Cephalopods as model organisms: historical and theoretical reflections

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“We must apply the achievements of experimental physiology to the inquiry of the function of marine animals, if we want to avoid that important insights remain inaccessible, and indispensable instruments unused.”

Anton Dohrn, 1876

Cephalopods as model organisms: historical and theoretical reflections

1. What are model organisms?
2. The role of marine biology stations
3. Can a cephalopod be a model organism?

Biology ≠ Physics

evolution, biodiversity, individuality

typical “biological” dialectics between:

individuality ⟺ uniformity

variability ⟺ universal laws

concrete manifestations ⟺ common data

⟺ $E = mc^2$

Biology ≠ Physics

therefore, instead of laws and theories we have:

concepts, metaphors, models,
and
model organisms

model organisms

… are means as well as sources of knowledge

R.A. Ankeny & S. Leonelli (2011) 313:

"… are a specific subgroup of organisms that have been standardized to fit an integrative and comparative mode of research, … that … must be clearly distinguished from the broader class of *experimental organisms*."

model organisms

R.A. Ankeny & S. Leonelli (2011) 313:

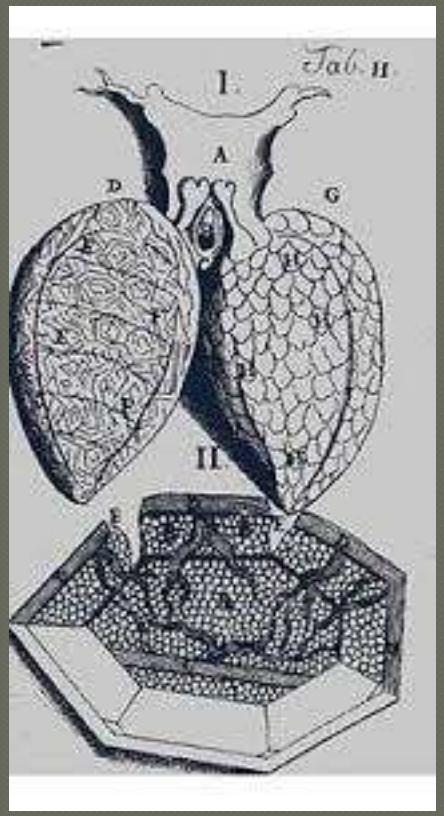
"In the most general terms, model organisms are non-human species that are extensively studied in order to understand a range of biological phenomena, with the hope that data and theories generated through use of the model will be applicable to other organisms, particularly those that are in some way more complex than the original model."

Marcello Malpighi
(1628-1694)

“Nature’s microscope”

To investigate structures and functions where they are bigger or more simple

(not only for comparative reasons)



Frog’s lung

model organisms

The NIH list 13 species as "Model Organisms for Biomedical Research":

- **2 mammals (mouse, rat)**
- **3 other vertebrates (zebrafish, *Gallus*, *Xenpous*)**
- **1 insect (*Drosophila mel.*)**
- **1 crustacean (*Daphnia*)**
- **1 nematode (*Caenorhabditis elegans*)**
- **2 yeasts (*Saccharomyces cerevisiae*, *S. pombe*)**
- **2 other microorg. (*Neurospora*, *Dyctiostelium disc.*)**
- **1 plant (*Arabidopsis*)**

http://www.nih.gov/science/models/

model organisms

- **cheap, easy to gather, high reproduction rate;**
- **easy to breed and maintain in good quantity in labs;**
- **easy to be experimentally manipulated;**
- **show particular experimental characteristics, e.g. appropriate size or anatomical arrangement, in relation to the specific process studied;**
- **results obtained are generalizable, or at least projectable onto a wider group of organisms;**
- **are the product of a complex standardization process and a good working 'model organism community'.**

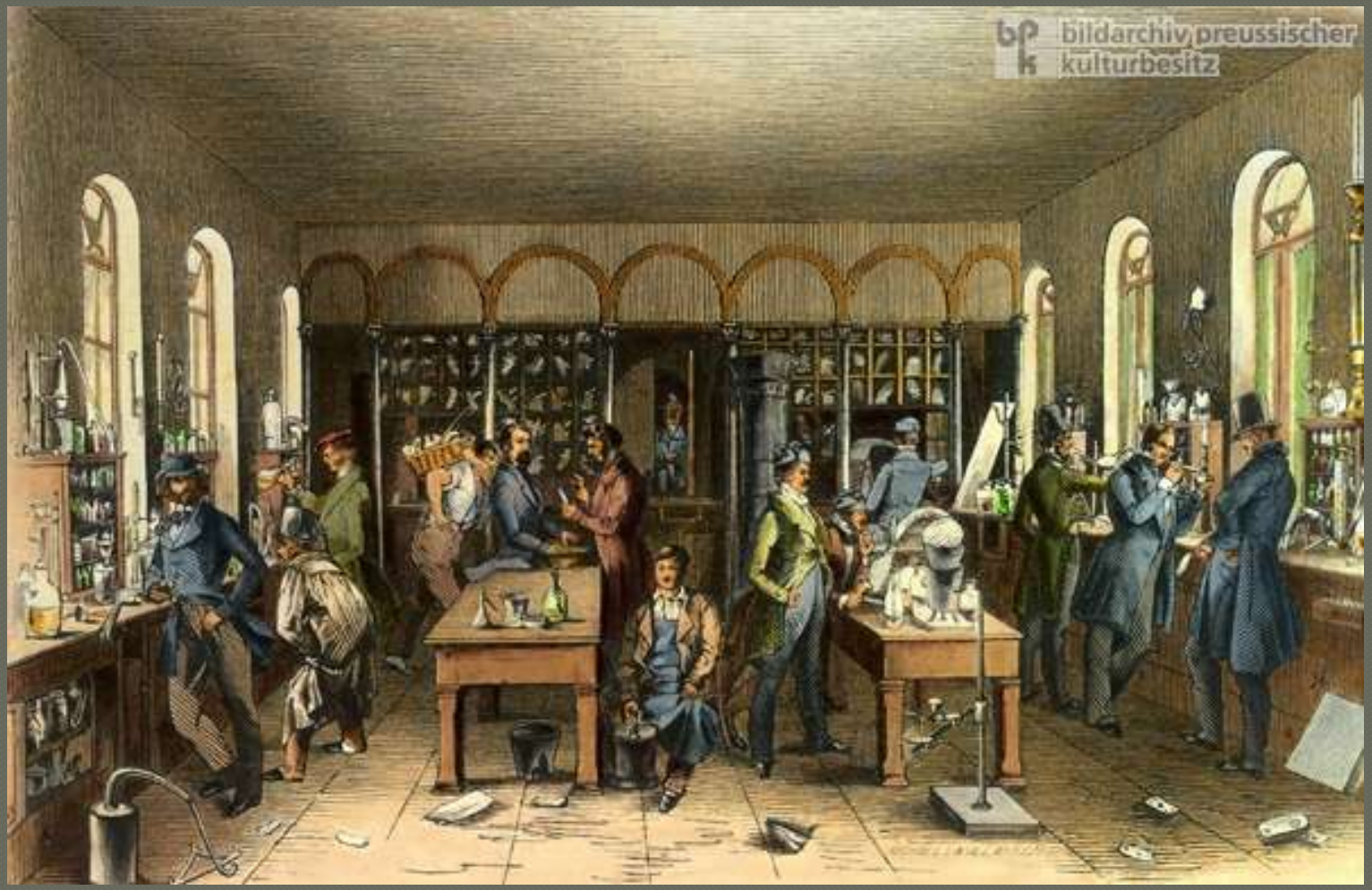
= practical, biological, experimental, epistemic and social criteria, largely shaped by tradition of genetic analysis

