INTERNATIONAL BIOLOGY OLYMPIAD e. V. IBO

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# PRACTICAL EXAM 1– PLANT ANATOMY, BIOSYSTEMATICS AND EVOLUTION

## INTRODUCTION

Max. total points 100
Exam duration 90 minutes
six questions

Land plants constitute a monophyletic lineage of Eucaryotes, that has been extremely successful in adapting to terrestrial habitats. Land plants structure terrestrial ecosystems physically and provide the framework for ecological interactions between all other land-living organisms. In this exam, we take a closer look at the evolution of the key characters, that led to the dominance of land plants on Earth.

Purpose of exam: Plant Identification , morphological description and reconstruction of ancestral relationships

The exam consists of five parts.

Identification of specimens (5 points)
Morphological description (36 points)
Morphological variation and character matrix coding (29 points)
Mapping character evolution on a phylogenetic tree (21 points)
Evolution of key characters in land plants (9 points)

We suggest you read the entire exam file before you begin the lab work.

## MATERIALS & EQUIPMENT

In order to do your lab work, you need the materials listed below. Please, ensure that these materials are available to you. **If anything is missing, contact the exam personnel by raising your pink card immediately – and no later than 15 minutes after the beginning of the exam. Please handle all the materials carefully as they will be used by all your teammates..**

5 Herbarium sheets (H1–H5). (Please note that the information included in the lables is not important for identifying the specimens to species). IMPORTANT: PLEASE DO NOT WRITE ON THE NEWSPAPER PAGES PROTECTING THE PLANTS - IF YOU DO IT WILL EXPEL YOU FROM THE EXAM.
5 Photos of live plants in nature (P1–P5)
2 Collections of live plants (F1–F2)
4 Alcohol-preserved collections of selected plant parts (A1–A4)
4 Anatomical sections mounted on microscope slides (M1–M4)

1 petri dish
1 forceps
1 teasing needle
1 click-on macro-lens for the tablet
1 touch pen for the tablet
1 microscope

Others
1 sheet with pictures of the included materials ,

## 1. IDENTIFICATION OF SPECIMENS (5 POINTS)

The materials (see above) belong to eight species of land plants, listed below in alphabetical and numbered order:

1 Allium ursinum (Wild garlic)
2 Equisetum arvense (Common horsetail)
3 Lycopodium annotinum (Bristly club-moss)
4 Pinus sylvestris (Scots pine)
5 Pisum sativum (Garden pea)
6 Polypodium vulgare (Fern)
7 Polytrichum commune (Common hair moss)
8 Selaginella kraussiana (African clubmoss)

These 8 species represent five major evolutionary lineages of land plants: Mosses (1 species), Lycophytes (2 species), Ferns and their allies (2 species), Gymnosperms (1 species) and Angiosperms (2 species). Notice that Selaginella kraussiana will be used throughout this exam as an exemplar species which signifies that some of the answers have already been provided

## Q. 1 Identification of specimens

**Identify each species on the five herbarium sheets as one of the eight species listed above.**

| | A.URS | E.ARV | L.ANN | P.SYL | P.SAT | P.VUL | P.COM | S.KRA |
|---|---|---|---|---|---|---|---|---|
| H1 | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ |
| H2 | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ |
| H3 | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ |
| H4 | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ |
| H5 | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ |

**Identify each species on the five photographs (P1-P5) as one of the eight species listed above.**

| | A.URS | E.ARV | L.ANN | P.SYL | P.SAT | P.VUL | P.COM | S.KRA |
|---|---|---|---|---|---|---|---|---|
| P1 | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ |
| P2 | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ |
| P3 | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ |
| P4 | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ |
| P5 | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ |

**Identify each species on the two live plants (F1-F2) as one of the eight species listed above.**

| | A.URS | E.ARV | L.ANN | P.SYL | P.SAT | P.VUL | P.COM | S.KRA |
|---|---|---|---|---|---|---|---|---|
| F1 | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ |
| F2 | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ |

**Identify each species on the four alcohol-preserved specimens (A1-A4) as one of the eight species listed above.**

| | A.URS | E.ARV | L.ANN | P.SYL | P.SAT | P.VUL | P.COM | S.KRA |
|---|---|---|---|---|---|---|---|---|
| A1 | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ |
| A2 | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ |
| A3 | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ |

| | A.URS | E.ARV | L.ANN | P.SYL | P.SAT | P.VUL | P.COM | S.KRA |
|---|---|---|---|---|---|---|---|---|
| A4 | | | | | | | | |

**Identify each species on the four anatomical sections (M1-M4) as one of the eight species listed above.**

| | A.URS | E.ARV | L.ANN | P.SYL | P.SAT | P.VUL | P.COM | S.KRA |
|---|---|---|---|---|---|---|---|---|
| M1 | | | | | | | | |
| M2 | | | | | | | | |
| M3 | | | | | | | | |
| M4 | | | | | | | | |

## 2. MORPHOLOGICAL DESCRIPTION (36 POINTS)

Locate the position of the nine morphological structures (listed below) on your materials and document your identification photographically (An example is shown in Fig. 2.1).

Morphological structure
Anther
Operculum
Sorus
Sporophyll
Microphyll
Sporangium
Sepal
Seed
Pollen grain

Protocol
1. Mount the click-on macro-lens for the tablet onto the camera lens of your tablet.
2. Choose one specimen from the materials, in which the relevant structure is represented.
3. Photograph plant specimen. Photograph only one specimen of each structure.
4. Indicate with an arrow on the photo the position of the structure (see Fig. 2.1 for an example).
5. Repeat this procedure (steps 2–5) for the remaining morphological structures.

Figure 2.1: Example of how to mark a structure with an arrow: Calyptra on Polytrichum commune (step 4 in the protocol above)

Each uploaded photo with an arrow placed at the correct structure earns you 3 points. An additional point is awarded for clarity of the photos. The structure should be, 1) fully represented, 2) fill up the picture frame and, 3) in focus.

Drag-and-drop the blue arrow. The arrow point has to be exactly at the structure in question.

Q. 2 Photos of 9 morphological structures (27 points) and clarity of structure (9 points)

**Anther photo – 3 points**



**Operculum photo – 3 points**

Sorus photo – 3 points



Sporophyll photo – 3 points

Microphyll photo – 3 points

Sporangium photo – 3 points

Sepal photo – 3 points

**Seed photo – 3 points**

**Pollen grain photo – 3 points**

**Additional Points due to "missing" pictures (Pictures that failed to upload without further attempt).**

## 3. MORPHOLOGICAL VARIATION AND CHARACTER MATRIX CODING (29 POINTS)

As a first step in the character analysis, we want you to describe the morphological variation across the following eight species in a way that will allow for mapping character evolution on a phylogenetic tree:

1 Allium ursinum
2 Equisetum arvense
3 Lycopodium annotinum
4 Pinus sylvestris
5 Pisum sativum
6 Polypodium vulgare
7 Polytrichum commune
8 Selaginella kraussiana

In Table 3.1. below you will find 9 morphological characters of key importance for the evolution of the Land Plants listed. Each character is broken down into two states. Notice that the assignment of character states implies an evolutionary direction, where '0' indicates the least derived (older) condition and '1' the derived (newer) condition:

Table 3.1. Definition of character states (0 or 1) for 9 characters.

| | State 0 | State 1 |
|---|---|---|
| Character 1 | Dominated by gametophyte phase | Dominated by sporophyte phase |
| Character 2 | Stem without roots | Stem with roots |
| Character 3 | Stem without vascular tissue | Stem with vascular tissue |
| Character 4 | Female gametophyte released from sporophyte | Female gametophyte retained on sporophyte |
| Character 5 | One sporangium per sporophyte | More than one sporangium per sporophyte |
| Character 6 | Sporophyll with either one sporangium or sporophyll absent. | Sporophyll with more than one sporangium |
| Character 7 | Homosporous, i.e. with only one kind of spore | Heterosporous, i.e. with megaspores and microspores |
| Character 8 | Male gametes motile | Male gametes not motile |
| Character 9 | Without double fertilization | With double fertilization |

