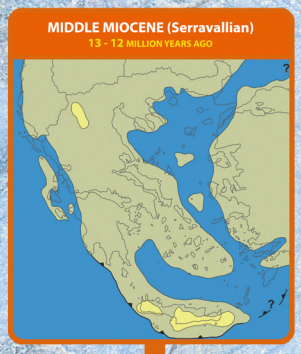


Natural History Museum of Crete

UNIVERSITY OF CRETE

MIDDLE MIOCENE (Serravallian)

UPPER MIOCENE (Tortonian)

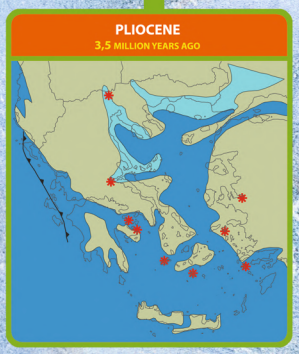
GUIDLINES
for the educator or parent

The Aegean Archipelago: an active evolutionary biology lab

EDUCATIONAL PACKAGE

UPPER MIOCENE (Messinian)

PLIOCENE



2022

Funded by the European Society of Evolutionary Biology (ESEB) Outreach Initiative Funds
https://eseb.org/

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Production: Natural History Museum of Crete-University of Crete (NHMC-UOC), Greece. 2022

CONTENTS

We would like to thank:

- **Ilias Maragakis**, Chief Operating Officer, and **Dionysis Ntampakis**, Wildlife Hazard Manager, Fraport Greece, for their help in making the introductory video on bird strikes in airports.
- **Dr George Iliopoulos**, Assoc. Professor, Department of Geology, University of Patras, for the check of the palaeontological data mentioned in the games.
- **Dr Ersen Yagmur**, Biologist, University of Celal Bayar, Turkey, for the provision of the photo of *Neocalchas gruberi* for the game "Aegean's Settlers".
- **Elias Strachinis**, Biologist, for the provision of the photographs of *Iurus dufoureius* and *Podarcis ionicus* for the game "Aegean's Settlers".

The Aegean Archipelago, an active evolutionary biology lab

Educational guide for teacher/parent

INTRODUCTION

(**: explanation of the words with a star can be found in the glossary*)

Evolutionary Biology* and research in Computational Phylogeny* are under-represented in Greek school and academic educational programs. In addition, Greece has an extremely high level of biodiversity* and endemism*, which are not sufficiently covered in the public-school curricula.

The aim of our educational materials, with the general title "The Aegean Archipelago *: an active evolutionary biology lab ", is to improve / expand the knowledge of young people on two pillars: a) the evolutionary processes that lead to unique biodiversity patterns* in the Aegean region and b) the important role of Computer Science* and Bioinformatics* in evolutionary research and, in general, in modern Biology.

A. Evolutionary processes create patterns of biodiversity

As a case study, for the first pillar, we use the Aegean Archipelago in the Eastern Mediterranean. The Mediterranean basin is hot spot of global biodiversity with thousands of continental islands*, most of which are in the Aegean Sea (over 27,000 islands and islets). With a complex geological history, significant species diversity and an extremely high rate of endemism, the Aegean Archipelago is one of the most interesting island ensembles for biodiversity studies and evolutionary studies, as it is a meeting place for species* of different geographical origin, being located at the crossroads of Europe, Asia and Africa.

In our educational package, the geological history and the evolutionary processes in the Aegean Archipelago are approached through the following two activities:

- Activity 1: "*Giants and dwarfs*"

board game that covers a timeline of 22 million years (Mya) and depicts major geological events in the Aegean archipelago. It combines these with emblematic species that used to inhabit the area and that are now extinct.

- Acivity 2: "*Aegean's settlers*"

A trump card game comprising the organisms that once lived and disappeared or are still living in the Aegean Archipelago, such as dwarf elephants, lizards, scorpions, beetles, and plants. Each card corresponds to a species and includes a photo of the species, information on its biology and ecology, its phylogenetic tree* showing depicting its evolutionary position and a palaeogeographical map* showing the geography of the Aegean when the species was differentiated.

The purpose of these two activities is to explain to the children that the land masses as we know them today, have not always been like this, and that life forms on Earth change over time. Our planet was formed approximately 4,5 Billion years ago and will continue existing for a long time to come, but life on it changes: species disappear, and other species emerge by taking their place. In general evolution happens in a perpetual cycle of speciation* and extinction* events.