2. The role of marine biology stations

a. new institutions
b. new objects

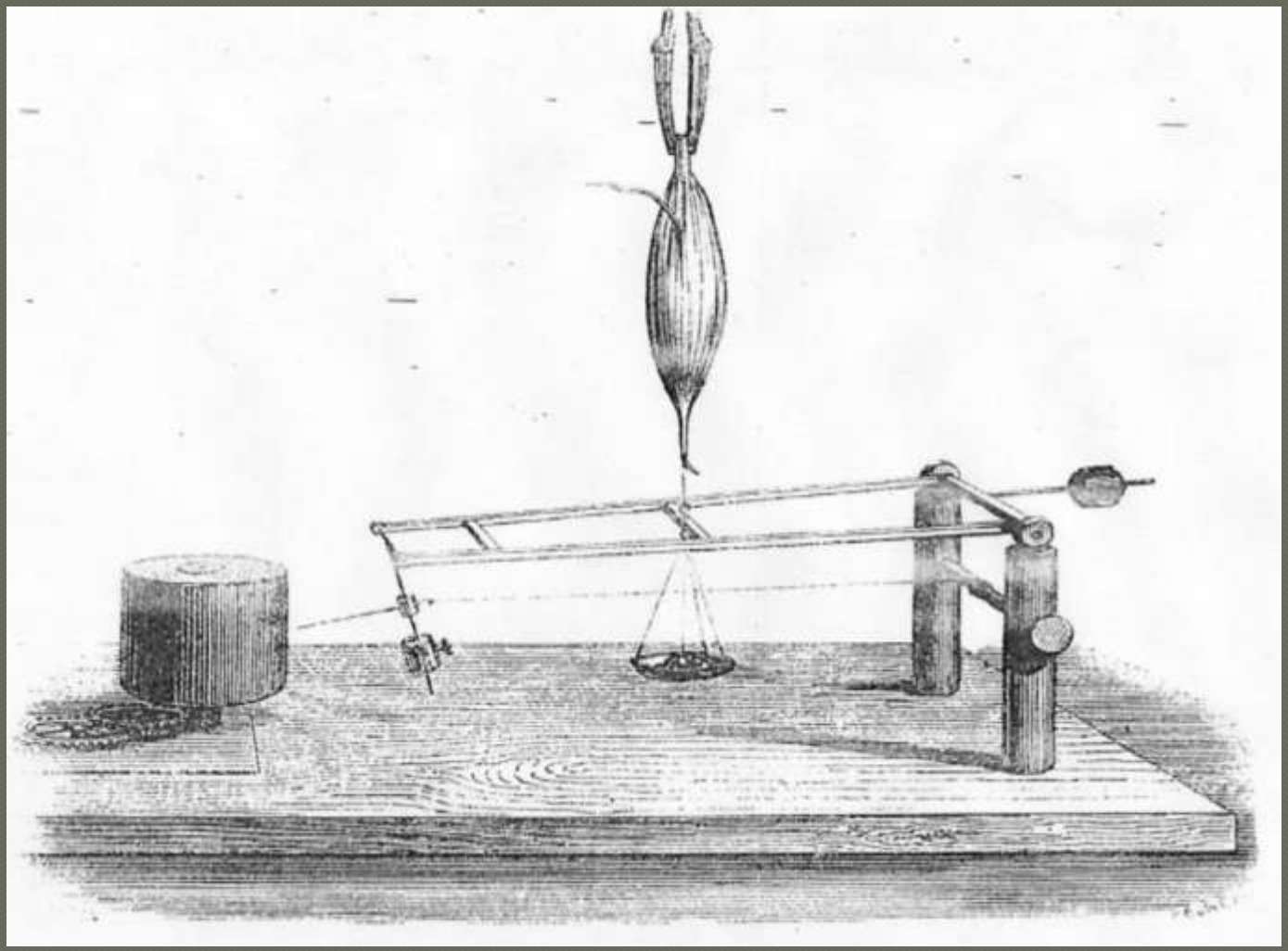
Throughout the 17th and 18th century, science was a “private affair”

From about mid-19th century: the ‘second academic revolution’, i.e. the institutionalization, professionalization and experimentalization of science, and …



Chemical laboratory of von Liebig at Giessen, ca. 1840

… to a good extent an “experimentalization of life”



Helmholtz’s (1868) myograph, an apparatus for measuring muscle activity

In late 19th century, the foundation of marine stations were a means to “renaturalize” biological research

