Powers and Laws of Nature in Late Medieval and Early Modern Philosophy: The Problem of Reaction

Sylvain Roudaut

- Introduction (the Aristotelian ontology of powers / the Aristotelian conception of science)

- The Problem of Reaction and its Implications for the Concept of Power

- Evolution of Physical Concepts (powers, laws, reaction and conservation of motion)

- Conclusion: Scientific Explanations and Laws of Nature in Early Modern Philosophy

The 'Aristotelian' Conception of Powers

- Aristotelianism = dominant framework of natural philosophy in the late Middle Ages

- Like Aristotle's physics, medieval natural philosophy relies on an ontology of powers

  → Powers are explanatory principles

  → Powers are primitive / non-eliminable

  → Powers are dispositional properties, characterized by what they do

- Very broad use of the term 'power' (*potentia*): physics but also biology, psychology ('powers' of the mind), metaphysics ('being in potency')

=> 'power' always connotes a *possibility* / a *disposition*

The 'Aristotelian' Conception of Powers

- Consequence: little interest for the idea of laws of nature

- Explaining natural processes means discovering the causal powers operating within substances

→ The 'laws of nature' add nothing to the powers inhering in natural substances

→ Laws are descriptions of relations between causal powers existing in concrete substances
= Neither *fictions* (instrumentalism), nor mere *generalizations* of perceived regularities (Hume), nor necessary connections between abstract properties (Plato)

→ In contemporary terms, medieval natural philosophers tend to consider laws of nature as *internal relations of necessitation* supervening on concrete substances. Laws are not 'real relations', nothing over and above dispositions proper to natural substances
= "*The laws of nature are the laws of natures*" (D. Oderberg)

How to explain on this basis the regularities of natural processes?

● Common principle (used in physics and metaphysics) : principle of 'causal similarity'

"Every agent causes something similar to itself" (*omne agens agit sibi simile*)

Examples: humans generate humans, cats generate cats, fire generates fire and so on

● Not a law of nature strictly speaking, but rather a principle describing the nature of causality in general

The Qualitative Character of Aristotelian Physics

Aristotle's physics is a *qualitative* theory of nature in many respects:

1) The basic active properties in nature are **qualities**

= hotness / coldness ; dryness / wetness (also heaviness / lightness, but debated point…)

→ these properties are organized as couples of <u>contraries</u> which resist/repel each other

= *hotness repels coldness, dryness repels wetness*

→ other properties of natural substances depend on these basic qualities

- higher-order dispositional properties (colors, smells…)
- categorical properties including geometrical ones (size, shape)

2) 'Qualitative' also because it does not really make room for quantification or mathematization

→ physics and mathematics are hardly compatible given the Aristotelian definition of these sciences (generally accepted in the Middle Ages)

- Mathematics studies objects *abstracted from matter and motion*
- Physics studies *material things* insofar as they have an internal *principle of motion*

→ serious conceptual obstacles for the application of mathematical/quantitative concepts to Aristotelian physics, from both philosophical and mathematical authorities

- Applying numbers to qualities implies violating the Aristotelian principle that distinct categories (like quantity and quality) are *equivocal*. Quantity and qualities cannot be directly related or compared
- Similar problem from the Euclidean theory of proportions. Two things can only be compared if they belong to the *same genus* (e.g. two volumes, two lines…)

→ writing that speed equals the proportion of distance on time ($S=D/T$) makes no sense from a medieval perspective. Same thing for the quantification of qualities in general

● Things started to change in the 14th century

→ New translations, new texts available outside the Aristotelian tradition: Archimedean tradition (Jordanus' statics), Euclid's *Elements*, Arabic scientific treatises…

● First attempts to provide a quantitative description of natural processes and rules of motions

→ Many results anticipating Modern physics (kinematics, dynamics, statics, optics)

→ Particularly important trend in England (the 'Oxford Calculators')

● Use of mathematical concepts to describe physical interactions, but in a still 'Aristotelian' physics

→ Application of numerical concepts to model interactions between qualities in nature

The Problem of Reaction

- Common observation: causal relations between qualities entail 'reactions'

Examples: Hot iron plunged into cold water is cooled, while the water is heated
A hand holding a stone is cooled by it, while the stone is warmed, etc

→ Aristotle speaks of 'reciprocal action' between the agent and the patient

⚠ This rule is *not* universally true according to Aristotle

→ not when the matter is not the same (stars vs sublunear substances)

→ not when there is a great disproportion between the agent and the patient (*cf*. drop)

The Problem of Reaction

- Hard to deny, but also necessary to admit for the consistency of Aristotle's system (no reaction => no mixtures, no compound bodies)

Nicole Oresme, *Questions on De generatione et corruptione* :

"If reaction between two elements were not possible, it would follow that a third would never be generated. The consequent can be proved, because if *A* is stronger than *B* and acts, then if *B* does not react on *A*, it would follow that *A* is not corrupted whereas *B* is, and thus *A* and *B* will never generate a third thing".