B. The role of Computer Science* and Bioinformatics in evolutionary research*

In the second pillar we try to explain how DNA sequencing*, Evolutionary Biology*, Ecology, Computer Science* and Bioinformatics* interact to identify unknown DNA sequences and solve contemporary everyday problems. As an example, we use the following scenario:

“Imagine that a plane takes off from Thessaloniki airport and one engine is struck by a bird. The airport officials and the airport wildlife management team want to know what kind of bird species that was, to devise appropriate measures to drive this species away from the airport. Unfortunately, not much of the bird will be left in the engine for identifying it, hence we need to sequence its DNA and then place it into an existing phylogenetic tree of named bird species using the phylogenetic placement algorithm (EPA, https://academic.oup.com/sysbio/article/60/3/291/1667010), so we can estimate what species the genetic material found in the engine comes from”.

The web game “*Aerial Collisions*” was designed, based on this scenario. By playing this game, children try to guess to which bird the DNA sequence we’ve "read" from the blood or feathers found in the airline engine belongs to.

The children will learn while playing and will understand that research in the area of evolutionary Biology constitutes an interdisciplinary endeavor., Evolutionary research questions can thus only be addressed via the interdisciplinary research in the following scientific fields: Biology*, Geology*, Systematic*, Phylogeny*, Bioinformatics* etc.

All three games can be easily implemented and translated into other languages than Greek or English.

A more detailed description of the activities is provided on the following pages.

A. Evolutionary processes create patterns of biodiversity

- Board game “*Giants and dwarfs*”
- Card game “*Aegean’s settlers”*

B. The role of Computer Science* and Bioinformatics in evolutionary research*

- Web game "*Aerial Collisions*"

A. Evolutionary processes create patterns of biodiversity

BOARD GAME "GIANTS AND DWARFS"
CARD GAME "*AEGEAN'S SETTLERS*"

Short description

The board game "*Giants and Dwarfs*" covers a geological period that starts about 20 million years ago (mya) and ends in the present. It comprises the major geological events that have shaped life in the Aegean region and combines these with emblematic species of plants and animals that once inhabited the area but are now extinct. Thus, via the game, children learn about all these processes, which at first appear to be very difficult and specialized.

"*Aegean's Settlers*" is a card game about the evolutionary processes, which concern organisms that have lived and disappeared or are still living in the Aegean Archipelago, such as dwarf elephants, lizards, scorpions, beetles and plants.

Each card corresponds to a species and includes a photo of the species, information on its biology and ecology, its phylogenetic tree* depicting its evolutionary position and a palaeogeographical map* showing what the Aegean region looked like when the species was differentiated.

The aim of these games is to familiarize children with the concept of geological time, to make them realize that land masses, coastlines and sea borders change over time and that life on our planet changes in general; species disappear, yet others take their place and evolve in an eternal cycle of speciation* and extinction*.

Keywords

Aegean Archipelago, Palaeogeography*, geological time*, species extinction*, speciation*, phylogenetic tree*, phylogeny*, biological species*, paleontological species*

Target audience

schools, families

Age range

9-15 years

Context

The board game "*Giants and Dwarfs*" consists of: (in print and digital format):

- The board game as a poster (to be printed in A3 or A2 size)
- Science Cards with scientific questions (to print on both sides and cut)
- Art Cards with commands for actions (to print on both sides and cut)
- An A4 card with the answers to the questions of the Science and Art cards (to print on both sides)

The card game "*Aegean's Settlers*" consists of 29 cards (to print on both sides)

- 5 cards for Scorpions (S1-S5)
- 4 cards for the Coleoptera (Beetles) (C1-C4)
- 7 cards for the Elephants and Mammoths (E1-E7)
- 7 cards for the Lizards (L1-L7)
- 5 cards for the Plants (P1-P5)
- 1 card with guidelines on how to play the game

Both games are accompanied by an extensive glossary of concepts that also serves as a theory book.

Required time

- Preparation time: 1-2 teaching hours
- Time for playing and discussion: 1-4 teaching hours

Materials required

- Files for printing provided by NHMC-UoC
- 1 dice and 2-4 pieces/game figures (for the board game)
- Pencil, eraser, and a notebook (for the board game)

Authors' background:

Biologists Ph.D. with experience in museum education, Biologist M.Sc./Music educator, Geologist Ph.D. with experience in planning relevant educational activities, Agronomist.

Science learning elements:

Biology*, Geology*, Paleogeography*, Paleontology, Evolution*, Phylogeny*, Phylogeography*, Speciation*, Biodiversity, Fossils*

Connection with the Greek public-school curriculum:

The content of the game board "*Giants and Dwarfs*" is fully compatible with the Greek public-school curriculum, for the 3 last grades of primary school and the first 2 years of high school. Furthermore, it is fully compatible with the interdisciplinary curriculum of the course "Environmental Study", especially concerning environmental changes and how they affect organisms, as well as in the geographical history of Greece. Additionally, it refers to the content of the textbook "Exploring the natural world" of the 5th and 6th primary school grades. For the High school, it refers to Biology, specifically the chapter covering changes of the natural environment and to Geology-Geography regarding tectonic plates, geographical landscape, fossils, etc.

