

DISCOVERY AND INSTRUMENTATION: HOW SURPLUS KNOWLEDGE CONTRIBUTES TO PROGRESS IN SCIENCE

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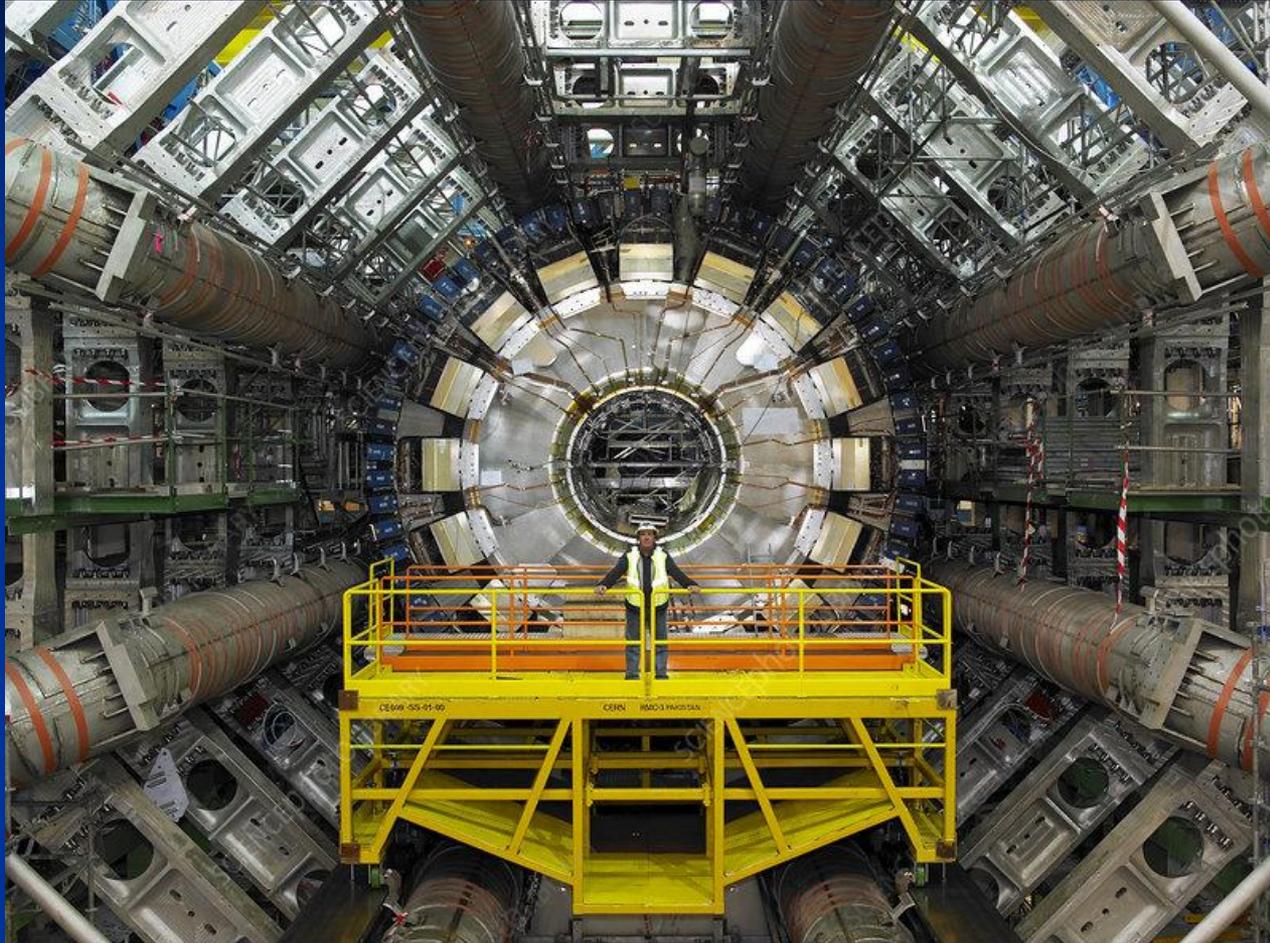


Explaining Scientific Progress

- ❑ **How, and in what sense, does science make progress?**
- ❑ **Often held that progress consists in the accumulation of beliefs of the right sort—true or true and justified**
- ❑ **Progress results from the application of the “Scientific Method”**
- ❑ **Neglects role of instrument-mediated action**