## Q. 3 Character states for the eight study species (max 29 points)

**The next step in the character analysis is describing the morphological variation in a table called a character matrix.**
**The character matrix below is constructed to describe the variation of the 9 above-mentioned key characters across the eight species, that we focus on in this exercise.**

**Code the matrix by filling out the empty cells. For any given combination of a species and a character assign either the state '0' or the state '1' to the cell. We have already coded Selaginella kraussiana and additional 5 cells for you in fig 3.1**
**By tapping in a cell, you choose a state (1 or 0). First tap gives you '1', second tap gives you '0', and third tap deletes the content of the cell. NB: Please, be patient - a short delay when shifting between states may occur!**

**0–29 correct cell values earn you no points, wrong or no value give 0 point**
**Every correct cell value > 29 correct cells earns you 1 point. Max. 29 points for 58 correct cell values.**

1 = 1

0 = 0

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| Allium ursinum | | | | | | | | | |
| Equisetum arvense | | | | | | | | | |
| Lycopodium annotinum | | | | | | | | | |
| Pinus sylvestris | | | | | | | | | |
| Pisum sativum | | | | | | | | | |
| Polypodium vulgare | | | | | | | | | |
| Polytrichum commune | | | | | | | | | |
| Selaginella kraussiana | | | | | | | | | |

Character number:

| Plants: | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| *Allium ursinum* | | | | | | 1 | | | |
| *Equisetum arvense* | | | | | | 1 | | | |
| *Lycopodium annotinum* | | | | | | | | | |
| *Pinus sylvestris* | | | | | | 1 | | 1 | |
| *Pisum sativum* | | | | | | 1 | | | |
| *Polypodium vulgare* | | | | | | | | | |
| *Polytrichum commune* | | | | | | | | | |
| *Selaginella kraussiana* | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 0 |

Figure 3.1: Cell values provided to Question 4.

## 4. MAPPING CHARACTER EVOLUTION ON A PHYLOGENETIC TREE (21 POINTS)

A phylogenetic tree is a hypothesis about the ancestral relationships among a set of study organisms (Fig. 4.1).

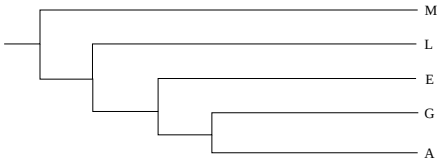



Figure 4.1: A phylogenetic tree showing the hypothetical relationships among the five major lineages of land plants. G = Gymnosperms; L = Lycophytes; A = Angiosperms; M = Mosses; E = Ferns and their allies (Monilophytes).

In this next step, we map character evolution on a given phylogenetic tree such as the one shown in Fig. 4.2. The tree represents a worldwide consensus between different hypotheses about the evolution of land plants.

We will use a character mapping procedure called deleted transformation (DELTRAN). Proceed according to the following protocol:

1. Characters are only allowed to change forward from '0' to '1'.
2. Minimize the number of times that a character changes on the tree (principle of parsimony)
3. If it is impossible to restrict a change in a given character to just a single branch, then let the character change more than once (parallel evolution).
4. Indicate on the tree on which branch a given character changes state. Notice that changes of characters evolving in parallel (= changing state several times) is indicated with two vertical bars (||), whereas a unique character state change ( = changing a single time) is indicated with a single vertical bar (|). Finally, indicate the number of the character that changes its state from 0 to 1 such as shown on the tree below.