Why is there a problem?

● Hard to explain given the usual (Aristotelian/medieval) understanding of action

→ For an action (a causal relation between an agent and a patient) to take place, there must be a relation 'of greater inequality' between two powers, the greater being called *force* and the other *resistance*:

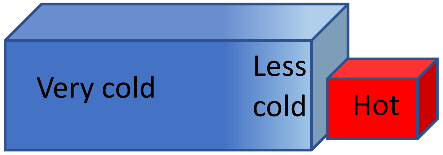
Action if and only if $F > R$

⇒ If a body *A* acts on a body *B*, then *A*'s power is necessarily greater than *B*'s

***How then is it possible for* B *to (re)act on* A?**

- Some cases were regarded as more difficult to explain than others

→ the case of 'difformly qualified bodies' (i.e. where the quality is *unevenly distributed*) was supposed to be more easily explainable

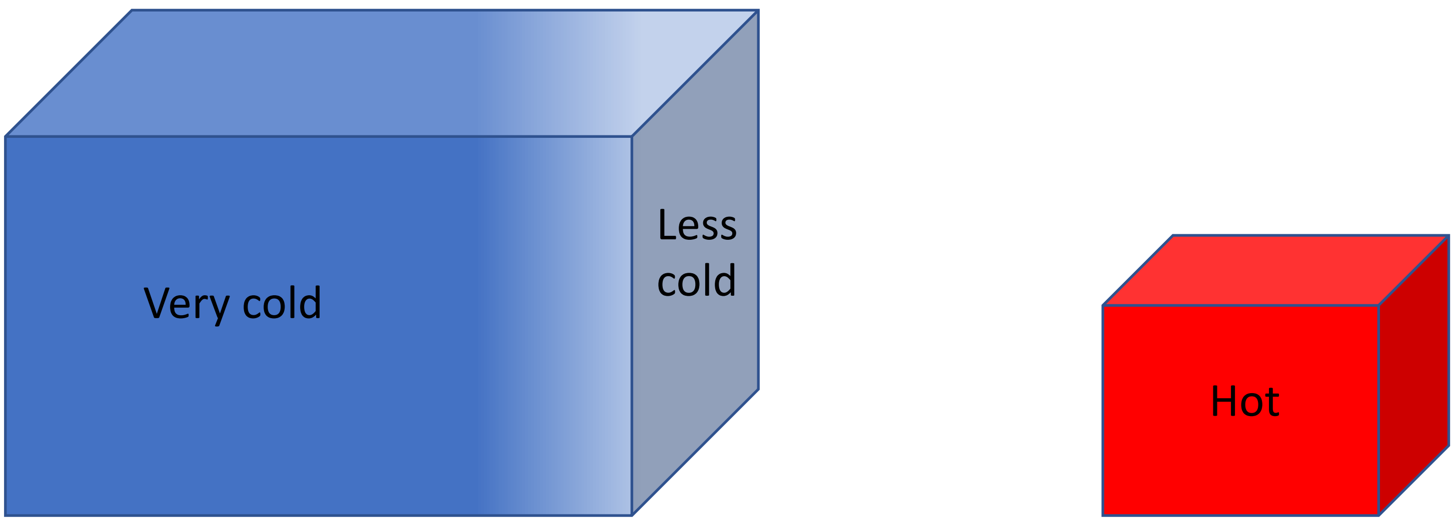


In this type of case, there is a reaction because a ***part*** of the agent is weaker than the whole patient.