Explaining Scientific Progress



- **Proposal: consider science as a form of labor**

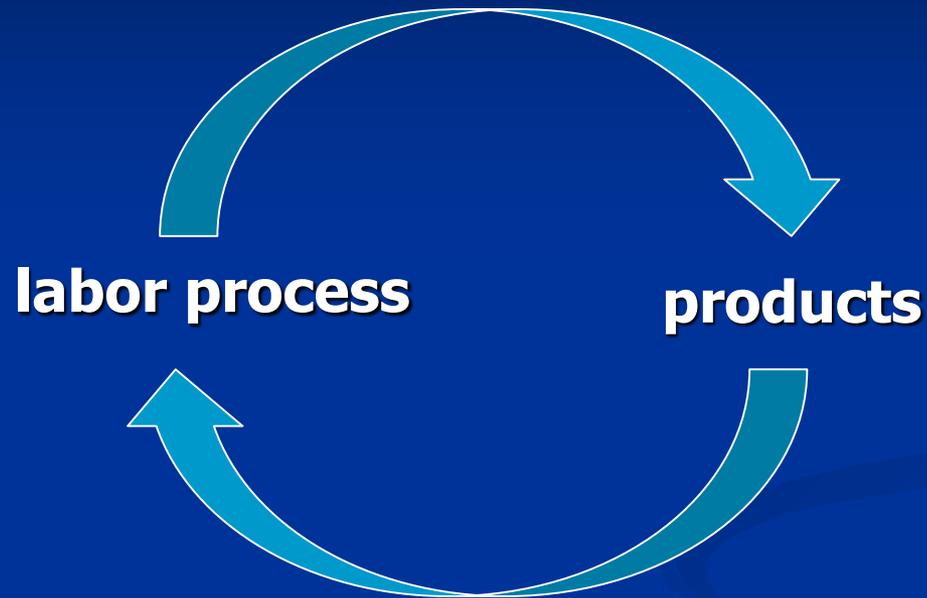


Science as a Form of Labor

- **Productive activity**
- **Conditions of production**
- **Workers' abilities**



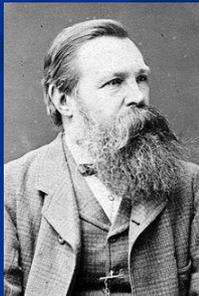
Expanded Reproduction



Engels on the Self-transformation of Labor

- **“Labor is the source of all wealth, the economists assert. It is this, next to nature, which supplies it with the material it converts into wealth. But it is also infinitely more than this. It is the primary basic condition for all human existence, and this is to such an extent that, in a sense, we have to say that labor created man himself.”**
- **“The hand is not only the organ of labor, it is also the product of labor. Only by labor, by adaptation to ever new operations, by inheritance of the resulting special development of muscles, ligaments, and ... bones ... and the ever renewed employment of these inherited improvements in new, more and more complicated operations, has the human hand attained the high degree of perfection that has enabled it to conjure into being the pictures of Raphael, the statues of Thorwaldsen, the music of Paganini.”**

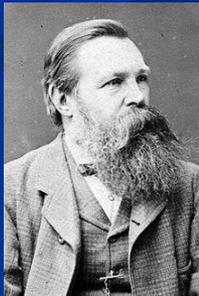
– “The Part Played by Labor in the Transition From Ape to Man” (1876)



Engels on the History of Science

- “If, after the dark night of the Middle Ages was over, the sciences suddenly arose anew with undreamt-of force, developing at a miraculous rate, once again we owe this miracle to production ... following the crusades, **industry** developed enormously and **brought to light a quantity of new mechanical ... chemical ... and physical facts, and this** not only gave enormous material for observation, but also itself provided quite other means for experimenting than previously existed, and **allowed the construction of *new* instruments; it can be said that really systematic experimental science now became possible for the first time”**

- *Dialectics of Nature* (1875)



Later Marxists on the Self-transformation of Labor

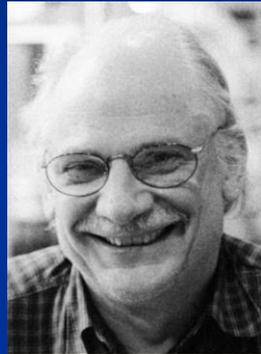
- “Une dialectique entièrement inédite par rapport à l’évolution des espèces vivantes prend ici consistance ... **Par cette incessante objectivisation [Objektivieren] de son activité matérielle et spirituelle, l’espèce *Homo sapiens* devenant genre humain a échappé peu à peu aux frontières de sa constitution naturelle pour s’engendrer elle-même**, quoique en des conditions bien éloignées encore d’une maîtrise consciemment concertée.”

L. Sève , *Penser avec Marx Aujourd’hui, T. III. “La Philosophie ?”* (2014)



- **“Inasmuch as the expanding environment of implements does not remain external to the labor process to which it owes its existence, but in turn itself releases its inherent possibilities, the process of accumulation is not a linear process but a process expanding and accelerating exponentially.”**

-P. Damerow, “The Concept of Labor in Historical Materialism and the Theory of Socio-historical Development” (1977)

