



Uniwersytet
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Towards a Contemporary Ontology

The New Dual Paradigm in Natural Sciences: Part II

Module 2 Class 1: The Aristotelian theory of the four causes

Course WI-FI-BASTI2

2014/15

Introduction

Introduction to the Class 1: “The Aristotelian theory of the four causes”

Course modules

| Modules | Topic | Suggested Readings |
|----------------------|---|---|
| SECTION ONE | | |
| 0. | <i>Introduction and Course Overview</i> | |
| 1. | QFT: an evolutionary interpretation of nature from cosmology to neuroscience | Refs.: 1-5. |
| 2. | QFT in fundamental physics and the Aristotelian-Thomistic ontology of nature | Refs.: 6 , chs. 5-6; 7-8. |
| SECTION TWO | | |
| 3. | Formal philosophy and formal ontology | Refs.: 9-11. |
| 4. | The formal ontology of the conceptual natural realism (CNR) | Refs.: 12-15. |
| SECTION THREE | | |
| 5. | The formal ontology of the natural realism (NR) | Refs.: 16-18. |
| 6. | The duality algebras/coalgebras in CT and the notion of Universal Coalgebra | Refs.: 19-24. |
| SECTION FOUR | | |
| 7. | “Modal logics are coalgebraic”: an application to NR and to the duality logical/ontological truth | Refs.: 24-28. |
| 8. | <i>Conclusions</i> | |

Main Contents of the Module 2

- in the second module we summarize the Aristotelian-Thomistic physical ontology of the four causes in order to suggest that it is the **descriptive (not yet formalized) ontology of QFT as a quantum thermal field theory**, and fundamental physics both in the relativistic realm (microphysics) and in many body physics (macrophysics).
- The contents of the **two classes** of our module are:
 - 1) The Aristotelian theory of the four causes
 - 2) Aquinas' metaphysical development of the Aristotelian ontology

Bibliography

Bibliography of the Module 2

Bibliography

- Main References:

1. G. BASTI, *Philosophy of Nature and of Science. Vol.I: The Foundations*, Rome 2002 (English translation for student use only), chs. 5-6 [[attached](#)].

- Other References:

- G. BASTI, «Intelligence and reference. Formal ontology of the natural computation». In: *Computing Nature*, G. DODIG-CRNKOVIC AND R. GIOVAGNOLI (Eds.), Springer-Verlag, Berlin Heidelberg, 2013, pp. 139-159 (Sapere, 7) [[attached](#)]
- G. BASTI, «The quantum field theory (QFT) dual paradigm in fundamental physics and the semantic information content and measure in cognitive sciences», in *Proceedings of AISB 2014 Convention. Symposium on: "Representation of Reality: Humans, Animals and Machine"*, London, April 1-4, 2014 <<http://doc.gold.ac.uk/aisb50/AISB50-S23/AISB50-S23-Basti-paper.pdf>> [accessed 24 May 2014] (in press) [[attached](#)]

Class 1

The Aristotelian theory of the four causes

Background: the Aristotelian criticism to Plato's metaphysics of the form participation (μεθέχισις) I

- The Plato's theory of «The One and the Dyad», as ultimate foundation of its metaphysical doctrine because it wants to justify the passage from the One to the multiple Ideas, belongs to his **unwritten doctrines** to which Plato entrusted his most important **metaphysical doctrines**, as he himself stated in his famous *Seventh letter* (344 c):
 - "Every serious man in dealing with really serious subjects carefully avoids writing." In the same letter he writes (341 c): "I can certainly declare concerning all these writers who claim to know the subjects that I seriously study ... there does not exist, nor will there ever exist, any treatise of mine dealing therewith." Such secrecy is necessary in order not "to expose them to unseemly and degrading treatment" (344 d).
- The core-doctrine of «The One and the Dyad» is the main object of Plato's discourse *On the Good*, where identified with the One – a doctrine anticipated as the term of the knowledge ascension of the *Republic* dialogue from the **physical realm to the intellectual realm**: the *noesis of the One* – reported in an absolute convergent way from several Authors such as Aristoxenus and Alexander of Aphrodisias, even though the main source of this unwritten doctrine is Aristotle himself.
 - Simplicius quotes Alexander of Aphrodisias, who states that "according to Plato, the first principles of everything, including the Forms themselves are One and Indefinite Duality (ἡ ἀόριστος δυάς), which he called Large and Small (τὸ μέγα καὶ τὸ μικρόν)", and Simplicius reports as well that "one might also learn this from Speusippus and Xenocrates and the others who were present at Plato's lecture on the Good".