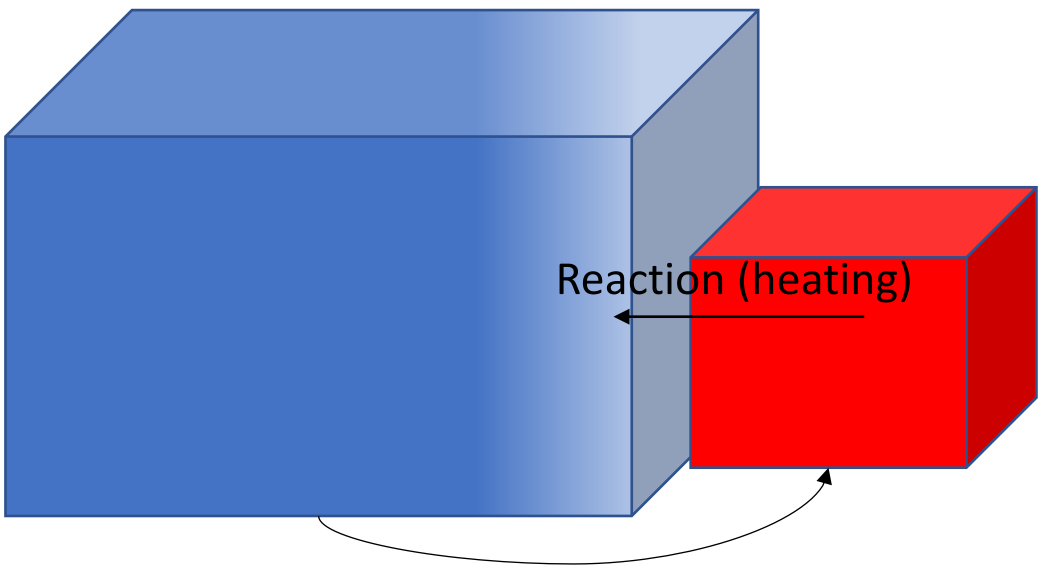
Whereas the power of the whole agent is greater than the whole patient ($F_w > R_w$) ,
this is not the case for this part of the agent ($F_p < R_w$)

- When it comes to detail, however, it is not clear at all how this is supposed to work

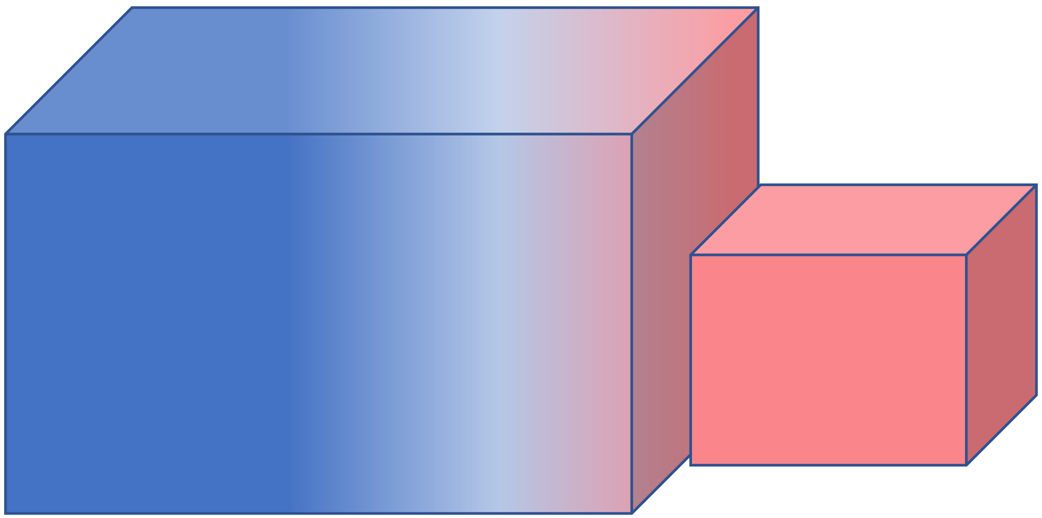
→ many problems / disagreements on the exact process of reaction