The content of the card game "*Aegean's Settlers*" relates to the school curriculum of the 5th and 6th grades of Primary School, as well as of all high school classes. Furthermore, it is fully compatible with the interdisciplinary curriculum of the Biology and Geology-Geography courses. More specifically, it is related to environmental changes and how they affect organisms, evolutionary processes through the study of genetic material, the diversity of organisms and how it emerges, the geographical history of Greece, geological evolution by tectonic events, geological time, etc.

Finally, both could also support the initiative "*Skills' Lab*" under the pillar: "*ENVIRONMENT*".

Learning objectives

- To understand a) the concept of change over time, in particular the concept of evolution at both geological and biological level, b) that animals and plants change over geological time, that is, some species go extinct and others emerge, evolve, and live, c) that these changes do not occur during the lifespan of a single animal or plant, but after many generations spanning a larger time frame and d) that, by calculating the genetic similarities among the DNA of different organisms, we can estimate their genetic relationships by computing phylogenetic trees*.
- To become familiar with approaching a scientific question, how to conduct research, to observe, to arrive at conclusions and solutions, etc., thereby acquiring a scientific way of thinking.

- To enhance cooperation, teamwork, development of critical thinking, socialization, environmental awareness, and sensitivity.
- To acquire advanced ways of thinking, such as analysis, synthesis, and comprehension of information.

The program is implemented in three phases as described below:

I. Preparation phase (before the games)

II. Playing the games

III. Discussion after the games

I. Preparation before the game (1-2 hours)

Exploring expectations and pre-existing knowledge

Provoke curiosity

The teacher tries to mobilize students' interest in various ways, such as through a short story. Examples of such stories are:

Book: "Who Was Charles Darwin?" May 19, 2005. By Deborah Hopkinson (Author), Who HQ (Author), Nancy Harrison (Illustrator). Publisher: Grosset & Dunlap. Pp. 112 (for 6-9 years old)

As a young boy, Charles Darwin hated school and was often scolded for conducting "useless" experiments. Yet his passion for the natural world was so strong that he suffered through terrible seasickness during his five-year voyage aboard The Beagle. Darwin collected new creatures from the coasts of Africa, South America, and the Galapagos Islands, and expanded his groundbreaking ideas that would change people's understanding of the natural world. About 100 illustrations and a clear, exciting text will make Darwin and his theory of evolution an exciting discovery for every young reader.

Book: "Darwin" April 6, 2009. By Alice B. McGinty (Author), Mary Azarian (Illustrator). Publisher HMH Books for Young. Pp. 48. (for 6-9 years old)

Filled with the fascinating words of Charles Darwin—designed as handwritten entries—this illustrated biography reveals the emergence of an important concept: the survival of the fittest. Two hundred years after his birth, 150 years after the publication of his book on the ORIGIN OF SPECIES, this thought-provoking, splendidly illustrated account invites us into the private thoughts, hopes and fears of a soul who forever changed the way we see the world.

Book: "Life on Earth: The Story of Evolution" Kindle Edition. By Steve Jenkins (Author). Publisher: Kindle Edition. Pp. 47. (for 8-12 years old)

There are millions of different kinds of plants and animals living on the earth and even more million kinds lived here in the past. Where did they all come from? Why have some become extinct, and others lived on? In this remarkable book for children, Steve Jenkins explores the fascinating history of life on earth and the awe-inspiring story of evolution, Charles Darwin's great contribution to modern science.

Book: "What Darwin Saw: The Journey That Changed the World". January 13, 2009. By Rosalyn Schanzer (Author). Publisher National Geographic Kids. Pp. 48. (for 10-14 years old)

In 1831 a 22-year-old naturalist named Charles Darwin stepped aboard the HMS Beagle as a traveling companion of an equally youthful sea captain called Robert FitzRoy. The Beagle's round-the-world surveying journey lasted five long years on the high seas. The young Darwin observed everything and proved himself an avid and detailed chronicler of daily events on the Beagle and onshore. What Darwin saw takes young readers back to the pages of his journals as they travel alongside Darwin and read his lively and awestruck words about the wonders of the world. We follow Darwin's voyage, by looking over his shoulder as he explores new lands,

asks questions about the natural world, and draws groundbreaking conclusions. We walk in his footsteps, collecting animals and fossils, experiencing earthquakes and volcanic eruptions, and meeting people of many cultures and languages. We examine his opinions on life in all its forms. We consider the thoughts of this remarkable scientist, who poured his observations and research into his expansive theories about life on Earth. In this exciting and educational account, Charles Darwin comes alive as an inspirational model for kids who think and question the world around them.

