Formal learning in botanic gardens:

From communicating knowledge on plants to promoting scientific literacy

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BRINGING NATURE TO THE CITY

My background

- Research: evolution, biogeography and taxonomy of umbellifers (Apiaceae)
- University teaching: general and systematic botany, taxonomy, evolution
- Involvement in secondary education:
  - co-authorship of the national biology curriculum (ISCED 2 & 3) and biology textbooks for secondary schools
  - development of ISCED 2 & 3 examination tests for the Central Examination Commission (Poland)
  - educational research

Issues

- Decline of formal education in botanic gardens
- How to counteract it? A short primer
- Scientific literacy: towards an universal science curriculum

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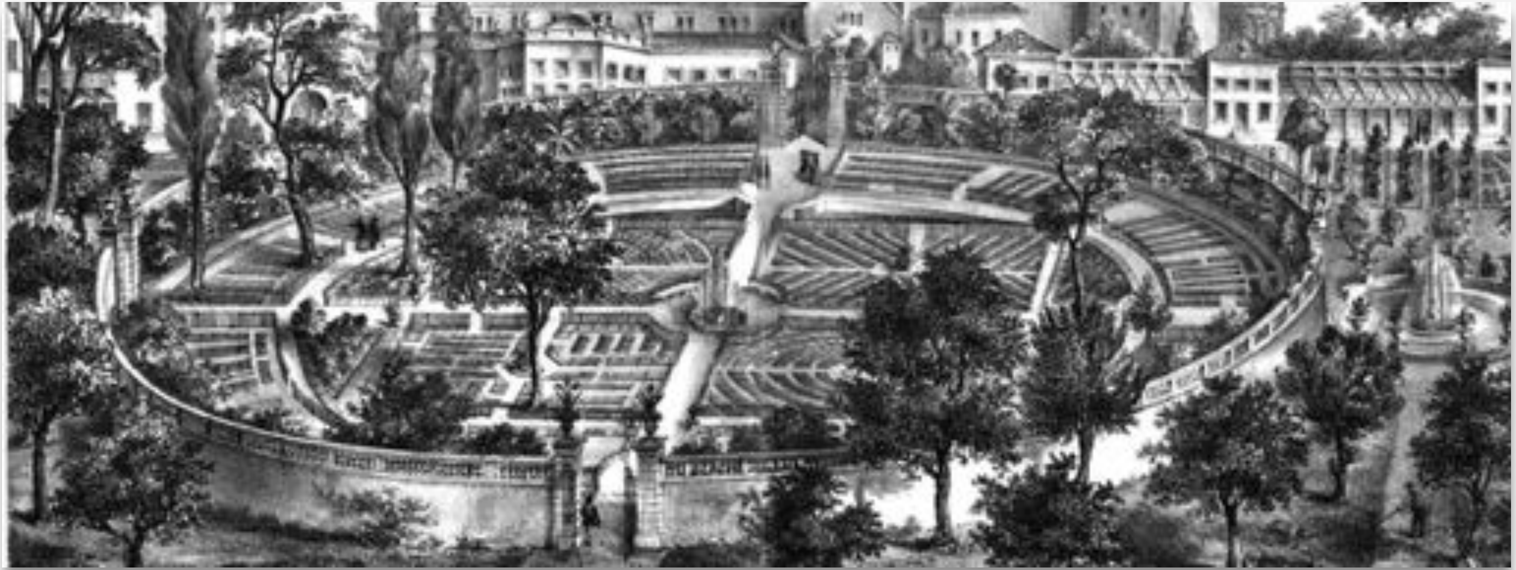

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Orto botanico di Padova (1545): the mother of all botanic gardens

First botanical gardens were physic gardens, where students of medicine learned to distinguish healing plants from false ones. Knowledge on medicinal plants was passed between generations.

Demise of pharmaceutical botany at universities

1853: chemical synthesis of aspirin

1928: discovery of penicillin

Pharmaceutical botany is no longer taught at medical studies.

Students of pharmacy have 60 hours of classes in botany including only a few hours in botanic garden.

Conclusion: botanic gardens are no longer necessary for teaching medicine and pharmacy.