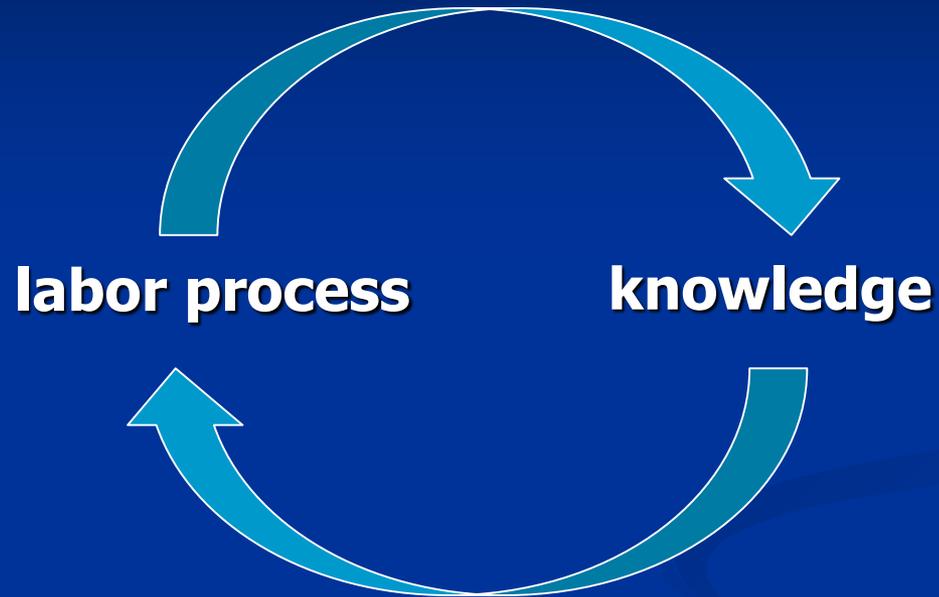


- **“We have, thus, a co-evolution of material means and knowledge of which a surplus of knowledge is characteristic.** This surplus is due to the simple but rarely sufficiently acknowledged fact that humans can gain more knowledge from the use of a means than was needed to invent it in the first place ... **the co-evolution of knowledge and material means of production ... holds for the process of scientific production as well.”**

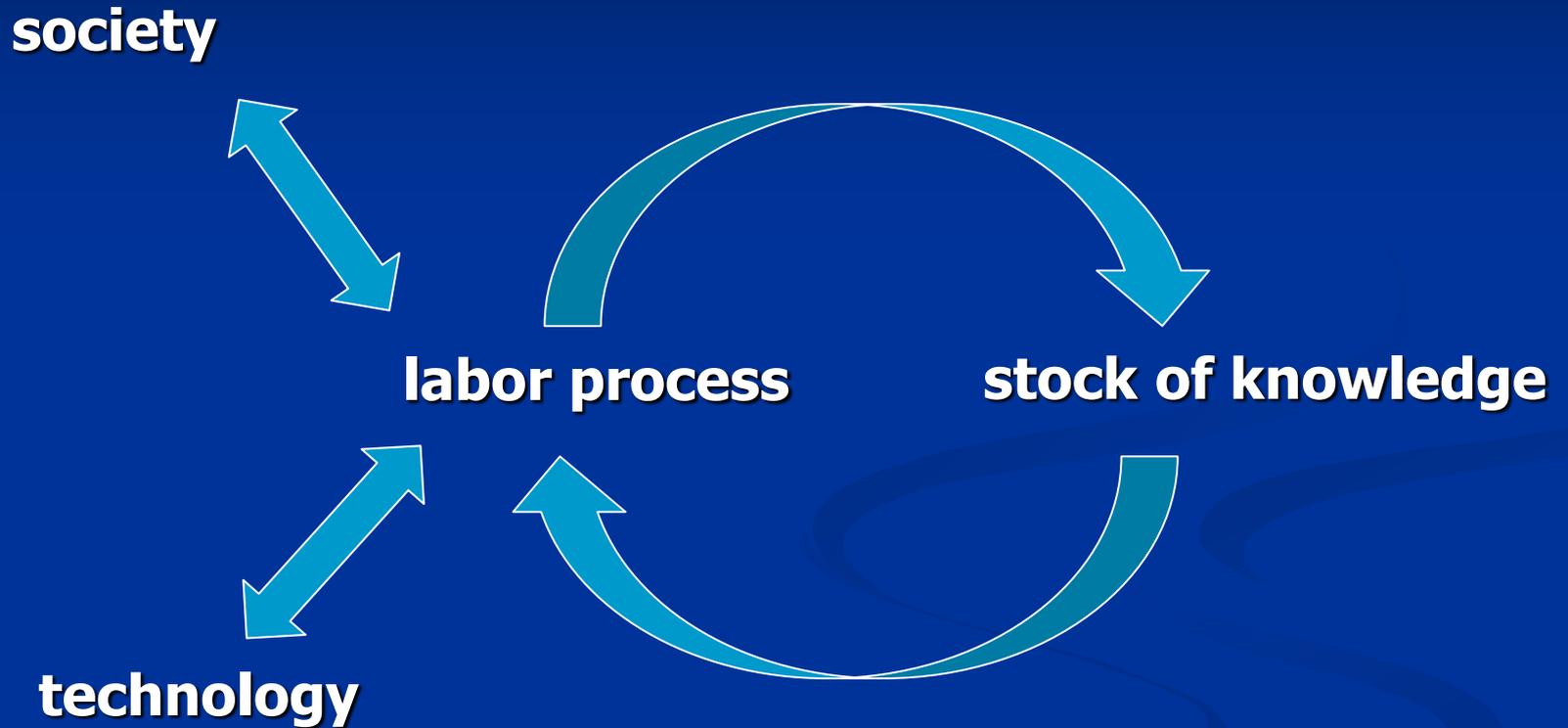
W. Lefevre, “Science as Labor” (2005)