Background: the Aristotelian criticism to Plato's metaphysics of the form participation (μεθέχισ) II

- In *Metaphysics* Aristotle writes: "Now since the Forms are the causes of everything else, he [i.e. Plato] supposed that their elements are the elements of all things. Accordingly he took the **Great** and the **Small** [i.e. **the Dyad, or (>,<) relations**] as the material element of Forms or Ideas and the **One** (τὸ ἓν), as the formal cause: indeed, he thought that Forms and Numbers derive **by participation** (κατὰ μεθέχισιν) of Great and Small in the One(...) " (987 b).
- "From this account it is clear that he only employed two causes: the formal cause, and the material cause; for the Forms are the cause of the essence in everything else, and the One is the cause of it in the Forms. He also tells us what the material substrate is of which the Forms are predicated in the case of sensible things, and the One in that of the Forms - that it is the Dyad (ἡ δυάς), the Great and Small (τὸ μέγα καὶ τὸ μικρόν). Further, he assigned to these two elements respectively the causation of good and of evil"(988a).
- The antinomy intrinsic to Plato's theory of μεθέχισ consists in the inderivability of Dyad from One, so synthesized by Aristotle. Duity, the principle of **difference**, cannot be derived by Unity, the principle of **identity**, just as «2» from «1». «2» indeed is not only two times 1, i.e., «1 1» but also the **formal unity** of the double unit, i.e., the Duity making «2» the double unit «1 1». So the «One» and the «Duity» are inderivable from each other, just as «1» and «2» are two **prime numbers**. In Aristotle *Metaphysics* words:

Background: the Aristotelian criticism to Plato's metaphysics of the form participation (μεθέχισ) III

- Each of the units that compose the Dyad will have to presume a prior Dyad, but this is absurd. In other words, by virtue of what is the number, which is compound, something unitary? (991b31-992a,1).
- (...) The Dyad itself will derive from the sum between another 'one' and the One in itself. But, if this is so, it is not possible that one of the two principles from which the number originates is the *indefinite* Dyad: the single unity (μόνας) engenders a numerical unit (μία) but, in this way, the Dyad will never be derived (1081b, 24. See also: 1090b, 22).
- The primality of «1» and «2» in arithmetics is thus strictly related with the irreducible character of «form» and «matter» as **first principles** in the Aristotelian ontology (**hylomorphism**), against **Plato's idealism** failure of reducing the latter to the former. On the other hand, Euclid's **fundamental theorem of arithmetics** («each natural number is the product of a finite set of prime numbers») matured in the same Academy environment.
- The relationship with the modern issue of set-theoretic foundation of arithmetics and hence with **Hilbert's «second problem»** becomes immediately evident, when we recall that the negative answer to Hilbert's issue by **Gödel incompleteness theorems** depends directly on **Gödel coding via prime numbers!**

