begin with the letter "M." One of you should pick a title from the left column and the other should pick one from the right column.

MACARENA	MANHATTAN
MADNESS	MASTERPIECE
MAGNIFICIENT	MIRACLES
MIGRAINE	MAGGIE
MERCENARY	MIDNIGHT
MACHETE	MACHINES
MAGNETIC	MAINSTREET
MANDINKA	MANEATER
MYSTIFY	MICHELLE

5. Using the genetic code, find a three-letter codon for each letter of your peptide song title. Write down each of these codons below (in order) to create an mRNA for your peptide. Keep in mind that for some letters/amino acids, there are multiple codons you can choose. That is okay; just choose one. Also, don't forget a stop codon at the end! Write this mRNA for your peptide song title here:

5'_____3'

6. Write the DNA sequence complementary to your mRNA here, and write it on the next page to give to your partner to complete. Notice that polarity (direction) of the mRNA is the opposite of the DNA sequence (they are antiparallel):

3’_____5’

Partner Sheet

7. Write the DNA sequence complementary to your mRNA here (the same DNA sequence written carefully from Question 6 and then give this page to your partner to complete.

3’_____5’

8. Transcribe and translate the DNA sequence/gene in the space above. Use the one-letter abbreviations for the protein sequence.

9. How many codons does this gene contain, including the stop codon? _____

10. How many nucleotides does this gene contain, including the stop codon? _____

11. Why did we choose song titles that begin with the letter “M”?

12. If you and your partner had chosen the same song title, could you have generated different DNA sequences? Why or why not?

Wrong Notes

Even the best musicians sometimes play a wrong note. And even the best enzymes sometimes make mistakes. We can think about mutations in the DNA as “wrong” notes, as we heard in the huntingtin example. Tis could be broadly applied to many other genes. If you play the music from a wild-type protein at the same time as a mutant protein, you would be able to hear the mutations—the places in the music where the notes don’t match. If you did this with the fully functional hemoglobin A allele and the sickle-cell anemia causing hemoglobin S allele, you would hear only one chord changed, but at a crucial spot.

13. Have your partner introduce a point mutation (a single nucleotide change) into the DNA sequence from your peptide song title. Transcribe and translate it below to see if you can determine what type of mutation (missense, frameshift, nonsense, or silent) and where it occurred. Does the song title stay the same or change?

References:

1. Carey J. Science and culture: musical genes // PNAS. 2016. 113(8): 1958–9. doi.org/10.1073/pnas.1601004113

2. Cold Spring Harbor Laboratory. n.d. Transcription and translation: RNA splicing. [Animation]. Running time: 1:37 min. https://www.dnalc.org/resources/3d/

3. Howard Hughes Medical Institute (HHMI) Biointeractive. n.d. DNA transcription (advanced detail). [Animation]. Running time: 1:55 min. URL: http://www.hhmi.org/biointeractive/dna-transcription-advanced-detail

4. Howard Hughes Medical Institute (HHMI) Biointeractive. n.d. Translation (advanced detail). [Animation]. Running time: 3:04 min. URL: http://www.hhmi.org/biointeractive/translation-advanced-detail

5. Biology, 7th edition by Campbell N.A., Reece J.B., Chapter 16 “The Molecular Basis of Inheritance”. Pp. 293–296, 299; Chapter 17 “From Gene to Protein”. Pp. 309–316, 320–324.

6. Takahashi R., Miller J.H. Conversion of amino-acid sequence in proteins to classical music: search for auditory patterns // Genome Biology. 2007. 8: 405. URL: https://genomebiology.biomedcentral.com/articles/10.1186/gb-2007-8-5-405

7. U.S. National Library of Medicine. 2018. Huntington disease // Genetics Home Reference. URL: https://ghr.nlm.nih.gov/condition/huntington-disease#genes

Case 5. Evolution. The silver fox domestication experiment

Today the domesticated foxes at an experimental farm near the Institute of Cytology and Genetics in Novosibirsk, Siberia are inherently as calm as any lapdog. What's more, they look eerily dog-like. All of this is the result of what is known as the silver fox, or farm fox, domestication study. It began with a Russian geneticist named Dmitri Belyaev.

Both as a result of his reading of Darwin's *The Variation of Animals and Plants Under Domestication* (Darwin 1868), and his interaction with domesticated animals, Belyaev knew that many domesticated species share a suite of characteristics including floppy ears, short, curly tails, juvenilized facial and body features, reduced stress hormone levels, mottled fur, and relatively long reproductive seasons. Today this suite of traits is known as the domestication syndrome. Belyaev found this perplexing. Our ancestors had domesticated species for a plethora of reasons – including transportation (e.g., horses), food (e.g., cattle) and protection (e.g., dogs) – yet regardless of what they were selected for, domesticated species, over time, begin to display traits in the domestication syndrome. Why?

Dr. Belyaev hypothesized that variation in tameness is linked to genes. If so, artificial selection during domestication should, therefore, change the frequency of tameness genes in a fox population over time.