Science as a Form of Labor



Labor and Scientific Progress



Surplus Knowledge

- ❑ **Scientific discoveries improve the stock of knowledge by adding new knowledge, correcting imprecision or exposing and correcting errors**
- ❑ **New knowledge also reveals new, useful employments of the old knowledge**
- ❑ **'Surplus knowledge' is knowledge that is acquired by means of pre-existing knowledge, and which transforms the latter as specified above**



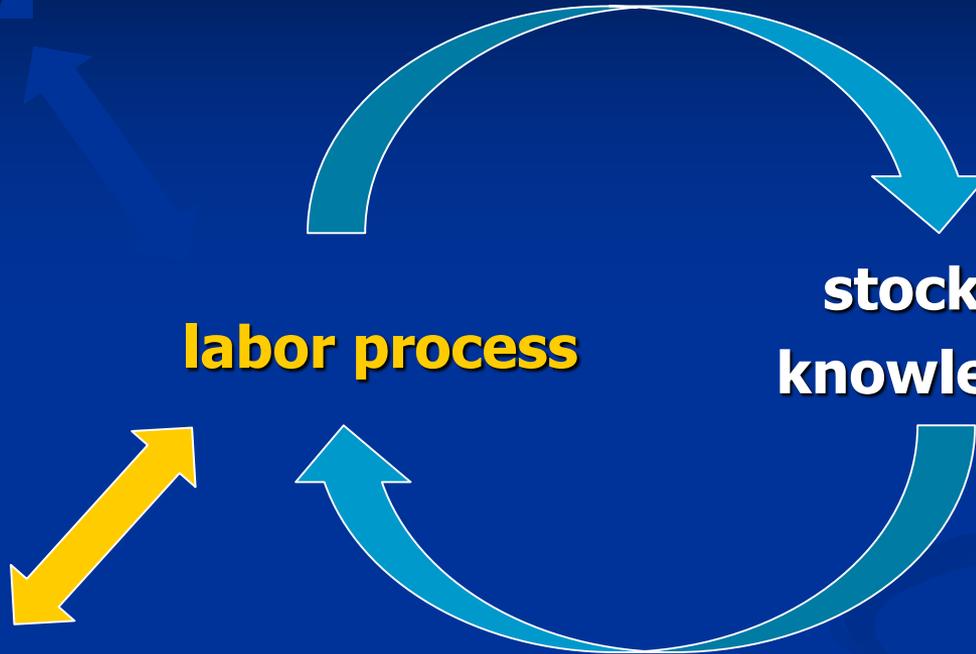
Labor and Scientific Progress

society

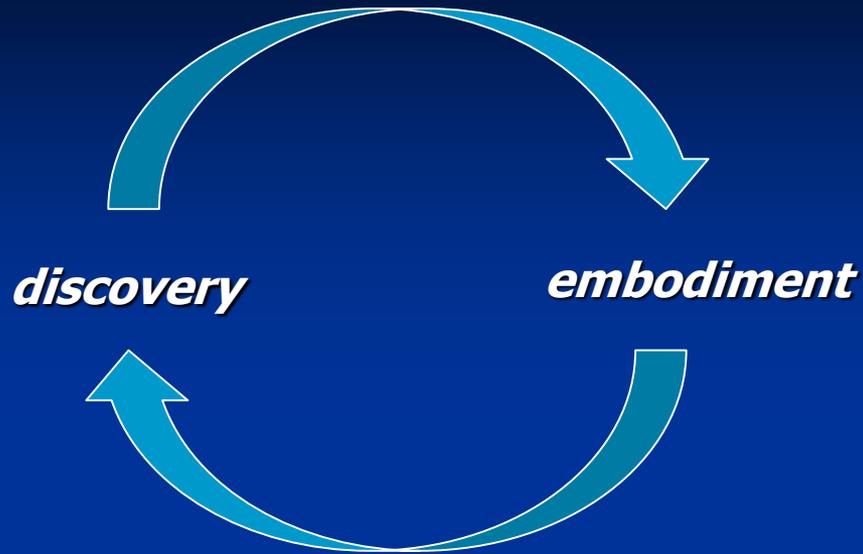
labor process

stock of
knowledge

technology



The Dialectic of Discovery and Embodiment



1. k_1, k_2, \dots, k_i $\xrightarrow{\text{production of}}$ instruments $\xrightarrow{\text{discovery}}$ $k_{i+1}, k_{i+2}, \dots, k_n$
(a) (b)

2. k_1, k_2, \dots, k_n $\xrightarrow{\text{repeat (a) and (b)}}$ $k_1, k_2, \dots, k_n, k_{n+1}, \dots, k_m, \text{ etc.}$



Form-Integration v. Source-Integration

- ***Form-integration:*** The integration of different kinds of knowledge distinguished according to their form
- ***Source-integration:*** The integration of different kinds of knowledge distinguished according to their source, i.e. a practice or field