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Hortus Upsaliensis: in search of order

Carolus Linnaeus reorganized the botanic garden in Uppsala. Since the 18th century botanic gardens have become centres of biodiversity research and teaching plant systematics.

Teaching general and systematic botany

Gradual decrease in the length of Botany course at the University of Warsaw

- 1950s: 240 hours
- 1970s: 180 hours
- 2010s: 90 hours

The course includes only four hours of classes in the botanic garden.

Conclusion: extensive systematic collections are no longer necessary for teaching botany at the university.

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Are garden collections useful for ANYTHING?

Many plants in botanic gardens:

- are not used in teaching for various reasons; for instance, plants are flowering and fruiting during summer holidays or respective courses were dropped from the curriculum
- are not used in scientific research because they are of unknown origin or are hybrids or are misidentified
- do not represent any value for conservation (are not rare, vulnerable or endangered species)
- are not ornamental, medicinal or do not have any other appeal to the general public

They are useless.

Of critical concern will be ensuring that the garden is delivering to the home unit what it expects from its investment in the garden.

Peter J. Olin (1995) Funding Botanic Gardens and Arboreta in the 21st Century

Botanical gardens' involvement in formal education is crucial for their existence as university units

Approaching formal education

- Read the curricula and programmes and check respective textbooks
- Find content/instructions/learning goals/requirements/desired students' outcomes that are related to plants, ecology, conservation, evolution, environment, agriculture etc.
- Think about students' **activities** in the garden rather than guided tours
- Adjust the collections to facilitate teaching
- Prepare teaching materials/instructions
- Contact teachers and show them the possibilities
- Do not expect immediate success

Recognising native conifers

Polish National Curriculum (ISCED-2)

- Learner is able to:
  - recognise the conifers native to Poland
  - describe the features of gymnosperms in Scots pine
  - use a simple dichotomic identification key

Approach

- Do we have all native conifers in the garden? Are they easily accessible? Should we plant new ones in one place? Where?
- Do we have trees producing cones? Should we assemble a cone collection?
- What teaching materials do we need?

How to attract geneticists to the garden?

Mendel’s peas

Gregor Mendel experimented on garden pea (*Pisum sativum*) and discovered his two **laws of genetics**

de Vries’ evening primrose

Hugo de Vries developed the concept of **mutation** based on his observations on variation of the evening primrose (*Oenothera lamarckiana*)

McClintock’s maize

Barbara McClintock discovered genetic **transposition** in maize *(Zea mays)* and demonstrated that genes turn physical characteristics on and off

Morning glories (*Ipomea purpurea, Ipomea nil*)

Transposable genetic elements in the species of morning glory turn off and on genes responsible for flower colour and structure resulting in variegated corolla or developmental abnormalities like additional corolla

By Dean Wiles - Flickr: Viridifolia Green Rose, CC BY-SA 2.0,
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Developmental biology in the botanic garden

Many garden varieties owe their ornamental value to homeotic mutations changing the identity of plant organs. Wild French rose has five petals while double-flowered garden varieties have some stamens transformed into petals. Chinese rose ‘Viridiflora’ has all petals changed into sepals. Peloric mutation in *Streptocarpus* reverts if floral symmetry from zygomorphic to actinomorphic.

Widening the target group beyond plant sciences

Some aspects of botanical knowledge may be useful for the students of ethnology, literature, the history of art and culture etc.

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Garden of historic roses

Roses painted by Flemish or Dutch masters included varieties of French or Gallica rose (*Rosa gallica*), Damask rose (*R.* x *damascena*), Provence or cabbage rose (*R.* x *centifolia*), white rose (*R. alba*) and Persian rose (*R. foetida* ‘Persiana’). In the 19th century most were replaced by modern tea hybrid roses.

Apollo and Hyacinthus

Hyacinthus orientalis

Iris pumila

Botany in classical education

According to a Greek myth, hyacinths had grown from the blood of Hyacinthus, a boy accidentally killed by the god Apollo. In fact, the myth refers to the dwarf iris (*Iris pumila* or *I. attica*).




What do we want to achieve?

Goals for primary, secondary and tertiary formal education are different

Do we expect students to remember the facts about plants? What is more important: factual knowledge or the knowledge on how science works? How about values and emotions? Is there an universal curriculum for science education?