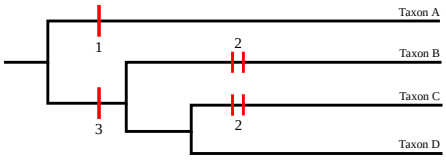
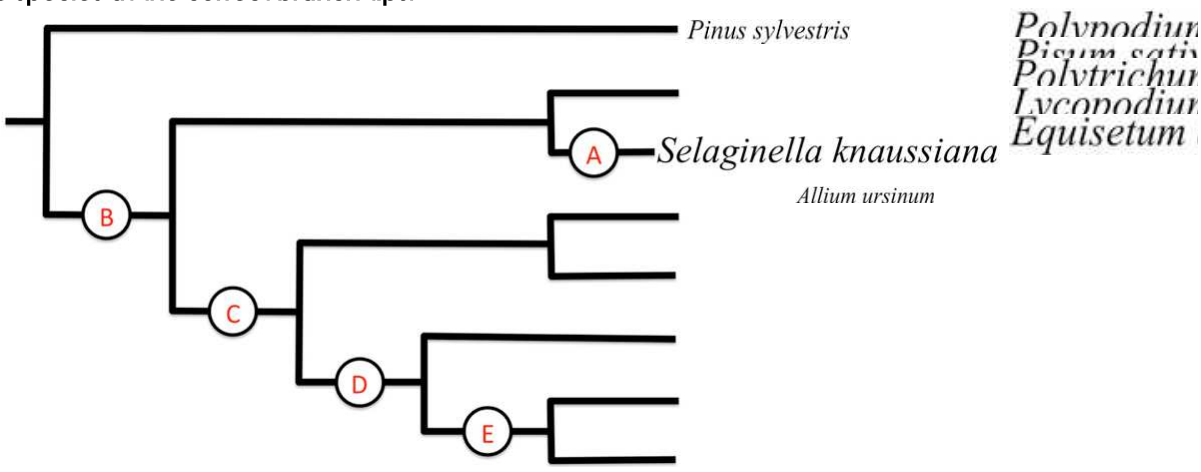



Figure 4.2: A hypothetical phylogeny of four taxa A–D.

Q. 4 Phylogenetical relationships of the eight study species (21 points)

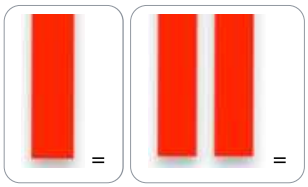
**Place the species at the correct branch tips.**



Q. 5

**In the table below you find the branches A-E of the phylogeny above in the rows and the key characters 1-9 in the columns. By tapping on the cells you indicate on which branches the character state changes occur, according to the DELTRAN principle described above. One tap gives you a unique character change, two taps a parallel character change. A third tap will delete the content of the cell. Notice that the character state changes may be unevenly distributed over the phylogenetic tree and consequently some cells will have to be left empty.**

**0-15 correct cells give you 0 point.**
**16-40 correct cells give you 8 points**
**41–45 correct cells give you 16 points**



| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| Branch A | | | | | | | | | |
| Branch B | | | | | | | | | |
| Branch C | | | | | | | | | |
| Branch D | | | | | | | | | |
| Branch E | | | | | | | | | |

## 5. EVOLUTION OF KEY CHARACTERS IN LAND PLANTS (9 POINTS)

Based on reconstruction of character evolution similar to what you have just been through, botanists discuss the drivers of early land plant evolution. Two hypotheses are widely accepted:

Hypothesis H1: Early evolution in land plants reflects an increasing independence of water for completion of reproduction

Hypothesis H2: Evolution in land plants reflects an increasing ecophysiological ability to cope with dessication.

Notice that the hypotheses are not necessarily mutually exclusive

Q. 6 Choice of evolutionary hypotheses (max. 9 points)

**Based on part 4, indicate below for each character state change, whether this supports H1, H2, both or none.**
**Each correct answer in a cell earns you 1 point.**

| ✓ = Support | — = No support |
|---|---|

| | H1 | H2 |
|---|---|---|
| Change in character 1 | | |
| Change in character 2 | | |
| Change in character 3 | | |
| Change in character 4 | | |
| Change in character 5 | | |
| Change in character 6 | | |
| Change in character 7 | | |
| Change in character 8 | | |
| Change in character 9 | | |

END