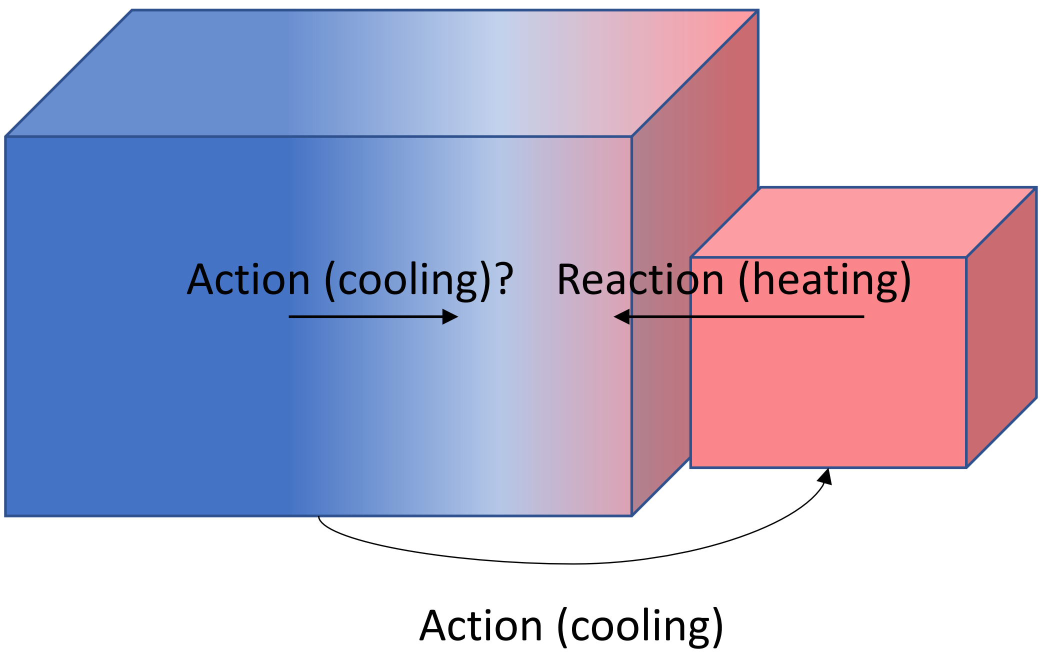
T_1 = beginning of causal interaction



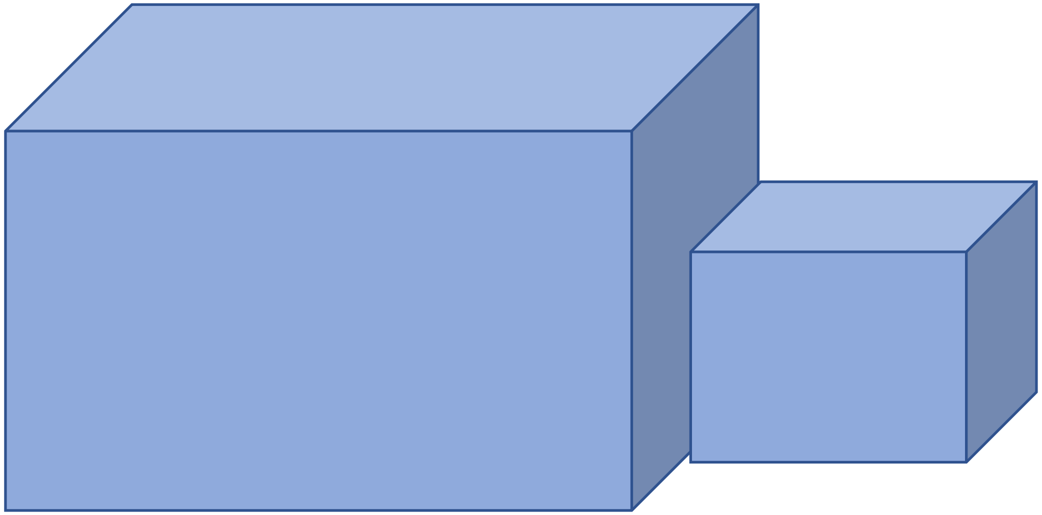
T_2 = new distribution of hotness and coldness



T_3 = second action/reaction process

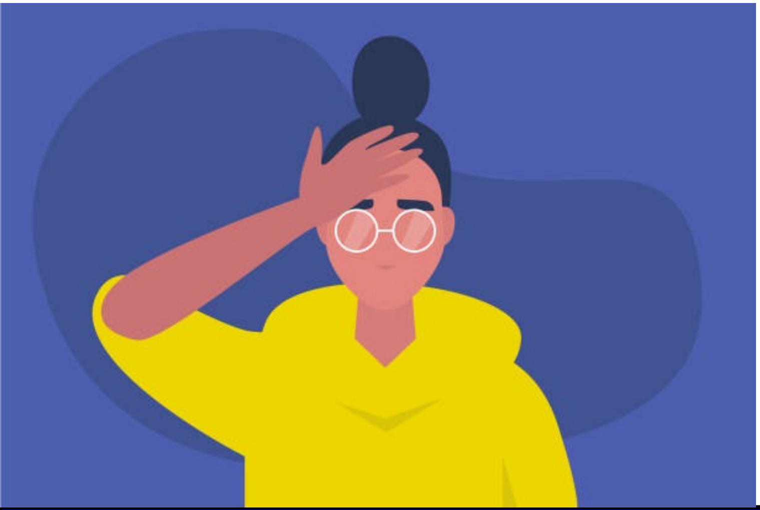


T_n = state of equilibrium



But what about cases where qualities are *evenly* distributed?