1872
Stazione zoologica Anton Dohrn di Napoli

1872
Station biologique de Roscoff

1874
Station marine de Wimereux

Between the laboratory and the deep blue sea

Between the laboratory and the deep blue sea

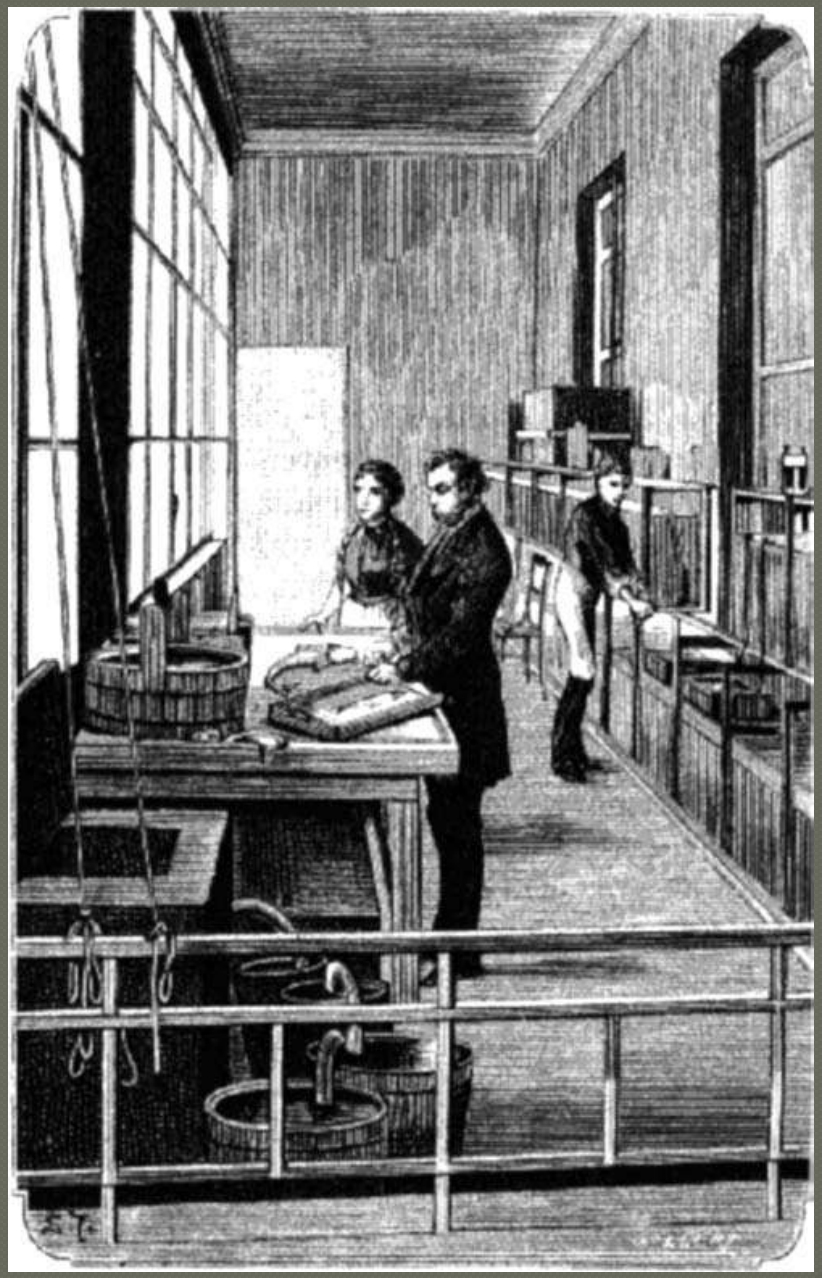
- Dohrn and Giard openly deplored the "lab-centrism" they perceived,
- and re-transplanted research from the university cities to the shoreline,
- bringing biologists closer to the natural environments of the creatures they were studying,
- and promoting a 'complete' biology, not confined to the lab or museum.

Giard: 'éthologie'

Dohrn: 'Lebensweise der Tiere'

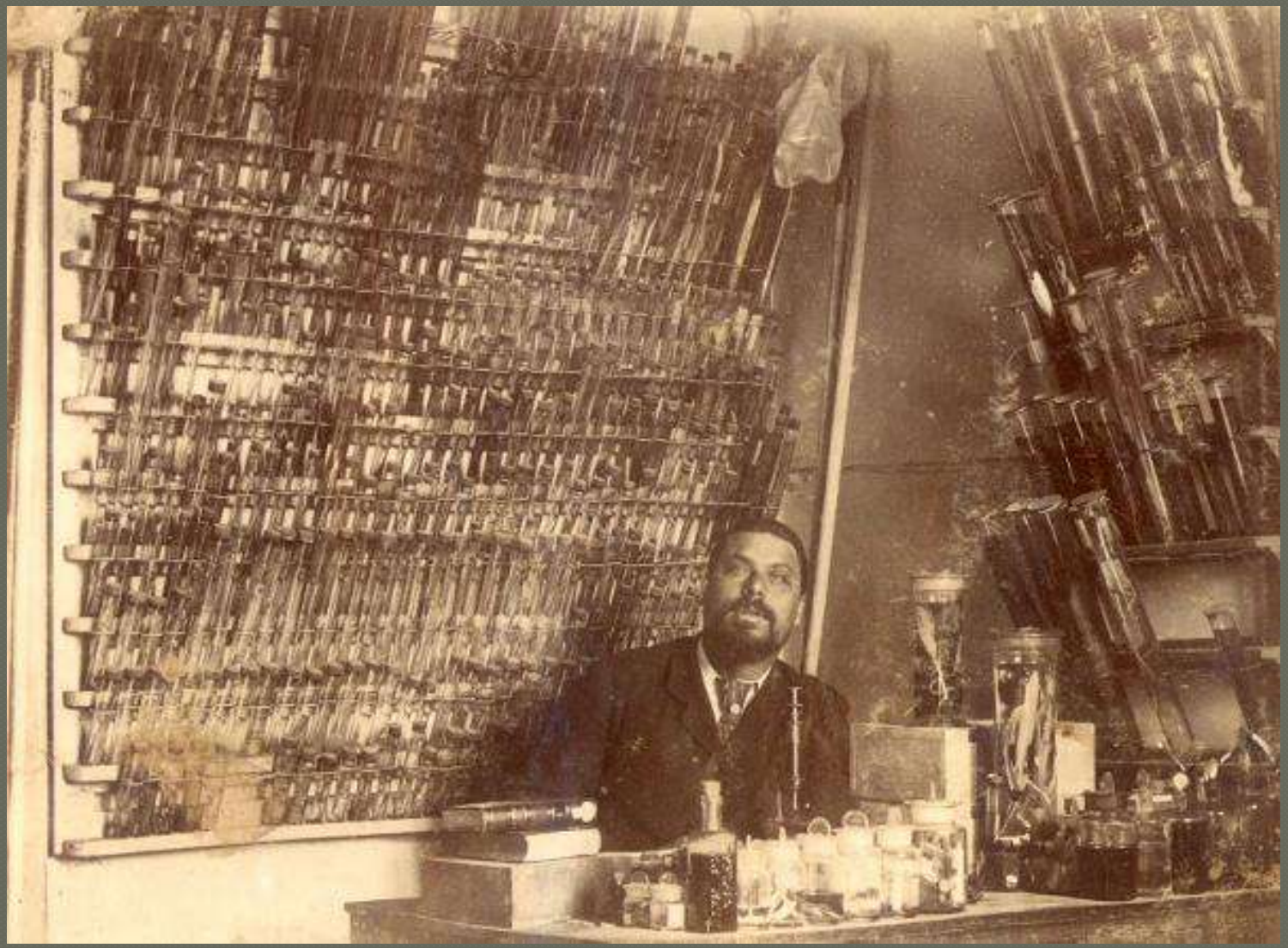
Yet, whereas Giard's station mainly preserved its 'field station' nature, Dohrn's *Stazione* developed more into a research institution (pioneering many important laboratory techniques).
The sorting room was the closest to the field most visitors got.

Dohrn prided himself on the fact that, thanks to his modern infrastructure, he was able to keep marine animals alive much longer than anywhere else.