Book: "Charles Darwin and the Beagle Adventure (Historical Notebooks)" August 25, 2009. By A.J. Wood (Author), Clint Twist (Author), Various (Illustrator). Publisher Templar. Pp. 30. (for 8-12 years old)

Discover the plants, animals, and people Darwin encountered during his groundbreaking voyage aboard the BEAGLE. Packed with novelties, including extracts from Darwin's diary and later works, CHARLES DARWIN AND THE BEAGLE ADVENTURE takes readers on an eye-opening exploration of our globe and uncovers the path that led to the cornerstone of natural history: the theory of evolution.

Book: "Darwin and Evolution for Kids: His Life and Ideas with 21 Activities" October 1, 2003. By Kristan Lawson (Author). Publisher Chicago Review Press. Pp. 160. (for 9 years and up)

Darwin and Evolution for Kids traces the transformation of a privileged and somewhat scatterbrained youth into the great thinker who proposed the revolutionary theory of evolution. Through 21 hands-on activities, young scientists learn about Darwin's life and work and assess current evidence of evolution. Activities include going on a botanical treasure hunt, keeping field notes as a backyard naturalist, and tying knots for ship sails like those on the HMS Beagle. Children also learn how fossils come to be, trace genetic traits through their family trees, and discover if acquired traits are passed along to future generations. By encouraging children, parents, and teachers to define the differences between theories and beliefs, facts and opinions, Darwin and Evolution for Kids does not shy away from a theory that continues to spark heated public debate more than a century after it was first proposed.

Through the discussion, concepts and definitions emerge, as an extension of daily life issues, as well as connections with the various scientific fields that are approached by the board game become evident.

An indicative way to help students understand the concepts of change in space and time, and biodiversity as a result of this change, would be to start with questions concerning themselves such as:

- As you grow older, do you change clothes? What does this mean? (body size change over time)
- Are there people who look like you, relatives or not? (diversity within a species)
- Are all dogs the same? (species, subspecies, breed, variety, etc.)

Support or guidance available

For more info, please contact Dr Iasmi Stathi, Head of the NHMC-UOC Education Lab: iasmi@nhmc.uoc.gr

II. Playing the Games (1-2 hours for each game)

Board game "Giants and Dwarfs"

The game can be played by 2-4 players or teams of players. You will need a dice and game figures, as well as a notebook, a pencil, and an eraser for answering some of the "Art cards" questions.

The player/team that correctly answers an "Art Card" plays first. Alternatively, the first to start can be determined by chance or by the teacher.

When you see a pink or yellow footprint on the field you are at on the board game, draw the corresponding card: an "Art Card" for the pink footprint and a "Science Card" for the yellow footprint. When you see a spiral or an asterisk, look in the glossary for the image or word/phrase shown on the board game field, respectively.

There are no winners or losers in this game. By playing the game you travel through time, from the creation of the Aegean Sea until the present day and you meet organisms that once lived in the Aegean during the last 20 million years; some of them might have become extinct by now.

Cards game "Aegean' Settlers"

This game consists of 28 playing cards and 1 card with the rules of the game. Each playing card has a letter and a number, in the upper right corner, which correspond to one species group: (S1-S5 for Scorpions, C1-C4 for Coleoptera [Beetles], E1-E7 for Elephants and Mammoths, L1-L7 for Lizards, and P1-P5 for Plants). The game can be played by 2-5 players or teams of players. There are two ways to play the game: the "Trump Card" and the "Quartet".

TRUMP CARD

To start the game, shuffle the 28 cards and hand out an equal number of cards to each player!

The player to the left of the one who handed out the cards starts.

The player chooses one of the card categories and reads it out loudly. The categories are: Size (cm or m), food (Carnivorous > Omnivorous > Herbivorous > Autotroph), closest cousin (1-4 points) and when did the species first appear? (thousands or millions years ago/mya). Then, he/she compares it with the values of the other players! The player with the highest value wins the cards and chooses the next category! The winner is the one who gathers all cards at the end of the game!

In case of a tie: shuffle the playing cards and the winner of the next round will get them.

Hyper trumps' card "Supreme": the wooly mammoth *Mammuthus primigenius*. Hyper trumps card automatically wins against all cards under all categories, EXCEPT for the cards with the number 1 (i.e., S1, C1, E1, L1, P1).

Winner: the one who manages to collect all cards.

QUARTET

We distribute the cards in such a way that all players can see them.