Belyaev's Experiment:

Fox pups (called kits) from the population were scored for tameness and assigned to classes:

Class 3: flee or aggressive response to experimenter

Class 2: allow petting but no emotional response to experimenter

Class 1: friendly to experimenter (wag tail, whine, etc.)

Next, they bred the most friendly Class 1 foxes (Elite Class 1 = E1) over many generations.

The number of E1 foxes increased in frequency and showed significant increases in "dog-like" behavior (docile, eager to please, lick hands, compete for attention) in relatively few generations:

Generation	% 1E Kits
10	18
20	35
35	70-80

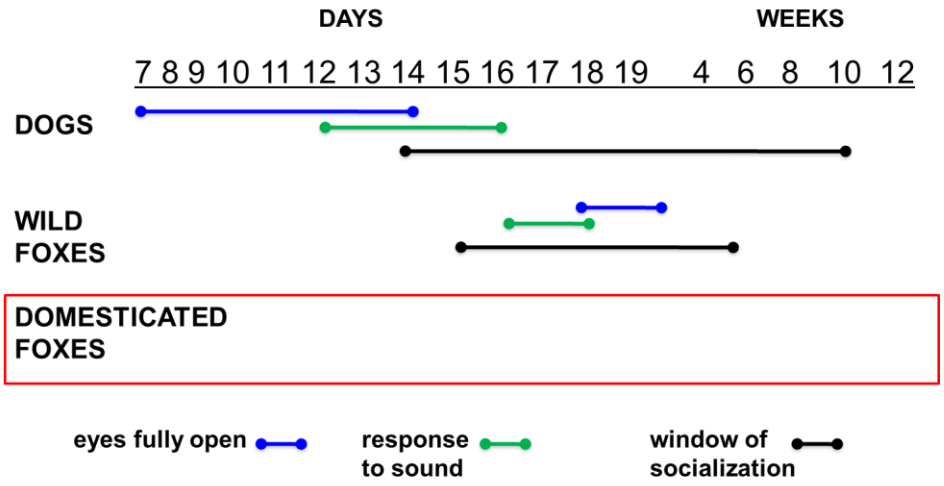
But, there were other changes as well:

Generation	Observations
2	decreased aggressive response
4	tail wagging, petting allowed
6	friendly kits follow and lick humans
9	floppy ears, piebald fur, forehead star appear
13	tail curls
15	shorter tail, fewer vertebrae

Over relatively few generations, the foxes displayed tremendous changes in behavior and appearance. They were starting to look and act like dogs! The researchers' data was showing how selection for a single characteristic was also related to a number of other unselected traits. They could see clear evidence of changes that could occur over the course of domestication.

Characteristic	Undomesticated Animals With Trait (per 100,000)	Domesticated Animals With Trait (Per 100,000)	Frequency Increase (%)
Star On Forehead	710	12,400	1,646
Mottled Fur Coloration	86	450	423
Floppy Ears	170	230	35
Shortened Tail	2	140	6,900
Curled Tail	830	9,400	1,033

In addition to appearance, other changes occurred. The time when different maturation events occur in dogs and foxes are show below. Complete the figure for when you think these events should occur in domesticated foxes.



Although the researchers observed specific changes, treating some kits differently could have changed their behaviors. That would mean tameness is learned, or at least influenced by environment, and not a heritable trait.

What experiment could the researchers do next to support their conclusion that artificial selection for tameness has produced an evolutionary change in the fox population? If tameness is genetically based, what would you predict would happen in a kit swapping experiment where an aggressive kit was given to a tame mother?

Darwin's Theory of Evolution by Natural Selection can be summarized with the simple acronym VISTA (Variation, Inheritance, Selection, Time, Adaptation). How does VISTA apply to the Farm-Fox case study?

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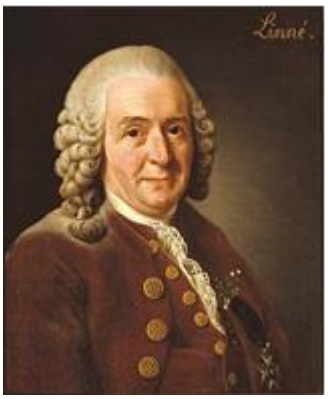
Case 6. Phylogeny and Systematics



Professor A. Smith has been invited to the meeting of young biologists and asked to present modern point of view to the classification of Carl Linnaeus. He agreed and began to prepare for his report with all responsibility. It is important to explain why the system of Linnaeus was a breakthrough for biology of 19th century and why categories of taxons are necessary till nowadays for understanding the place of each alive being in the system of living organisms. But Smith was sure that he should highlight development of current systematics which uses not only morphological and evolutionary approaches but phylogenetic methods based on principles of cladistics. Organizers of meeting know that our professor is an excellent choice as a speaker about such issues because he is a specialist of nomenclature and conduct molecular genetic surveys to reveal an evolutionary path of his objects.