- So difficult to explain that some authors simply chose to *deny* such phenomena and tried to reduce them to cases of unevenly qualitative distribution



Richard Swineshead, *Book of Calculations* [*Liber calculationum* (Venice: 1520), f. 34r]:

"[Regarding the argument from experience] it must be said that a cold hand placed on a warm head is heated by it and cools it because small hot bodies go out from the head, enter the pores of the hand and heat its weak parts, which is the reason why the hand feels warm. Similarly, cold bodies present in the hand or being released from it generate coldness in the weak parts of the head or flesh. By this way, all the alleged experiments involving natural actions between elements can be solved. Whenever we feel a certain reaction, there exists a difformity in the mixed bodies, by which a part of one body can act and another part can undergo reaction".

The 'Oxfordian' Solution

● Reaction is impossible when *only two* opposite (evenly distributed) qualities are involved
→ *cf*. later criticisms of this view by Pomponazzi

● Richard Swineshead and John Dumbleton defend a corpuscularist account of cases where only two qualities are present: these are not true cases of reaction between equal qualities

⚠ The Oxford Calculators are generally opposed to the Parisian model, but there are a few differences between their accounts
→ William Heytesbury's position (*cf*. Toletus' classification of possible solutions)

● Defense of a '**four qualities model**': where there seems to be an action/reaction process between two equal qualities, the two other elementary qualities are always involved. For instance, hot iron plunged into cold water is not really cooled, but it loses dryness and acquires wetness.
→ Reaction *is* an action of the patient on the agent, but not between the same qualities


Walter Burley
Oxford
William Heytesbury
John Dumbleton
Richard Swineshead
Paris
John Buridan
Nicole Oresme
Marsilius of Inghen
Albert of Saxony
≈ 1350
Pavia
Padua
Bologna

The 'Parisian' Solution : the Double Property Model

→ Defended by John Buridan; Nicole Oresme; Albert of Saxony; Marsilius of Inghen

● Every quality has two distinct properties : **activity** and **resistance**

● The degree of activity proper to a quality is not equal to its degree of resistance
Example: hotness is highly active but has a very low degree of resistance

● This model was perfected and systematized by Marsilius of Inghen (*Quaest. De gen. et corr.*)

Activity	Resistance
1. Hotness	1. Dryness
2. Coldness	2. Wetness
3. Wetness	3. Coldness
4. Dryness	4. Hotness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The Italian Context

→ From the end of 14th century onward, important reflections on the theme of reaction were developed in northern Italy

→ Direct influence of the English tradition on Italian authors (e.g. Giovanni Casali, Paul of Venise, Gaetan of Thiene, Giovanni Marliani)

- Discussed by natural philosophers but also *physicians*

    → philosophical training strongly connected to medical formation in Italy

    → important for explaining food digestion and effects of medicines on the body (e.g. James of Forli)


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The Quantification of Power

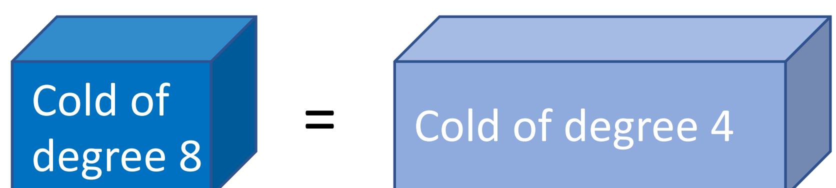
● Evolution of the debate in the new calculatory framework: use of numerical values to quantify ‘power’

→ The *power* of a thing is often taken as a product between different values:

* *the **intensity** of qualities*
* *their **extension** (volume of a body)*
* *the material **density** of the body*

● Noticeable change in the grammatical use of the term ‘power’, employed as a *mass term*
→ a body can be said to contain more power than another [*plus habet de potentia*…], according to a certain degree [e.g. *x habet potentia ut 8* (degrees)]