The aim of the game is to create as many quartets as possible (set of 4 cards from the same organism's category).

The player to the left of the player who dealt the cards starts.

He/She asks a player for the card he/she needs to make a quartet.

If the player responds positively, he/she takes the card and keeps asking for cards from other players until someone says no. Then the player who said 'no' continues, asking for a card from another player of his/her choice.

Each time a player makes a quartet, he/he places it on the table.

End of game: when there are no more cards left.

Winner: the player with the most quartets.

ATTENTION: Don't forget to read the information that each card provides about its respective organism!!!

III. Discussion after the games (1-2 hours)

Summary/Feedback

At this point, each group reflects and discusses the issues that were raised during the games.

At the same time, the teacher can also ask the following questions:

- Why did we finally deal with the concept of change / evolution?
- How does the knowledge we have gained about the changes of organisms living on our planet apply to everyday life?
- Why did we play these games after all?

These questions will enable students to reflect on what they have learned, to connect the knowledge they have gained with their daily lives, to express themselves freely and finally to assess the utility of this knowledge.

The teacher should encourage all children to express their opinion.

Some thoughts are:

We learn about the planet's history/past, about its geo- and biodiversity, and finally we understand that we are not the most important and wisest species on Earth.

We revise misconceptions we may have about some animals/plants and gain a better understanding of life around us.

We transfer the concept of evolution/change to our daily lives.

We ask students to report behaviors of people that help them live a better life (e.g. cooperation, teamwork, communication, sociability, etc).

B. The role of Computer Science* and Bioinformatics in evolutionary research*

WEB GAME "*AERIAL COLLISIONS*"

Short description

With the web game " *Aerial Collisions"* children try to guess which bird could belong to the unknown DNA sequence of the blood or feathers found in the engine of an airplane, after a bird strike. This unknown DNA sequence was "read" by Molecular Biology scientists and subsequently analyzed by Bioinformatics researchers on a computer.

The aim of this web game is that children become familiar with the concept of DNA and the genetic code, by which the characteristics/morphology of each organism are determined. The more similar

the DNA of two organisms is, the more closely related they will be (in general, we know that there are exceptions). The affinity of organisms, which in the case of this game are different birds' species, is illustrated by the phylogenetic tree*. Thus, by comparing a portion of the DNA of the known birds of our phylogenetic tree with the corresponding part of the DNA found in the blood or feathers of the bird that was struck by the plane, we can estimate with good accuracy which bird species it could have been and then take appropriate measures to protect this bird species and move it away from the airport.

Keywords

Phylogenetic tree*, DNA sequence*, Bioinformatics, Ecology, Molecular Biology, Bird strikes

Target audience

schools, families

Age range

9-15 years old

Context

- Introductory video by Thessaloniki airport wildlife team member "*Bird strike: Resolving the problem with the cooperation of molecular biology, bioinformatics and ecology*"
- Video for teachers with theoretical info and guidelines for the web game "*Aerial Collisions*"
- The web game "*Aerial Collisions*"

Time required

- Preparation time: 1-2 teaching hours
- Time for playing and discussion: 1-4 teaching hours

Materials required

- Computer, tablet
- Internet connection

Authors' background

Computer Scientist Ph.D., Bioinformatics specialists Ph.D. and M.Sc., Biologists Ph.D. with experience in museum education, Biologist M.Sc./Music educator.

Science learning elements

Biology*, Phylogeny*, Mathematics, Informatics, Ecology, Biodiversity.

Connection with the Greek public-school curriculum

The web game "*Aerial Collisions*" is related to the Greek school curriculum of the 5th and 6th grade of Primary School, as well as all high school grades.

It is compatible with the Interdisciplinary Curriculum on Informatics and Computer Science (uses of computers in everyday life, impact of Information and Communication Technologies on science, environment, quality of life, programming languages, etc.), and of Biology (DNA, Transfer of Genetic Information, Inheritance, Genetic Diversity, Genetic Engineering, Biotechnology, Evolution of Species, etc.)

Finally, it supports the initiative "*Skills' Lab*" under the pillar: "*ENVIRONMENT*".

Learning objectives

- Students should understand: a) that by calculating the similarities between the genetic material, i.e. DNA, of different species we can calculate their evolutionary relationships through phylogenetic trees*, b) how DNA sequencing*, Molecular Biology*, Computer Science* and Bioinformatics* can help to identify unknown/anonymous DNA sequences (i.e., pieces of DNA for which we do not know to which sepcies they belong) and solve contemporary everyday problems, and c) that research in evolution is an interdisciplinary process that involves various scientific fields (Molecular Biology*, Systematic*, Phylogeny*, Ecology, Mathematics, Bioinformatics* etc.)
- Familiarize students with how to approach a scientific issue, how to conduct research, to observe, to arrive at conclusions and solutions, etc., thereby acquiring a scientific way of thinking.
- Enhance cooperation, teamwork, development of critical thinking, socialization, environmental awareness, and sensitivity.
- Cultivate complex forms of thinking, such as analysis, synthesis, and comprehension of information.