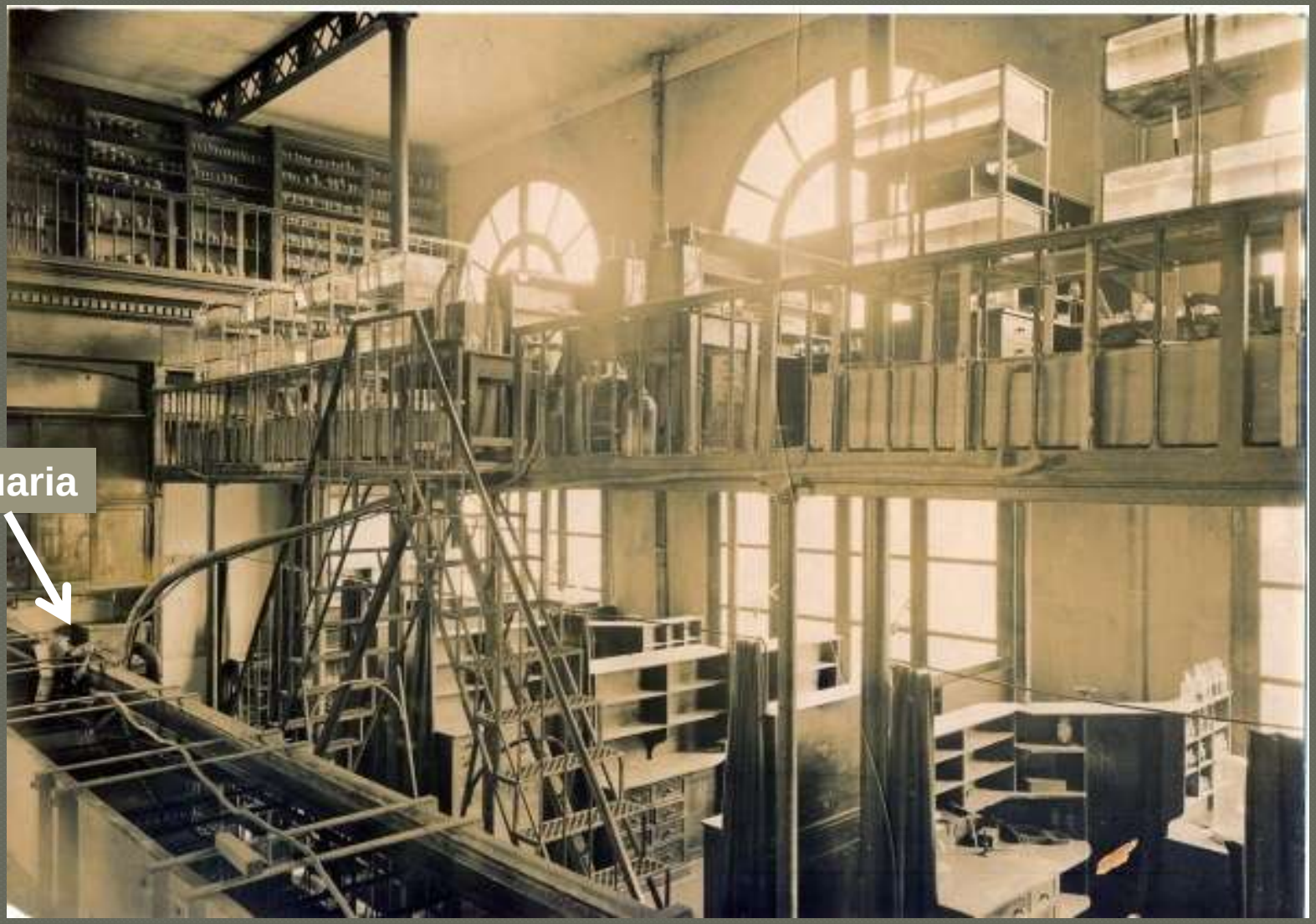


The sorting room of the Naples Station, 1881

Salvatore Lo Bianco (1860-1910)



Working *at* the sea side (not on the open sea)



Research facilities at the Stazione Zoologica

First basic notions about the Neapolitan cephalopods:

Salvatore Lo Bianco
(1860-1910)

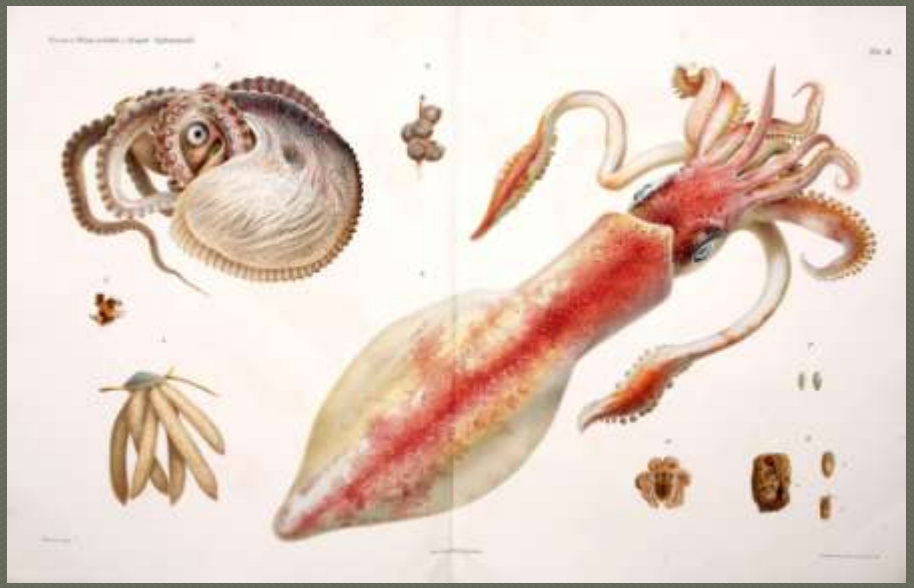
1888 Notizie biologiche riguardanti specialmente il periodo di maturità sessuale degli animali del Golfo di Napoli. Berlin (Verlag R. Friedländer & Sohn).

1909 Notizie biologiche riguardanti specialmente il periodo di maturità sessuale degli animali del Golfo di Napoli. 3rd edition. *Mitteil. Zool. Stat. Neapel* 19, 1909: 513-761 (spec. 645-657).

First basic notions about the Neapolitan cephalopods:

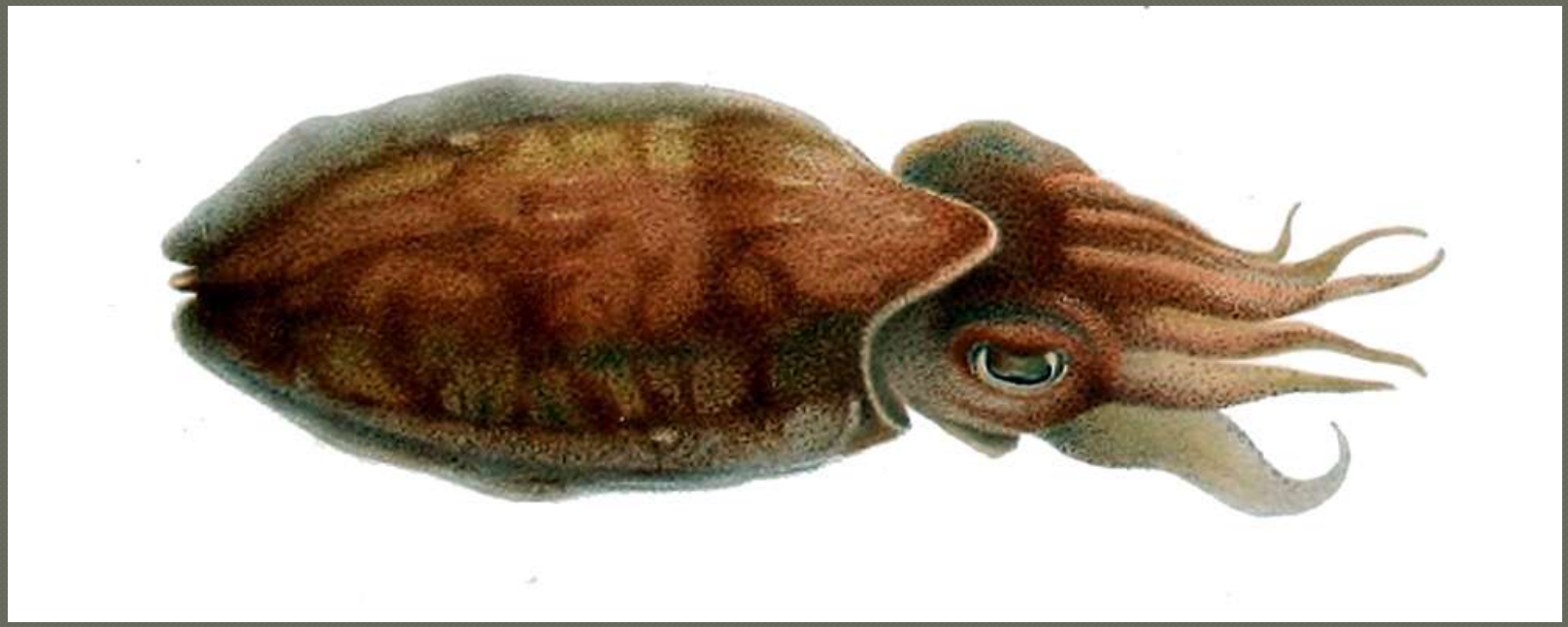
Giuseppe Jatta (1860-1903)

1896: *I cefalopodi viventi nel Golfo di Napoli (Sistematica).*
(Flora und Fauna des Golfes von Neapel, 23)



Adolf Naef (1883-1949)

(1923-28)



3. Can a cephalopod be a model organism?

Francis Bacon (1561-1626)

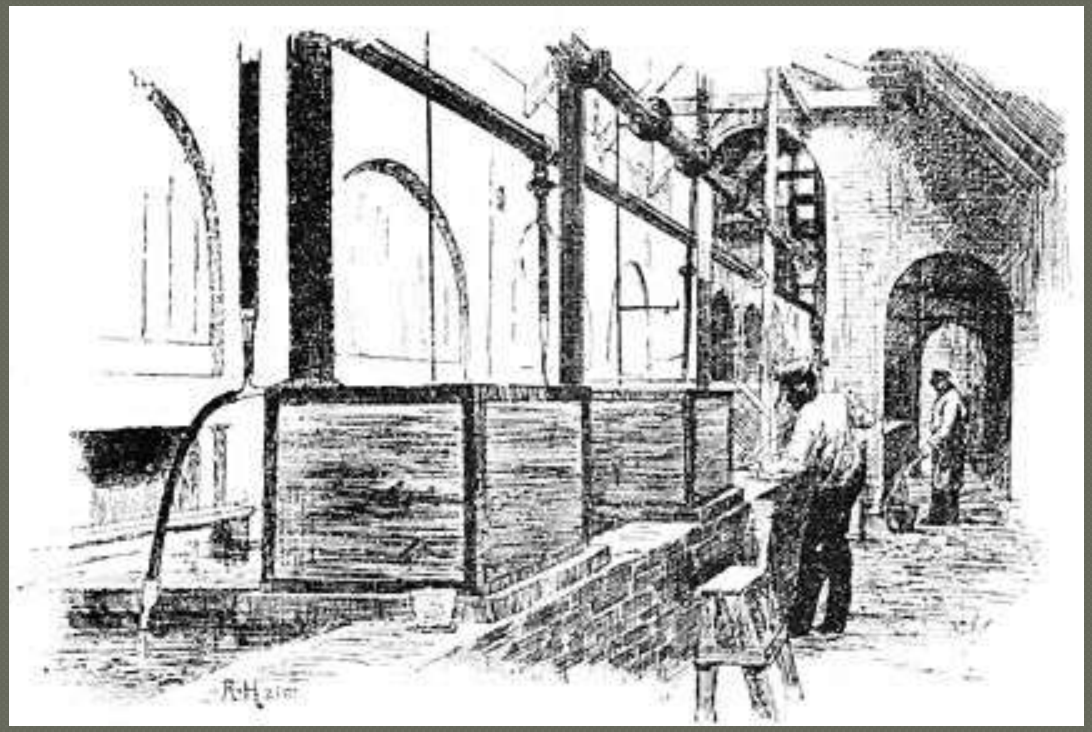
An experiment is an *experientia quaesita*,
a "torture of nature in order to reveal its secrets",
and a *fact* (*facere*) is an experience *made*

The more the experiment is programmed and restricted ,
the more all possible interfering variables are under control,

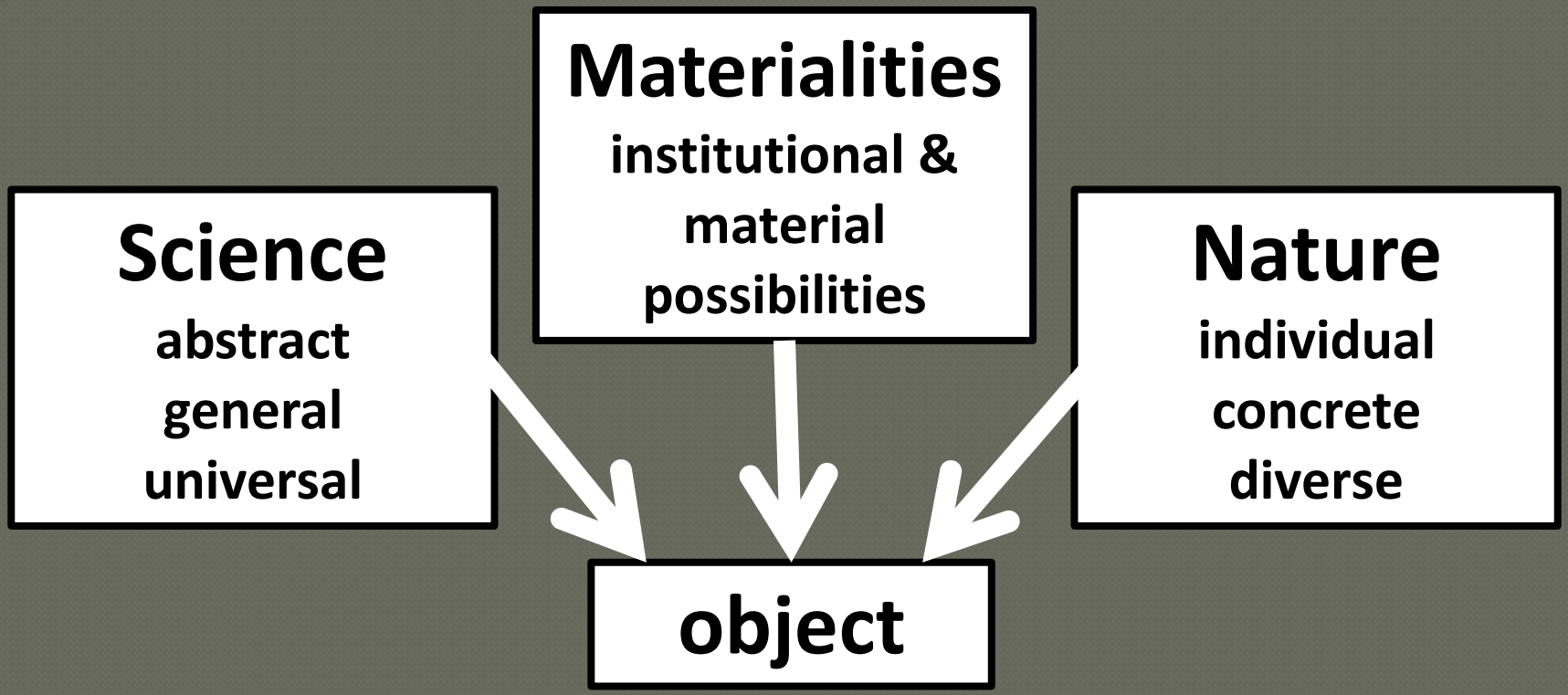
the more nature's 'answer' will be concrete, but
the more the setting will become unnatural and abstract.