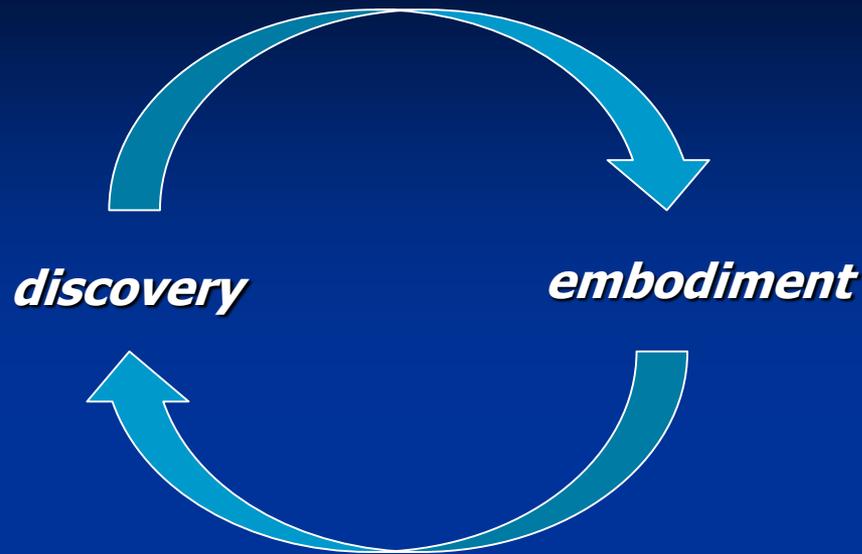
Form-Integration

- ❑ (EK) ***Empirical Knowledge***: Empirical knowledge usually comes in the form of experimental and observational results.
- ❑ (TK) ***Theoretical Knowledge***: Theoretical knowledge usually comes in the form of well-confirmed hypotheses.
- ❑ (PK) ***Practical Knowledge***: Practical knowledge usually comes in the form of both immediate and long-term practical applications.
- ❑ (MK) ***Methodological Knowledge***: Methodological knowledge usually comes in the form of methods and techniques of learning about nature.
- ❑ (IK) ***Instrumental Knowledge***: Instrumental knowledge usually comes in the form of instruments or techniques for carrying out operations or actions.

-For EK, TK, PK, and MK, see Mizrahi (2013), "What is scientific progress?"



Source-Integration



• optical theory
• lens-crafting and other know-how

integration in production of telescopes

(a)

discovery

(b)

EK (e.g., rings of Saturn)

TK (confirmation of Newton's mechanics)

MK (distant objects)

PK (determining longitude)

IK (improved components)



Embodiment

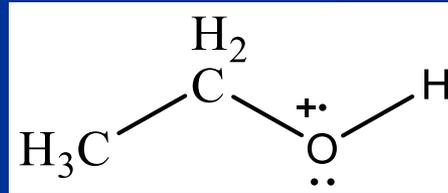
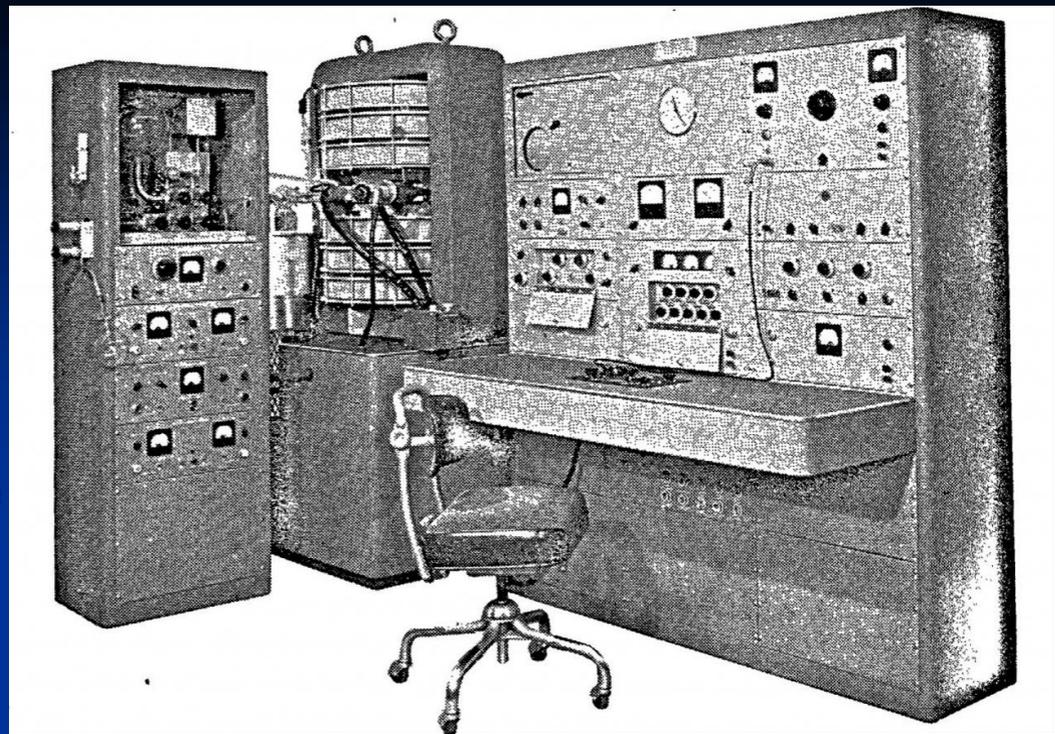
(EK) Empirical Knowledge