The program is implemented in three phases described below:

I. Preparation phase (before the games)

II. The web game

III. Discussion after the game

I. Preparation before the game (1-2 hours)

Exploring expectations and pre-existing knowledge

Provoke curiosity

An indicative way to help students understand the concept of biodiversity, which is the result of the expression of the genetic code* of each organism, would be to start with questions that concern themselves, such as:

- Are there people who look like you, relatives or not? (diversity within the species)
- Are all your close relatives the same as you or as each other? (diversity within the species)
- Are all dogs the same? (species, subspecies, breed, variety, etc.)

In all the above, the main cause is the difference in the genetic material, that is in the DNA, of the organisms.

The teacher then tries to mobilize students' interest and tries to help them understand the problem of bird strikes by watching the video "*Bird strike: Resolving the problem with the cooperation of molecular biology, bioinformatics and ecology*" (in Greek with English subtitles) here: https://www.youtube.com/watch?v=jXPf-nHdoxo, where the problem is introduced and an introduction to how the scienctific fields of Molecular Biology, Bioinformatics and Ecology can help solve real life problems is provided.

Prior to this, teachers may watch the introductory video here:

https://www.youtube.com/watch?v=B_GqEYCqfB8, to understand some basic theoretical concepts and how to play the game.

Support or guidance

For more information, you can contact Dr. Iasmi Stathi, Head of Education at NHMC-UoC, here: iasmi@nhmc.uoc.gr or Prof. Alexandros Stamatakis at Alexandros.Stamatakis@h-its.org

II. Playing the web game (1-2 hours)

To play the web game, follow the suggested steps on the web page https://cme.h-its.org/exelixis/eseb/public/en/core/title.html. The game depicts a phylogenetic tree* that describes the evolutionary relationships of birds around the world. A research team has discovered how these birds relate to each other, using the laboratory methods of Molecular Biology and the computational methods of Bioinformatics. In this tree, which is based on real data[1], you can see which birds are related to each other. If you click on the pictures, you can learn more about these birds. Also, if you drag the mouse over the photo of each bird, corresponding information will be displayed. You are then asked to conduct a bit of research to find out which bird belongs to the bird tissue sample from the plane, which was first sent to a molecular laboratory for reading the DNA. This yielded some DNA sequences[2] such as AT AATACTAGAG ~~~, which the Bioinformatics team then placed onto the tree (this is real phylogenetic placement data). By clicking on one of those sequences, a question mark will appear on the tree showing the location where this unknown sequence was placed by the computational methods (placement methods).

Then, observe the birds with which the unknown bird is related to in the tree. Thereafter, compare them with the 8 candidate birds shown in the pictures on the right.

Can you guess which of these could be the bird we are looking for? With your answer (i.e. by clicking on one of the 8 birds) you will also receive the relevant feedback, depending on whether it is correct or incorrect.

III. Discussion after the game

Summary-Feedback

At this stage, each team reflects and discusses the issues that were raised during the game. At the same time, the teacher can also ask the following questions in class:

- Why did we finally deal with the concept of genetic diversity and DNA sequences?

[1] Data source: https://www.science.org/doi/abs/10.1126/science.1253451

[2] After the DNA sequencing, we can imagine the DNA as a long word comprising the letters A, C, G and T. Below, is an example of a small part of the DNA of the brown pelican.

00000 GAAATTTAGTAGCGCAGTCCTGCGGCCGATAAGAGAAAGTAAACAAGTGAATTCGAGGAATATTAGTACACAG
TGGTCGCAAAGAGGAGACACAACGAGT
00100 AGTTGTGCAGTCTCCCCGAGGTTGACGTTGTCTCCACTCGGGCAGAAGGAGAGTGAGCCCCAACGGAAGGATG
ACATCGGCATGGCTACTCCAAAACATT

- How does the knowledge we acquired regarding the scientific fields of Molecular Biology, Ecology and Bioinformatics help us in our daily lives? You may sse the recent SARS-CoV-2 pandemic as an example.
- Apart from the problem of bird strikes on airplanes, do you know any other everyday problem that could be solved with the help of the above sciences?

The above questions will enable students to reflect on what they have learned, to connect the knowledge they have acquired with their daily lives, to express themselves freely and finally to assess the utility of the acquired knowledge.