The Aristotelian ontology of the natural realism

- As we anticipated in the previous class the Aristotelian solution of Plato's antinomy was to introduce the **existence modality** making dynamic the Platonic *χωρα*, i.e. by making it a *δύναμις*, «a being finite and ever always different» like the decimal expansion of the just discovered **irrational numbers** from which **infinite periodicities** and hence **infinite forms intended in a dynamical way** can be educed, i.e., **made actual** from matter potency, by an **acting causality**, and **remain stable, ordering** their matter substratum, till the action of the cause **persists in time**.
- In other terms, Aristotle gives a **causal foundation** of **physical natures/essences (natural kinds: genera, species)** that are therefore distinct from **the logical universals** abstracted by them, so to pass from the ontology of the **logical realism** of Plato – in which persists Parmenide's identification of the logical and the natural realms, i.e. **ideas** are also **essences** – into the ontology of the **natural realism**.
- The Western Encyclopedia of sciences, based on the distinction among **physical (natural), mathematical, logical and metaphysical sciences** is thus essentially an Aristotelian heritage.
- In this sense, the «four causes» in Aristotle's **natural ontology** are as many «why's» (*διότι*) that the natural philosopher must answer **for determining** natural bodies («**essential or substantial forms**») and/or natural processes («**accidental forms**») **existence**, so to make it **logically predictable**, as far as the **causally founded ontological/logical laws** can be abstracted (→ distinction between **causal/ontological** necessity/possibility and **ontological/logical** necessity/possibility, with the relative modal bi-conditionals/conditionals in sentential logic).

The four causes: the acting causality

- The **acting causality** exerted by physical bodies: it can also be defined as «the **efficient cause of**» (= «a cause having as an effect that»), whose main effect as **forces** is the **eduction of a form from the matter substratum**, that is, a correlation (ordering) in the disordered movements of the elementary particles constituting the material substratum of everything. From this, the other effects are:
 1. **Local movement (= acting cause as moving cause)**, essentially the moving causality of Democritus' mechanics, moving the **elements**, the elementary particles of air, water, earth, and fire, of which the material substratum of all earthly bodies is constituted. The local movement (κίνησις) of bodies is the basis of all other derived alterations, qualitative and quantitative, of physical bodies.
 2. **Intensive alteration** (μεταβολή) of the qualitative properties of the material substrate of bodies. These “qualities” correspond, in substance, to the **active-passive dispositions** of elementary particles constituting the bodies to dynamically interact with each other (= active-passive qualities (heat, cold, humidity, dryness) among which heat is the main one). These qualities are at the basis of sensible qualities (tastes, smells, colours...), and for this reason they are defined also as **hidden qualities**. Their function, is effectively, very similar to the four fundamental forces (electromagnetic, gravitational, weak, and strong) of our fundamental physics.
 3. **Extensive alteration** of the extensive quantities (dimensions, weights, etc.) characterizing a body.

The four causes: the material causality

- The **material cause** can be defined as the **passive** material substrate of the action performed by the acting causality. Since the **material cause** and the **moving cause** are considered by Aristotle the **initial causes** of the local motion and hence of all the other physical alterations, their modern equivalents are two particular **variable quantities**, i.e., the **position**, that varies in relation to the variations of the first quantity, namely the **momentum**. More precisely, in the equations of classical mechanics, **position** and **momentum** (mv , that is tightly bound to the kinetic energy, $\frac{1}{2} mv^2$) constitute the so-called **canonical variables** of the motion equations of classical (Newtonian) mechanics.
- The relationship between the Aristotelian **initial causes** (acting and material causes) and the modern **initial conditions** (momentum and position) of the classical mechanics exemplifies at best the modern difference between natural science (*cognitio certa per leges*) and natural ontology (philosophy) (*cognitio certa per causas*).

Difference with atomism

- The basic ideas of Aristotle potentiality of matter is that it can be **actualized in one form at a time**, so to be deprived of many others (**principle of privation**).
- This number will be **finite** for all matter that Aristotle calls «secondary» (**secondary matter**), which is made of particular combinations of elements at varying degrees of complexity (in present physics, they can be situated at the sub-atomic, atomic, molecular levels, considering simply «microscopic» physics).
- For example, in the words of modern condensed matter physics (molecular physics), «organic matter», the macromolecular compounds of carbon stand «in passive potency» to an undefined, but **still finite** number of forms of cells and therefore of organic tissues that are compatible with their nature. Conversely, inorganic matter, so-called «mineral», does not stand «potentially» to organic compounds, but **to finitely many** other inorganic compounds that cannot be obtained from organic macromolecules.
- Of course, lower is the complexity level of secondary matter compounds, higher is the number of more complex compounds to which these types of secondary matters are in potency. Till here however no essential difference there is with an atomistic notion of matter. Where the difference appears – and at the same time its connection with modern quantum physics in the relativistic (special relativity) realm – is when we arrive at the level of **elementary, non composed particles** of earth, water, fire, and air for Aristotle, quarks and leptons for the actual **standard model** in quantum fundamental physics.
- **What is common to both theories** is that the elementary particles for Aristotle - but also in quantum physics for the relativistic effect: the distinction between «rest mass» and «kinetic mass» - can **reciprocally transform into each other**. This means that the elementary particles, Democrite's «atoms» are not the ultimate level of matter substrate. Beyond this there is a purely **potential substrate in potency** to the same forms of elements and hence **in potency** as to **an indefinite number of forms**, of organization of element compounds. If these are different forms of secondary matters, this purely **potential substrate without any form** is denoted by Aristotle as **prime matter**, something very close to QV of QFT.