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Case 7. Neither Plants, Nor Animals And Fungi: Place Them In The System Of Living Beings

Group of scientists studying biodiversity of the Ob’s basin collected 3 samples of unknown microorganisms.

Living organisms of the 1st sample were found on the moist soil surface. They are multirowed multicellular branching filament forming dark films. Microscopic investigation of the sample proved that its cells have no nuclei and plastids while chemical analysis revealed the content of chlorophyll a.

Organism of the 2nd sample was discovered on the trunk of a dead tree and formed the faintly remarkable reddish mucilage which had been changing its placement on the bark measurably while it was observed during several hours. Microscopy demonstrated that the mucilage was the multinuclear amoeba. Chlorophyll wasn't found in the chemical compound of this organism but scientists revealed enzymes decomposing wood that confirmed heterotrophic type of nutrition.

The 3rd sample was collected on the plant stem. The living being consists of snow-white coenocytic mycelium while part of it is embedded into the tissues of plant. Biciliate heterokont zoospores are releasing formations remindful oogonia.

Scientists need to identify taxons of these findings within modern considerations about the system of life and to argue why their features correspond to certain divisions and differ them from others groups.It is important to take into account that the volume of such kingdoms as Algae, Fungi and Animals was rethought.

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Case 8. Flowering Water «Dino»

After *Montsechia vidalii* had been discovered 150 years ago, hypothesis of origin of main groups of higher plants changed a lot. Earlier scientists refer this species to mosses, equisetums, ferns or gymnosperms erroneously on the basis of outer indicators and structure of tissues. However *M. vidalii* had no such vegetative organ as the root, anatomy of this fossil organism testify its concern to the most progressive group of land plants. It had shoots with certain phyllotaxy and morphology of leaves. Female generative organs on shoots greatly differed with reproductive organs of more primitive groups of higher plants. Professor Smith was asked to make a plenary report about *M. vidalii* at the International Symposium on Structural Botany. Finally, he will be able to explain popularly the anatomical and morphological differences between groups of higher plants and clearly prove why *M. vidalii* belongs specifically to angiosperms.

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Case 9. Invertebrate. The Big Riddle of a Small Insect

In the 18th century, the theory of embedding was popular. Some scientists believed that all future new generations are inside the body of the mother (nested in each other).

In 1779, Charles Bonnet gave an experimental proof of this theory. He took the newborn aphid and placed it in a jar isolated from males and other females. This young unfertilized female soon gave birth to other females. Charles Bonnet again isolated the newborn aphid and repeated it so many times. And each time, women produced a new generation of aphids. The theory, in the end, turned out to be erroneous, but the experiment was of great scientific importance in embryology. This experiment can be reproduced today by anyone. Is it possible to reproduce this experiment today?

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Case10. Vertebrate (Amphibia/Reptilia). Sensitive nature

The circulatory system of vertebrates, although it has a general structure plan, is still quite significantly different in representatives of different classes. Imagine that you have caught a frog and a lizard and decided to take a closer look at them. You turned both of them on their backs and began to study them from the abdominal side, and after a few minutes the frog froze and stopped moving (she fainted), and the lizard's behavior did not change. You turned the frog back and after a while it came to its senses again.

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Case11. Vertebrate (Aves). Alternative solution

Birds, like mammals, are warm-blooded animals. Just like mammals, birds have a very high metabolic rate. But here's an interesting fact: in mammals, nuclei in erythrocytes disappeared in the process of evolution, and why in birds the nuclei in erythrocytes remained as before?

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Case 12. Vertebrate (Mammalia)

There are a large number of mammalian species in the world (about 5500). They are all different and live in different conditions. There are very small ones – the tiny shrew *Sorex minutissimus* Zimmermann, 1780 (weighing 1.5 grams) and very large ones – the blue whale *Balaenoptera musculus (*Linnaeus, 1758) (weighing 150 tons). You were given the task of who would you take into space (in conditions of a limited supply of oxygen) two elephants weighing 6 tons or 2000 hares (weighing 6 tons)? Argument your answer.

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Case 13. El Ninõ broke the chain

Galapagos Islands host some of the world’s most vibrant biodiversity. Their ecosystem, which once inspired Charles Darwin to his great discovery, has been suffering more and more from global climate change in recent decades. In 1982–83 and 1997–98, complicated food chains of Galapagos were damaged by El Nino. Urchins reproduced a lot. Part try to discover of the coral reefs lost their algae and became lifeless. The population of endemic gannets has decreased by half, and some species of animals have become extinct. Scientists from all over the world try to discover how the decreasing of sea water temperature influences to trophic chains of Galapagos islands.

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Издание подготовлено в авторской редакции

Подписано в печать 24.11.2020 г.

Отпечатано на участке цифровой печати
Издательства Томского государственного университета
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Заказ № 4493 от «24» ноября 2020 г. Тираж 50 экз.