The teacher should encourage all children to express their personal views.

Some thoughts are:

We review misconceptions we may have about some scientific issues and gain a better knowledge about life around us.

- We transfer the concepts of evolution and phylogeny into our own daily life.
- We ask students to report to us the skills and behaviors of people who help them live better. Some are: the use of technology, combinatorial thinking, scientific methodology, collaboration, teamwork, communication, sociability, etc.

EVALUATION

If you used a part or all the material of the educational package "*The Aegean Archipelago, an active evolutionary biology lab*", please send us feedback via the evaluation form that you will find here:

https://docs.google.com/forms/d/e/1FAIpQLSd8fH70m-rg61H5YIOpCdrcG9vdDffFM-gbQpE_avAl1BQKyA/viewform

Your comments will help us to improve the quality of the games and to better respond to the entire educational community.

Thank you in advance for your time.

LITERATURE-RESOURCES

Giokas S., 2000. Notes on Biogeography. Biology Dept., University of Crete, Heraklion, Crete, Greece. Pp. 89 (in Greek).

Duggen S., Hoernle K., van den Bogaard P. *et al.*, 2003. Deep roots of the Messinian salinity crisis. *Nature* 422, 602–606. https://doi.org/10.1038/nature01553.

Fassoulas Ch., 2018. The geodynamic and paleogeographic evolution of the Aegean in the tertiary and quaternary: A review. In: *Biogeography and Biodiversity of the Aegean*. In honour of Prof. Moysis Mylonas. (eds. S. Sfenthourakis, P. Pafilis, A. Parmakelis, N. Poulakakis & K. A Triantis), pp. 25-43, Nicosia: Cyprus, Broken Hill Publishers Ltd.

Krijgsman W., Capella W., Simon D., Hilgen F. J., Kouwenhoven T. J., Meijer P. Th., Sierro F. J., Tulbure M. A., van den Berg B. C.J., van der Schee M., Flecker R., 2018. The Gibraltar Corridor: Watergate of the Messinian Salinity Crisis. *Marine Geology*, 403 (1): 238-246. https://doi.org/10.1016/j.margeo.2018.06.008.

Lyras G., 2020. 3B. *The paleofauna of Greece-Fossils Vertebrates*. In: *Fauna of Greece-Biology and Management of Wild Fauna*. Editor Panayiotis Pafilis. Broken Hills Publishers Ltd. Pp. 59-103 (in Greek).

Poulos S., 2020. 3A. *The geological evolution of Greece*. In: *Fauna of Greece-Biology and Management of Wild Fauna*. Editor Panayiotis Pafilis. Broken Hills Publishers Ltd. Pp. 41-58 (in Greek).

Rouchy J.M., Caruso A., 2006. The Messinian salinity crisis in the Mediterranean basin: a reassessment of the data and an integrated scenario. *Sediment. Geol.:* 188–189, 35–67. https://doi.org/10.1016/j.sedgeo.2006.02.005.

Web pages

- https://en.wikipedia.org/wiki/
- www.stratigraphy.org
- http://www.herpetofauna.gr/
- Taxonomy-Systematics (in Greek) http://www.biology.uoc.gr/courses/BIO102_zoologia/For%20website/05%20Lecture.pdf
- Phylogenetic trees (in Greek) https://docplayer.gr/10436470-Fylogenetik-a-dentra.html
- Phylogenetic Analyses-Part 1 (in Greek) https://docplayer.gr/10548920-Meros-1-o-eisigitis-n-poylakakis.html
- Phylogenetic Analyses-Part 2 (in Greek) https://docplayer.gr/31000190-Meros-2-o-eisigitis-n-poylakakis.html
- Evolutionary Biology: Phylogeny (in Greek) https://docplayer.gr/32410629-Exeliktiki-oikologia-fylogenesi.html
- Evolution (in Greek) http://archive.eclass.uth.gr/eclass/modules/units/?course=SEYC109&id=3611
- CONVENTION ON BIOLOGICAL DIVERSITY. 5th NATIONAL REPORT of Greece https://www.cbd.int/doc/world/gr/gr-nr-05-en.pdf