Between the laboratory and the deep blue sea

The fundamental step in the transformation of an organism into a research object is the standardization of the procedures of husbandry, feeding, housing, reproducing etc.



The Amsterdam Aquarium

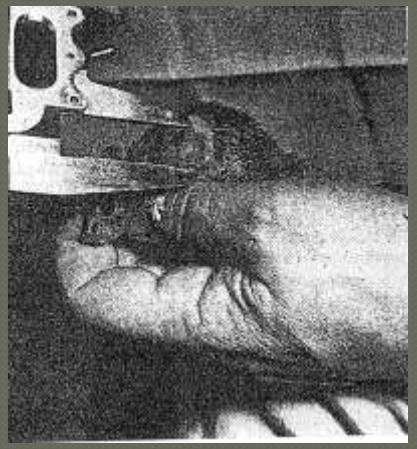

Materialities
institutional &
material
possibilities
Science
abstract
general
universal
Nature
individual
concrete
diverse
object

Due to decisions taken at the start of their projects, two initially similar research aims (transmission of characters) produced two completely different model organisms

Drosophila:

impossible to research the formation of visible traits

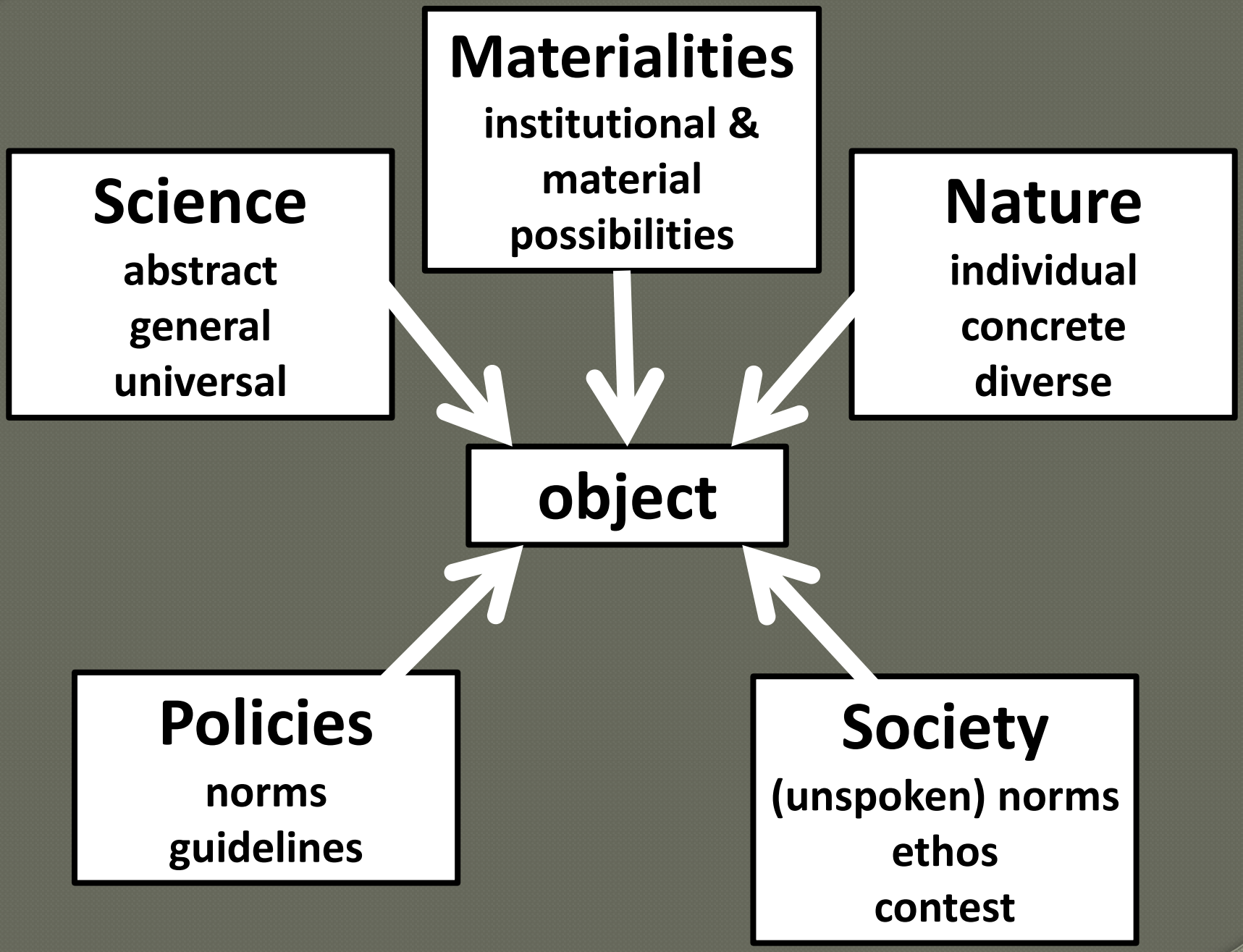
→ was made conform to the ideal of (statistical) Mendelian theory



Mice:

suited to research the formation of visible traits and considered as better representatives of humans