Programme for International Student Assessment (PISA)

- Worldwide study by the Organisation for Economic Co-operation and Development (OECD) intended to evaluate educational systems by assessing 15-year-old students performance on mathematics, science, and reading.
- In 2015, ca. 540,000 students from 72 countries participated in the study.
- PISA is the best available educational system benchmark.

Box 2.2 **The 2015 definition of scientific literacy**

Scientific literacy is the ability to engage with science-related issues, and with the ideas of science, as a reflective citizen.

A scientifically literate person is willing to engage in reasoned discourse about science and technology, which requires the competencies to:

- **Explain phenomena scientifically** – recognise, offer and evaluate explanations for a range of natural and technological phenomena.
- **Evaluate and design scientific enquiry** – describe and appraise scientific investigations and propose ways of addressing questions scientifically.
- **Interpret data and evidence scientifically** – analyse and evaluate data, claims and arguments in a variety of representations and draw appropriate scientific conclusions.

PISA 2015 Assessment and Analytical Framework

'The use of the term "scientific literacy", rather than "science", underscores the importance that the PISA science assessment places on the application of scientific knowledge in the context real-life situations'

OECD (2017), *PISA 2015 Assessment and Analytical Framework: Science, Reading, Mathematic, Financial Literacy and Collaborative Problem Solving, revised edition*, PISA, OECD Publishing, Paris.
http://dx.doi.org/10.1787/9789264281820-en

Living systems that require knowledge of:

- Cells (e.g. structures and function, DNA, plant and animal)
- The concept of an organism (e.g. unicellular and multicellular)
- Humans (e.g. health, nutrition, subsystems such as digestion, respiration, circulation, excretion, reproduction and their relationship)
- Populations (e.g. species, evolution, biodiversity, genetic variation)
- Ecosystems (e.g. food chains, matter and energy flow)
- Biosphere (e.g. ecosystem services, sustainability)

Knowledge of the content of science is not enough

Scientific literacy also includes **procedural knowledge** (empirical enquiry: collection analysis and interpretation of scientific data) and **epistemic knowledge** (understanding the constructs and features of science)

OECD (2017), *PISA 2015 Assessment and Analytical Framework: Science, Reading, Mathematic, Financial Literacy and Collaborative Problem Solving, revised edition*, PISA, OECD Publishing, Paris.
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Figure 2.6 ▪ **PISA 2015 procedural knowledge**

Procedural knowledge
▪ The concept of variables, including dependent, independent and control variables.
▪ Concepts of measurement, e.g. quantitative (measurements), qualitative (observations), the use of a scale, categorical and continuous variables.
▪ Ways of assessing and minimising uncertainty, such as repeating and averaging measurements.
▪ Mechanisms to ensure the replicability (closeness of agreement between repeated measures of the same quantity) and accuracy of data (the closeness of agreement between a measured quantity and a true value of the measure).
▪ Common ways of abstracting and representing data using tables, graphs and charts, and using them appropriately.
▪ The control-of-variables strategy and its role in experimental design or the use of randomised controlled trials to avoid confounded findings and identify possible causal mechanisms.
▪ The nature of an appropriate design for a given scientific question, e.g. experimental, field-based or pattern-seeking.

Concepts of evidence

'It is this knowledge of the concepts and procedures that are essential for scientific enquiry that underpins the collection, analysis and interpretation of scientific data.'

OECD (2017), *PISA 2015 Assessment and Analytical Framework: Science, Reading, Mathematic, Financial Literacy and Collaborative Problem Solving, revised edition*, PISA, OECD Publishing, Paris.
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Figure 2.7 ■ **PISA 2015 epistemic knowledge**

Epistemic knowledge
The constructs and defining features of science. That is: ▪ The nature of scientific observations, facts, hypotheses, models and theories. ▪ The purpose and goals of science (to produce explanations of the natural world) as distinguished from technology (to produce an optimal solution to human need), and what constitutes a scientific or technological question and appropriate data. ▪ The values of science, e.g. a commitment to publication, objectivity and the elimination of bias. ▪ The nature of reasoning used in science, e.g. deductive, inductive, inference to the best explanation (abductive), analogical, and model-based. The role of these constructs and features in justifying the knowledge produced by science. That is: ▪ How scientific claims are supported by data and reasoning in science. ▪ The function of different forms of empirical enquiry in establishing knowledge, their goal (to test explanatory hypotheses or identify patterns) and their design (observation, controlled experiments, correlational studies). ▪ How measurement error affects the degree of confidence in scientific knowledge. ▪ The use and role of physical, system and abstract models and their limits. ▪ The role of collaboration and critique, and how peer review helps to establish confidence in scientific claims. ▪ The role of scientific knowledge, along with other forms of knowledge, in identifying and addressing societal and technological issues.