The prime matter as endless changing of matter

- This resemblance becomes much more **intrinsic** when we consider that this potentiality to the **reciprocal transformability** is what makes the matter of Aristotle a **dynamic entity** a δὴναμις, (*dynamis*), and not something **static** because made of unchangeable elements like Democritus' atoms, but also like Plato's χῶρα, with respect to which the forms are **extrinsic** like seals as to the wax or patterns as to the sand.
- This property of «**endless changing**» of the element substrate, is not only at the fundamental level of the «originary melt of elements», their μίγμα, as Aristotle denoted it by giving a modal meaning to this Anaxagora's term at the basis of its ontology that in «everything there is the seed of whatever else» (ἐν παντί, πάντα, «in tutto, tutti») is present at all levels of secondary matter organization, constituting the **potentiality to change** of the matter substrate at whichever level of the substrate organization.
- All notions that make the resemblance of the notion of prime matter as **endless changing** intrinsic to whichever matter substrate very close **to the unavoidable fluctuations of the QV** intrinsic to any quantum system in QFT. In this sense the infinite forms of matter ordering to which prime matter is in potency, are **educible from matter** like as many **stable states** as long as the acting causality on matter persists in time. In this way, two fundamental passages we comment also for explaining the notion of the «formal causality» are essential:

The infinity of prime matter I

- “The natural form is the end (τέλος) and the “that-because-of-which” (τὸ ὅυ ἔνεκα). Indeed, since the (element) change is in itself **endless**, we also need an **end** and a **that-because-of-which** such an end is achieved” (*Phys.*, 194a, 27-29).
- “When the agent is present, the object undergoes a change. But **when the habits are present**, the object is not becoming any longer, rather it **is**. Now, the acts (= forms) and the final states of change are a kind of habit (*De Gen. et Corr.*, I, 7, 324b, 15-18).
- Where «habit» (ἕξις) in the Aristotelian jargon means a «stabilized disposition to change» so to become a (relatively) stable property of an object.
- All this is confirmed through a metaphor by which Aristotle explains in which sense the potentiality of prime matter to infinite forms has to be intended. Matter is in potency like «A day *is* or a race *is* because they always become something different», so that the potential infinite of prime matter is «**a being *finite* and yet always different**» (*Phys.*, III, 206a, 6, 23.34) , something very close to G. Cantor’s definition of potential infinite in modern mathematics as «the indefinite variation».

The infinity of prime matter II

- To sum up, the potential infinite of prime matter corresponds to what today can define as an **infinite random sequence of unstable states** (the «being *always* different») of Aristotle, generated by a **finite set of elements** the («the moments of a day, or the runners of a race») in which, by definition, an infinite set of **periodicities** and hence of «forms» can be educed, stabilized. In symbolic dynamics, given the **infinite random sequence** that can be generated by a **finite set** of alphabet letters:

XCGDXWQCOXUIZWNPFQYTRQWEXCVU....