→ was made conform to cancer research


Materialities
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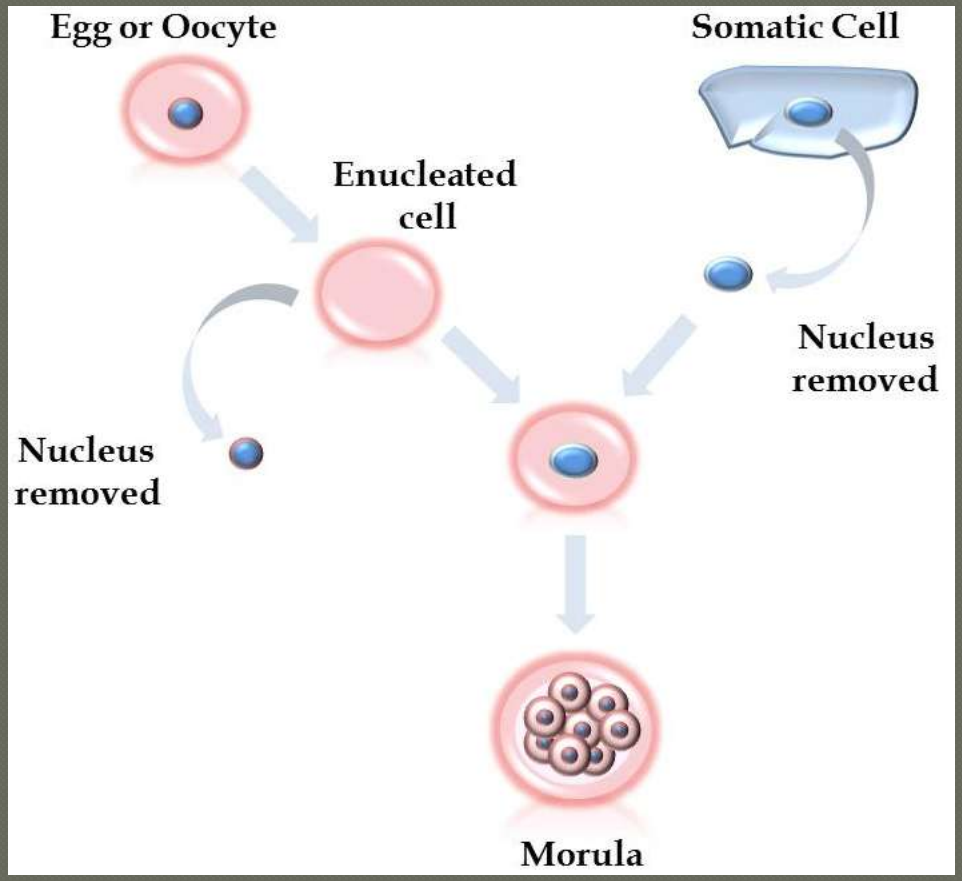
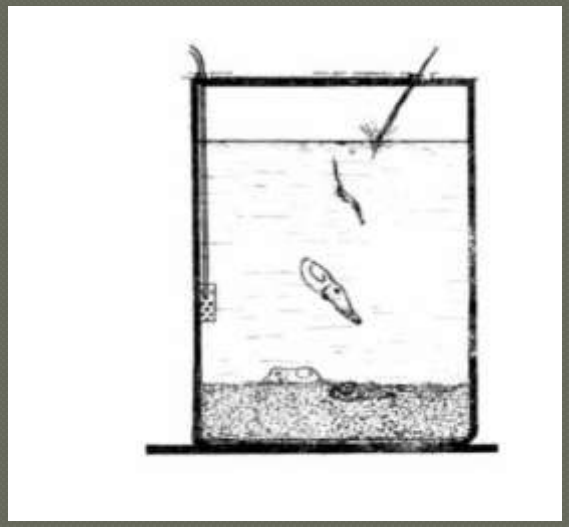
object
Policies
norms
guidelines
Society
(unspoken) norms
ethos
contest

A politically constructed research object: Cells produced through Somatic cell nuclear transfer (SCNT)



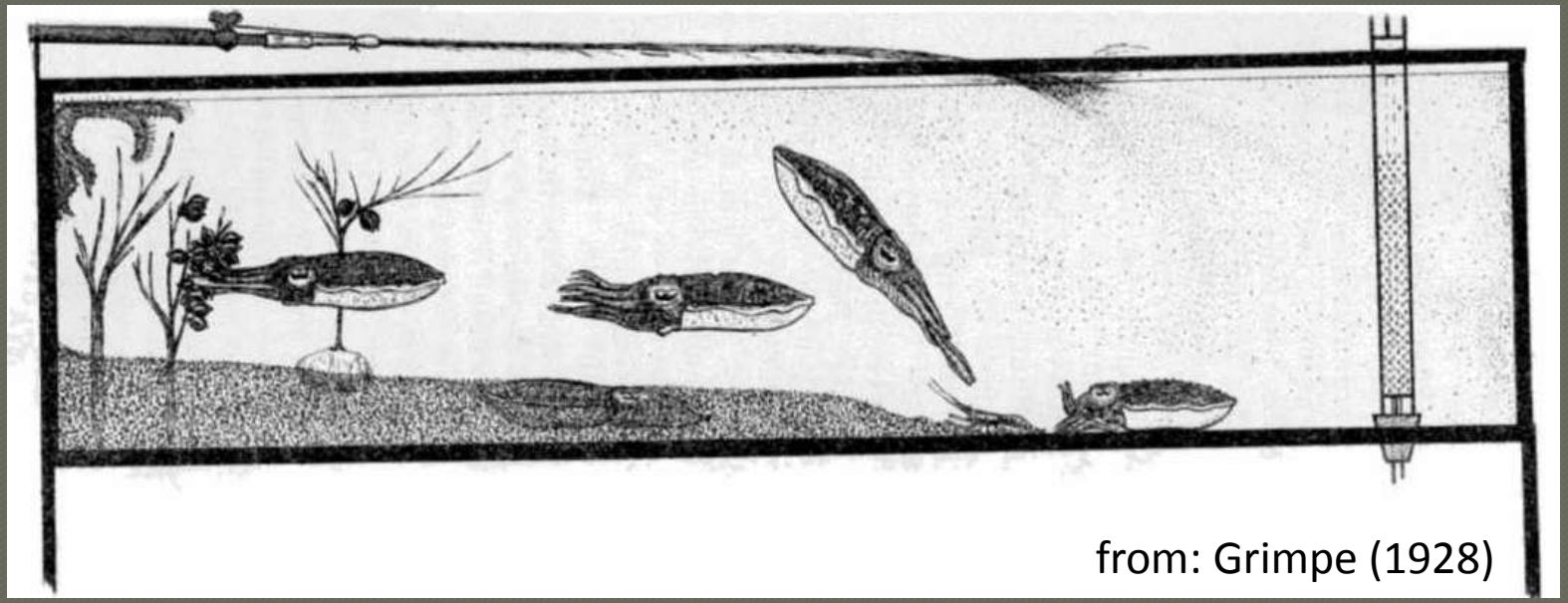
Georg Johann Grimpe (1889-1936)

“Cephalopods are the marine guinea-pigs”



1928:

Pflege, Behandlung und Zucht der Cephalopoden für zoologische und physiologische Zwecke
(Husbandry, treatment and breeding of cephalopods for zoological and physiological purposes).
In: E. Abderhalden, Handbuch der biologischen Arbeitsmethoden,
Berlin-Wien, 1928, pp. 331-402



from: Grimpe (1928)

The aquarium: a Nature–lab hybrid and, therefore, a double challenge:

1. conceptual, i.e. the question if nature can be reproduced with equal value in an aquarium;
2. technical, i.e. the creation of proper environments in order to permit the organisms to survive and perform their functions as normally as possible.