Constructs and defining features of science

'Epistemic knowledge provides the foundation for the basis of belief in the claims that science makes about the natural world.'

OECD (2017), *PISA 2015 Assessment and Analytical Framework: Science, Reading, Mathematic, Financial Literacy and Collaborative Problem Solving, revised edition*, PISA, OECD Publishing, Paris.
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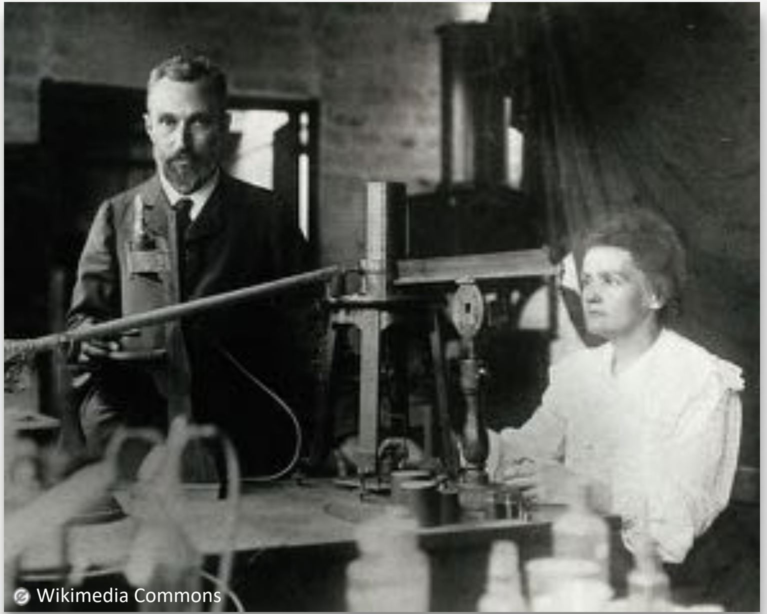
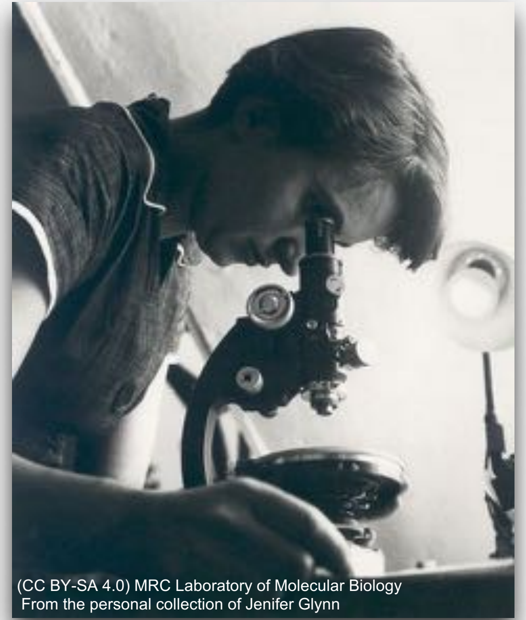


Pierre and Marie Curie



Rosalind Franklin

Louis Pasteur

Building trust in science

Science makes true claims not because the scientists are trustworthy but because they do not trust each other. Each scientific claim becomes a hypothesis. If it cannot be rejected based on evidence, it is accepted.

Science and culture

The specimen of the Mediterranean dwarf palm (*Chamaerops humilis*) in the Botanical Garden of the University of Padua was planted in 1585. German poet, writer and plant morphologist Johann Wolfgang Goethe, after observing it in 1786, described this plant in his "Essay on the Metamorphosis of Plants”. Since then, It has been known as ‘Goethe’s Palm’.

Let it grow!