● Leads to a distinction somewhat analogous to the modern distinction between **temperature** (intensity of a quality) and **quantity of heat**



Conservation of Quantities

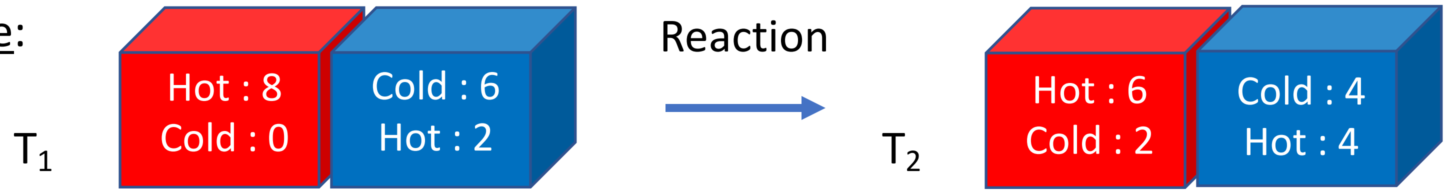
- The Parisian 'double property' model is hotly debated by Italian philosophers as opposed to the Oxfordian model ("*What cannot act cannot resist in any way*", William Heytesbury)

→ Activity and resistance are one and the same thing. Cannot be different in the same quality

→ Speaking of action and reaction, or force and resistance is just speaking about an interaction of quantities

- Action and reaction are increasingly defined as an *exchange of power*, and are sometimes described as an interaction in which the total quantity of quality (or power) remains *constant*

<u>Example</u>:



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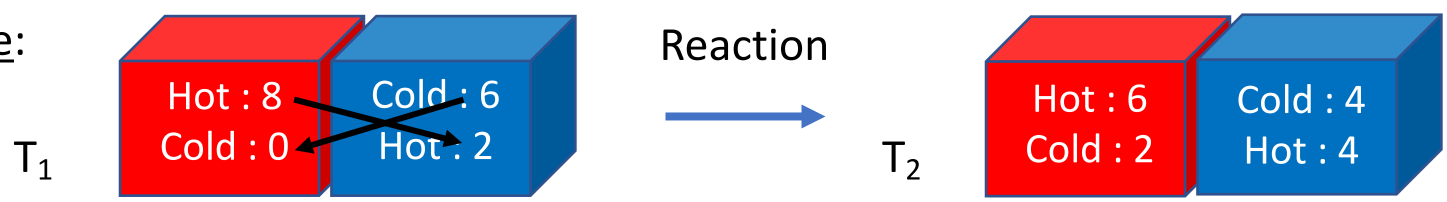

Conservation of Quantities

● Not everybody agrees that the total quantity of power is conserved, but this tendency to regard reaction as a type of quantitative *exchange* results from two main ideas:

1) The intensification of a quality is usually measured owing to a *relative* scale

→ given the convention that a maximally hot body is 8 degrees hot, a warm body of 6 degrees will have 2 degrees of coldness ; a temperate body has 4 degrees of hotness and 4 of coldness... => The ***total sum*** of qualitative degrees in a body is **constant** (8 degrees)

→ In the 14th century, this convention for representing qualitative intensities was adopted by the Parisian school (Buridan/Marsilius mainly, but also Oresme/Albert — although from a different ontological point of view) as well as the Oxfordian tradition.

2) Cold is defined as a real/active quality, not as a *privative* property.
→ when a body is cooled, it really acquires something

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≈ 1500-1520
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Paul of Venice
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Gaetan of Thiene
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Casali
Pomponazzi
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Agostino Nifo
Domingo de Soto
Toletus
Rome
Francisco Valles
Coimbra
Madrid

Reaction and Resistance in the Late 16th Century: Two Important Ideas

1) Toward 1560, the physician Francisco Valles, taking part in these discussions, defended the view that the rule of action and reaction is universal (*pace* Aristotle)

→ Cases where the patient seems to be entirely assimilated by the agent are just cases of *imperceptible* reactions

2) In 1570, Giovanni Paoli Pernumia includes *local motion* in the types of change involving reaction (≠ Buridan, Oresme and virtually every author before the 16th century)

→ Growing interest in the 16th century for mechanics

→ Distinguishes between **positive reaction** (qualities) and **privative reaction** (local motion), the latter being *not an action* strictly speaking, but a deprivation of action (foreshadowing *inertia*). This distinction will be discussed by the Coimbrans, whose works served as textbooks in most European universities