(TK) Theoretical Knowledge

(PK) Practical Knowledge

(MK) Methodological Knowledge

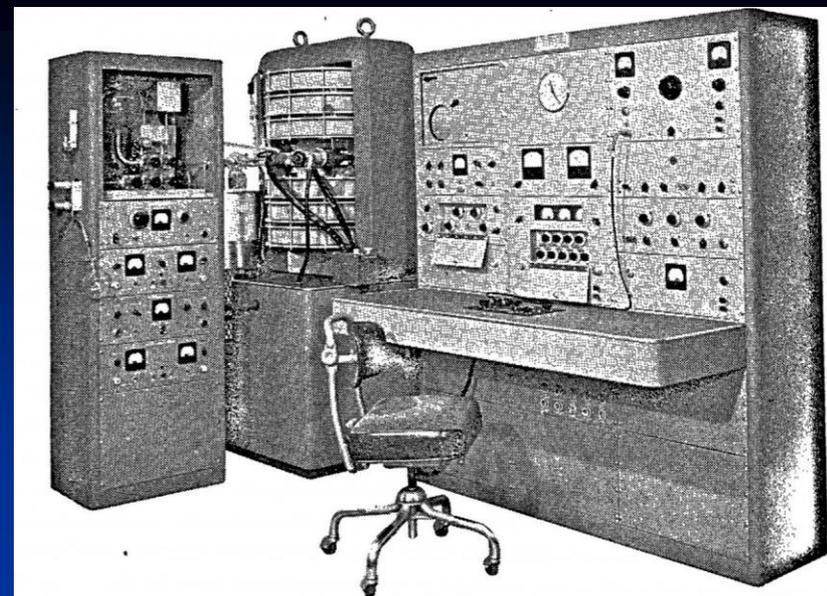
(IK) Instrumental Knowledge.



- Knowledge needs to be built into the instrument in order to be exploited
- Involves finding some functional substitute in material form for whatever items of TK, EK, MK, IK and PK are needed to build the instrument



Mass Spectrometer: Embodiment



- ❑ **(TK) Theoretical Knowledge:** laws governing the motions of charged particles; quantum mechanics; chemical reaction mechanisms; mathematical techniques
- ❑ **(EK) Empirical Knowledge :** calibration data; data interpretation rules
- ❑ **(MK) Methodological Knowledge:** mass spectrometry itself guides new instrument design; data tabulation
- ❑ **(PK) Practical Knowledge:** photography; knowledge of how to produce materials with requisite properties; ionization techniques
- ❑ **(IK) Instrumental Knowledge:** electronic detectors; computers; magnets¹⁹

Instrumentation Beyond Sensory Extension

- ❑ Instruments are often reduced to their role as extenders of the senses

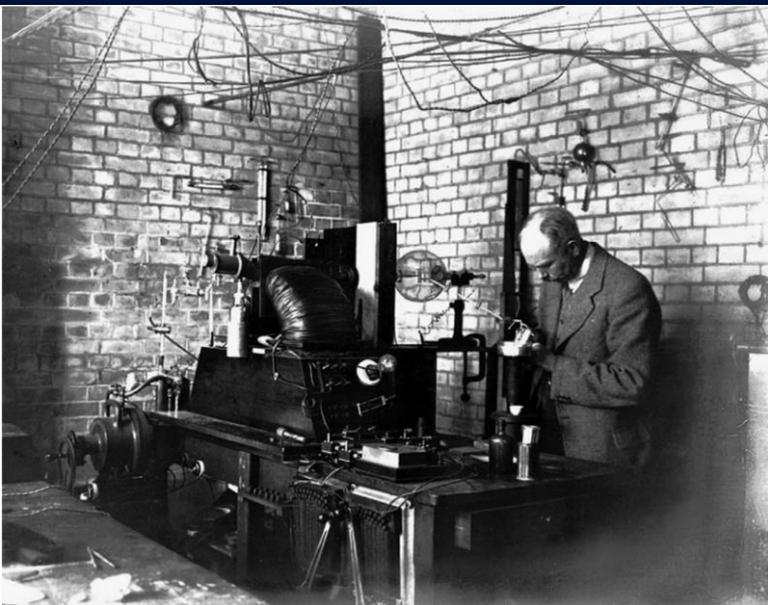
- ❑ But they have other distinctive properties that contribute to scientific progress
 1. Their form is highly modifiable (**plasticity**)

 2. they can be used without knowing all the things necessary to make them ("**black-box-ability**")