ANNEX

PALEOGEOGRAPHIC MAPS - INTERNATIONAL CHRONOSTRATIGRAPHIC CHART

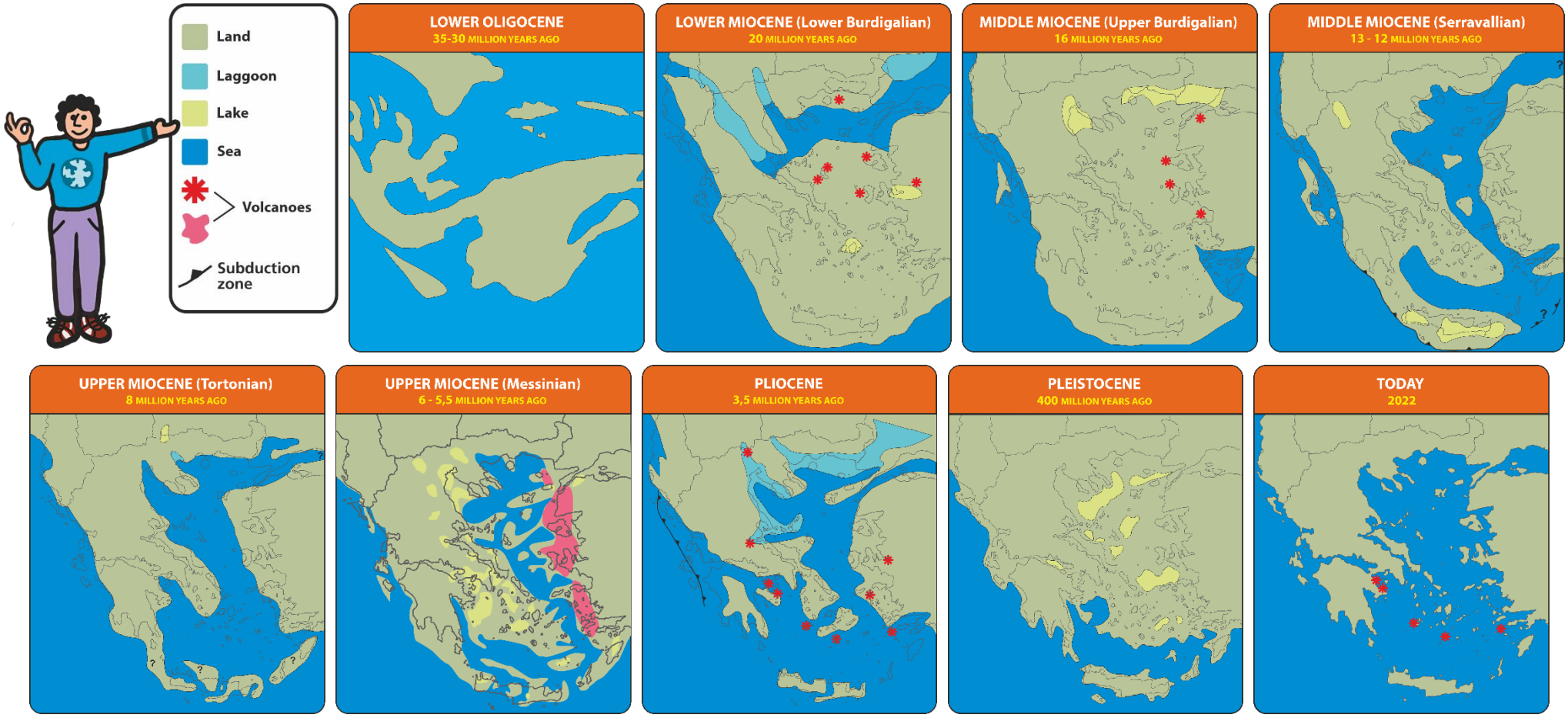
The games "*Giants and Dwarfs*" and "*Aegeans' Settlers*" refer to the geological time starting about 20 million years ago (mya) until the present.

The Aegean Archipelago was not always as we know it today. The following palaeogeographic maps, which are also used in the games, show us what the Aegean looked like during the corresponding geological periods. The following table provides the relevant geological time scale (from www.stratigraphy.org).

Geological time scale (from www.stratigraphy.org)

Erathem / Era	System / Period	Series / Epoch	Stage / Age	Numerical Age (Ma)
Cenozoic	Quaternary	Holocene	Meghalayan	0
			Northgrippian	0.0042
			Greenlandian	0.008276
		Pleistocene	Stage 4	0.0117
			Chibanian	0.129
			Calabrian	0.774
			Gelasian	1.8
	Neogene	Pliocene	Piacenzian	2.58
			Zanclean	3.6
		Miocene	Messinian	5.333
			Tortonian	7.246
			Serravallian	11.63
			Langhian	13.82
			Burdigalian	15.97
			Aquitanian	20.44
	Paleogene	Oligocene	Chattian	23.03
			Rupelian	27.82
		Eocene	Priabonian	33.9
			Bartonian	37.8
			Lutetian	41.2
			Ypresian	47.8

The paleogeographic maps used in the games



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Funded by the European Society of Evolutionary Biology (ESEB) Outreach Initiative Funds https://eseb.org/