Octopus:

brain organization; learning and memory, hormones; …

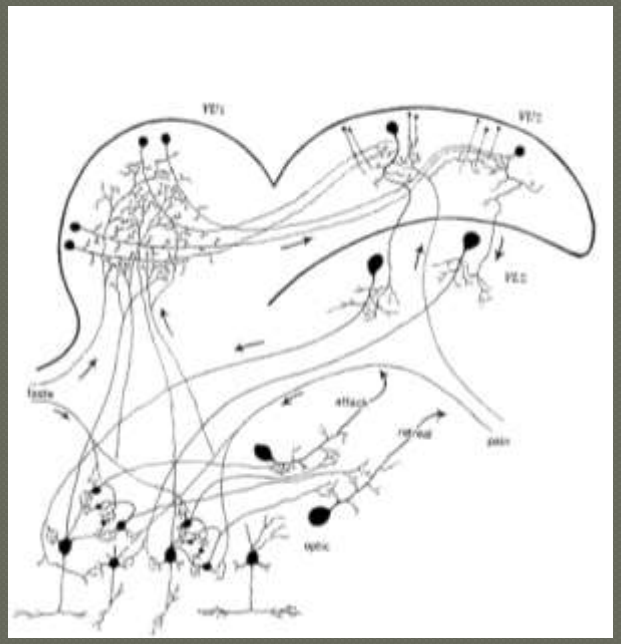
Squid:

the giant axons; eye; blood; ink; olfactory system; oculomotor/equili-brium system; neurodegenerative disorders; …

Cephalopods turned out extraordinary research objects e.g. for the electrophysiology of vision:

- eye's big dimension
- retina survives a long period after extirpation
- retina presents only one type of receptor cell
- nerve fibres start directly at the back side of every photocell
- optic nerves are very long
- optic nerves run separately in the optic ganglion

A failed attempt to establish a cephalopod model organism



John Zachary Young (1907-1997)

1940s-50s: neural circuit model

Submitting in 1958 his research project on shape discrimination and memory to the European office of the US Air Force (USAF):

"The relative simplicity and the overt nature of the connections of the parts of its brain allows an investigation of the various parts without the complexity encountered in the vertebrate brain where all parts are interconnected and lesions fail to make a clear cut differentiation of the specific role played by any one part."

The prospected outcome was a "practical application in many computer, radar and control systems" and, later, "the construction of a self-teaching computer".

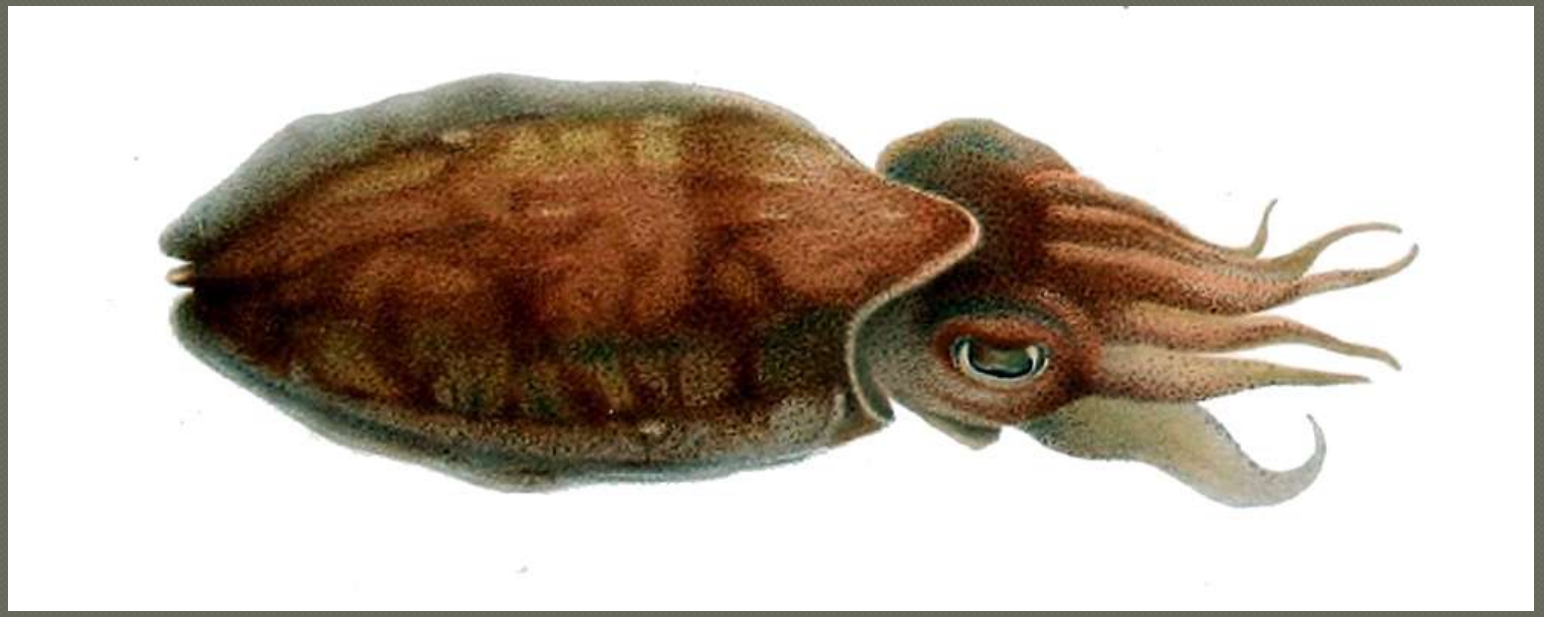
(from: De Sio F., Language, models and animals in the quest for the physical basis of memory in post-War Britain (1947-1965), forthcoming)

Young received a 7-years-grant, but:

- **he was unable to prove nerve communication through intracellular recording,**
- **his concept of 'memory' was too vague,**
- **Octopus brains resulted to be extremely complex,**
- **research remained confined to Naples**
- **… .**

Steven Rose, *The Making of Memory*, 1993:

"Biologists like to say that, for each problem, God has created a specific animal to provide the solution. Octopus proved not to be God's animal for the solution of the memory problem."



3. Can a cephalopod be a model organism?

Cephalopods are not model organisms according to the 20th century definition,
they might become one in the future,
but should they become one?