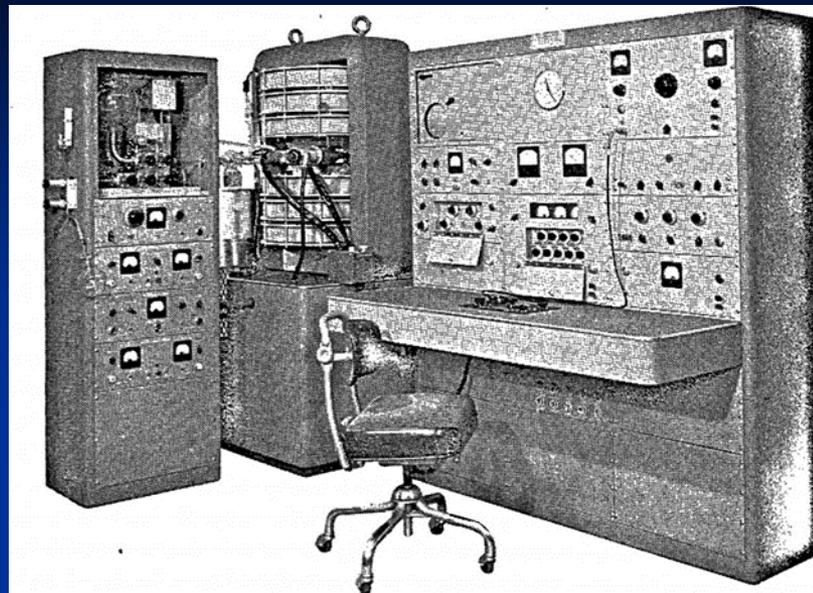
 3. they can subsist beyond the subjective activities that engendered them and serve in new activities (**durability**)

 4. they can provide a structure that allows a new structure to be constructed from it (**scaffolding**)

Mass Spectrometer: Scaffolding



mid-1930s

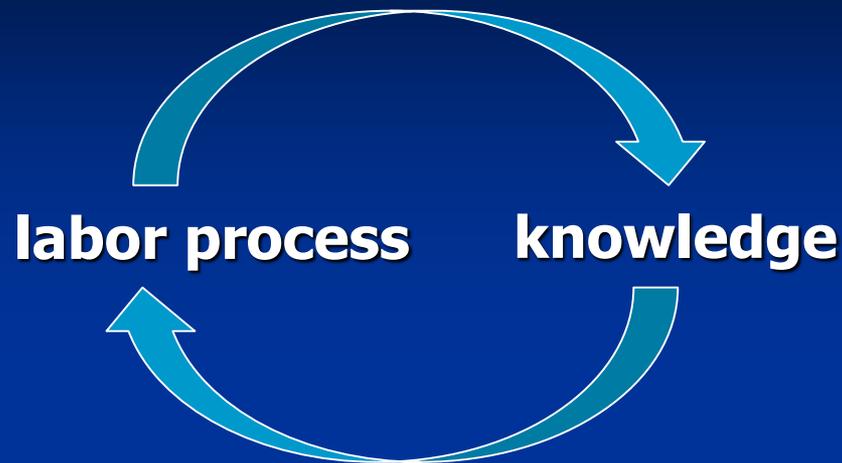


1960s

- The spectrograph of the 1930s provided **a scaffold for the exploitation of new knowledges, techniques and technology**
- The process of integrating these forms of knowledge into the mass spectrometer resulted in instrumentation with capabilities that far exceeded what was possible with the old spectrograph.
- The instrument became an essential tool in chemistry and industry



Instrumentation and Progress



- **this enhancement of abilities suggests an alternative conceptualization of progress, from conceptions based on truth or theoretical knowledge to one that takes into account the evolution of abilities brought about by scientific and technological change**



Abilities-Progress

- An episode of science constitutes scientific progress if it shows the **transcendence of limitations of native human epistemic abilities**.
- As opposed to the accumulation of knowledge, the accumulation of true beliefs, or the achievement of specific goals of a science.



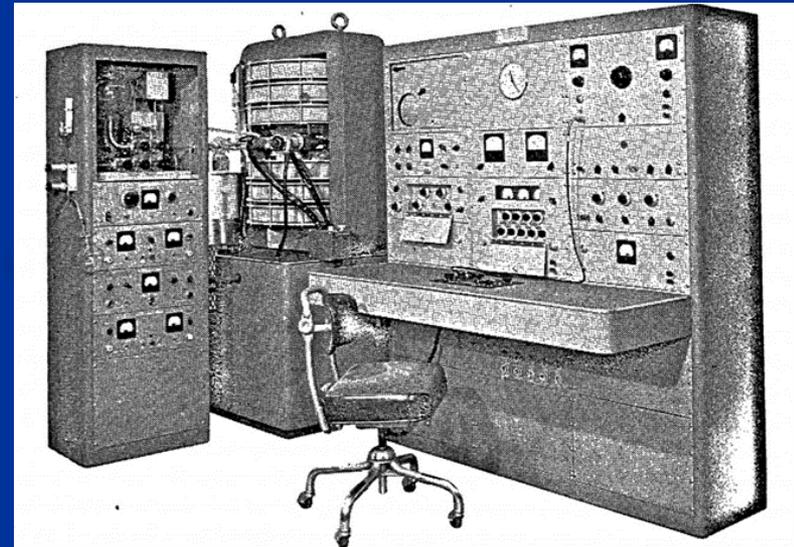
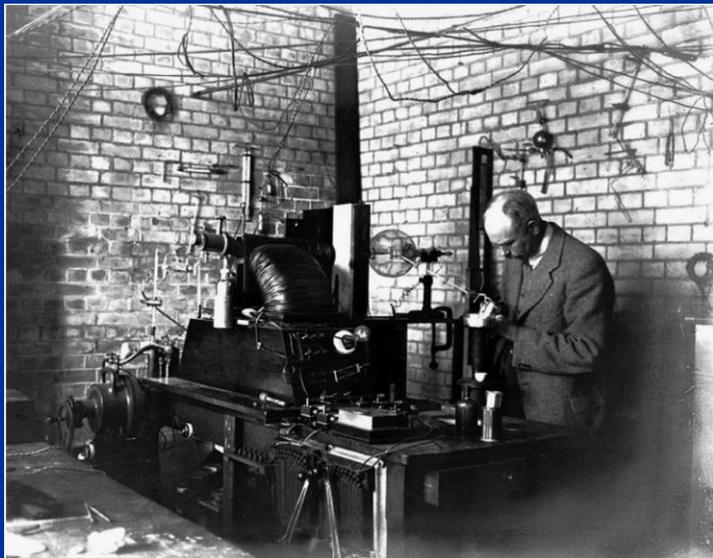
Abilities-Progress