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Impact and Consequence on Modern Mechanics

- No one provided an entirely satisfying solution to the problem of reaction as to the interactions of qualities (esp. in the case of evenly uniform bodies)

- Gradual decline of the notion of 'action' in the 17th century, replaced by a description of motion as a quantity which can be transmitted from one body to another

→ Paradigmatic example of the new 'mechanistic philosophy' : Descartes gets rid of the concepts of actions and agency, and eliminates powers from his ontology

→ According to Descartes, in a collision between two bodies the *quantity of motion* (= size*speed) is conserved. Its direction changes, but it is *not 'caused'* by an action

Cf. Descartes' third law of motion: *"When a body impels another, it cannot give it any motion without losing at the same time the same amount of its own motion; nor take from it any, without augmenting its own by the same amount".*

Impact and Consequence on Modern Mechanics

- Modern mechanics took up the medieval reflections on reaction as the conservation of two quantities during an interaction between two bodies

- Modern mechanics also kept the idea of 'power' as an actual quantity to which numerical concepts can be associated

But:

→ Essentially retains the case of local motion, and seeks to reduce qualitative action to it (development of corpuscular or atomist conceptions of bodies and qualities)

→ No longer attributes any dispositional character to the terms 'action' or 'power' which are still employed in 17th-century treatises on motion

New Relations between Powers and Laws

- Modern mechanics was built on many materials inherited from the late Middle Ages

→ Descartes' third law of motion, just like Newton's own third law (the so-called law of reaction), are examples of ideas taken up from results already available, but integrated into a new framework

- The reduction of qualities to a corpuscular ontology entails a change in the relation between causal powers and laws

→ Whereas laws of nature were grounded on powers in the medieval perspective, what a thing can and cannot do, from the 'modern' point of view, depends on the laws of nature

- The notion of power is now devoid of any modal content : it does not denote a disposition, or a possibility, but an actual quantity. Heat, for instance, is not the power of generating motion, but motion itself (more precisely a certain quantity of motion)

New Relations between Powers and Laws

● Consequently, the laws of nature have now a stronger explanatory role

→ For 'Aristotelians', laws were only general descriptions of causal powers inhering in substances. For this reason, they are not contingent (they directly supervene on causal powers)

→ In the new mechanistic framework, laws could have been different. *Cf.* Descartes: all things being equal, laws *could have been different* (***including the law of reaction***)

Example: Newton's law. The force of gravity between two bodies could have been inversely proportional to the cube of the distance, and not to the square of the distance

→ Shift in the concepts associated with explanation. *Cf*. Descartes: *Laws are 'causes'*

● From the modern point of view, laws describe external (contingent) relations of necessitation between properties (= only *nomological necessity*). Discovering a law means discovering something new (not a mere generalization of descriptive statements about powers)

Summary

Four stages:

1) Powers are conceived as qualitative dispositional properties, which cannot really be described in quantitative terms (*before 1320*)

2) Mathematics is applied to qualities so as to study the rules of motion (action and reaction)
→ *hybrid phase*: still a qualitative framework, an ontology of real powers, but analyzed in quantitative terms; powers are now conceived as actual quantities (*1320 — ca. 1550*)

3) The laws of reaction are defined as universal laws of conservation of quantities, true and without any exception, *including the case of local motion* (ca. 1550/1560 —)

4) Those results are integrated into a corpuscularist/atomist framework, where the modal content of powers is now fully eliminated, and reaction becomes restricted to local motion
→ *final phase*: new role played by the concept of laws of nature (ca. 1600/1620 —)

The problem of reaction was only one factor among others in the evolution of the concept of power in modern philosophy

● The emergence of atomism (rediscovery of ancient texts, plus new versions of atomism)

● A new ontology of mathematics as constituting the deep structure of reality
→ cf. Metaphor of the two books. By contrast, mathematical are not conceived as mind-independent in Aristotelianism (tools used by the mind)
→ Frequent use of ‘laws’ are indicative in this respect. The term connotes the idea of a contingent institution, but also something constitutive of reality. Medievals rather used ‘rules’ (i.e. of motion), which has a more instrumentalist connotation

● A new conception of science. More and more experimental

● Correlatively, invention and use of technology in scientific practice in the 16^{th} and 17^{th} centuries, giving rise to new theories of matter