- ❑ **“transcend”** —an instrumental ability is acquired that is either less error-prone or of broader scope than a native human epistemic ability that it enhances or replaces.
- ❑ **“epistemic ability”** — the ability to engage in a mental or physical action that is intended to contribute to the acquisition of knowledge.
- ❑ **“native”** — biological facts about humans are required for their successful exercise of that ability.



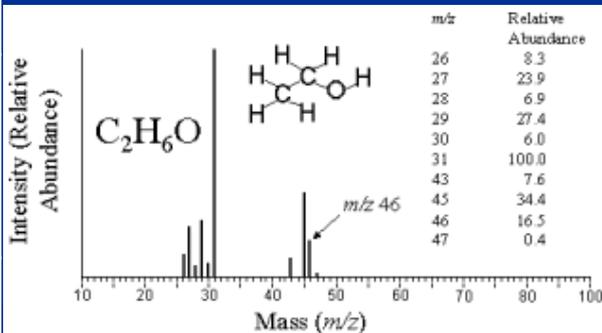
Surplus Knowledge and Abilities-Progress

- The extension of knowledge shows that some native human abilities involved in scientific work are subsumable under more general abilities associated with general types of instruments.



Abilities-Progress in Mass Spectrometry

Abilities	How Exercised	How Transcended
Ocular detection	Reading of photographic plates	Electronic detectors, amplifiers
Data processing	Tabulation of analog recording data	Digitizers, minicomputers
Problem-solving	Interpretation of spectra	Interpretation algorithms
Memorial	Data storage, instrument control, multi-tasking	Hard disks, RAM, CPUs
Pattern recognition	Comparison of spectra of unknowns to references	Pattern recognition algorithms
Searching abilities	Searching of spectral libraries	Search algorithms
Manipulative	Instrument control; sample handling and transferring between instruments; densitometry	Computer control; automated sample handling and direct instrument coupling; automatic recording



How, and in what sense, does science make progress?

- ❑ Progress made not just in beliefs or problems solved, but also in the ability to acquire knowledge
- ❑ This progress crucially depends on the material properties of instruments ...
- ❑ ... as well as on the diversity of knowledge on which scientists can draw
- ❑ The holistic character of scientific progress supports the view of proponents of “open science,” that epistemic diversity is really important for scientific progress.



How, and in what sense, does science make progress?

- ❑ Mechanism of progress involves a 'feedback loop'
- ❑ Scientific discoveries have a transformative role in the reproduction of scientific practice
- ❑ The mediation of technology in this process also has a dark side, insofar as excessive prestige gets attached to technology.



Thank you

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Extras

Later Marxists on the Self-transformation of Labor

- **“The reproduction of animals is characterized by ... by the identical reproduction of the characteristics of the species by means of procreation and its genetic determination. It is, by comparison, unique to the labor process characterized by the use and production of tools that, in the form of the means of production produced, the means of labor, exemplarily represented by the tools, it possesses a material result exceeding the cycle of the identical reproduction of the characteristics of the species in the individual, a result that accumulates in an environment of implements ... **Inasmuch as the expanding environment of implements does not remain external to the labor process to which it owes its existence, but in turn itself releases its inherent possibilities, the process of accumulation is not a linear process but a process expanding and accelerating exponentially.**”**
- P. Damerow, “The Concept of Labor in Historical Materialism and the Theory of Socio-historical Development” (1977)



Naturalist Theories of Scientific Change

□ Karl Popper:

“Science, or progress in science, may be regarded as a means used by the human species to adapt itself to the environment.”

– **“The Rationality of Scientific Revolutions” (1981)**

□ Thomas Kuhn:

“The analogy that relates the evolution of organisms to the evolution of scientific ideas can easily be pushed too far. But with respect to the issues of [progress through revolutions] it is very nearly perfect ... the resolution of revolutions is the selection by conflict within the scientific community of the fittest way to practice future science. The net result of a sequence of such revolutionary selections, separated by periods of normal research, is the wonderfully adapted set of instruments we call modern scientific knowledge.”

– ***The Structure of Scientific Revolutions* (1962)**



Naturalist Theories of Scientific Change

□ Bas van Fraassen

“science is a biological phenomenon, an activity by one kind of organism which facilitates its interaction with the environment ... any scientific theory is born into a life of fierce competition, a jungle red in tooth and claw. Only the successful theories survive ...”

- *The Scientific Image* (1980)

- Naturalist theories run the risk of reductionism, insofar as they evacuate features of science that are specific to human evolution