- Several finite random subsequences (words), such as the following «XCGDXWQCO» can be «cutted away» and made **stable**, i.e., because we are speaking of something anyway becoming, **periodic**

|XCGDXWQCO|XCGDXWQCO|XCGDXWQCO|

- This is confirmed by the famous Aristotle saying in his *Metaphysics* «**the form cuts**»: ἡ ἐντελέχεια χωρίζει, where *entelecheia* literally means «something having in itself its ends», as an **effect** of an impinging acting causality on the material substrate, i.e. as an **act**. This indeed justifies the Scholastic translation of the term ἐντελέχεια as **actus, forma ut actus** «form as an act», and the connection with the already quoted notion of form as «habit» or «stabilized disposition to change».
- The connection with the phase coherence domains like as many SSB's in the QV of QFT as **entangled state system/thermal bath** is evident, like it is evident the connection with the notion of quantum systems in QFT as **open systems**. The Aristotelian dynamics is indeed a **thermodynamics**, just as QFT is a thermal field theory! So the acting causality of Aristotle is the ontological counterpart only of the notion of **initial condition** of classical mechanics but also of **boundary condition** of thermodynamics, even though these modern distinctions are destined to become meaningless in the QFT as fundamental physics.

The four causes: the formal-final causality

- **The *formal* and the *final* causalities** are certainly the two farthest causes from modern mechanics and from the mathematical formalism of modern physics. Roughly speaking, we can say, in Kantian terms, that modern science with its **representational epistemology** substituted the **formal causality** intrinsic to dynamics, with the **mathematical formalism** imposed to the raw data by the human mind.
- Therefore, just for this cultural distance, and for the infinite misinterpretations of this Aristotelian doctrine by supporters and detractors during the modern age, it is extremely interesting to deepen what effectively Aristotle intended with it, as emerging from texts.
- The first step to avoid misinterpretations, is to realize that the formal and the final causality **are distinguished** only in the **intentional acts** of intelligent agents like humans, in the sense that the intended goal is **pre-existent and ordering** the physical process aimed at **effectively, concretely** reaching it. In physics, formal-final causes are **indistinguished** in the sense that **formal causality** emerges only at the end of the process **as the ordering** of the acting and material causes «because of which» a new, unpredictable **ordered, stable state of matter** is effectively reached at the end of the process.
- In this sense, if the acting and material are the **initial causes** determining a process the **formal cause is the final (unintended) cause** fully determining **a-posteriori** it, as far as it cannot be pre-determined **a-priori** by a known logical implication (law). → ontological and epistemological distinction between **intentional end (=goal)** and **natural end (=attractor)** of a dynamic **irreversible** process.
- To sum up, if there exists a relationship between **initial causes** and **initial conditions**, it is evident to the relationship between **the formal-final causes** and the **boundary conditions** of a dynamic process, overall when we consider that for Aristotle dynamics is essentially a thermo-dynamics. No dynamic system is for him a **closed system**.

Aristotle's characterization of formal causality I

- Three are the main characters of a **physical form** as intrinsic **determining principle (cause)** of a physical body/process:
 1. **Totality principle as irreducible to the summation of the composing parts.** That is, a physical form is the **intrinsic principle of ordering** which makes it possible for the **totality of the parts** in a body (i.e., physical entity), or in a proposition (logical entity), to be different from the mere **summation of the parts** (*Met.*, 1041b, 10-13). To use an example given by Aristotle, the pronunciation of a word, e.g., “who”, is different from the mere sum of the pronunciation of its individual letters “double-u-eich-o”. So a body, is different from the mere **aggregate** of its elementary components: it has an intrinsic **dynamic ordering of the parts** from which a new **more complex entity**, with **completely new physical properties**. To use famous Anderson's statement quoted in previous classes: “more is different”.

Aristotle's characterization of formal causality II

2. **Stable final state of an irreversible dynamic process.** The **final state**, that can be more or less ordered in comparison with the starting state, to which a physical process is irreversibly oriented. In modern kinematics and hence in statistical thermodynamics it corresponds to the **attractor** of a dynamics in its state space.
- “The natural form is the end (τέλος) and the “that-because-of-which” (τὸ οὐ ἕνεκα). Indeed, since the (element) change is in itself **endless**, we also need an **end** and a **that-because-of-which** such an end is achieved” (*Phys.*, 194a, 27-29).
 - The example that Aristotle gives elsewhere of the drop of water is particularly significant in the light of our previous discussion of DWQ bosons in QFT. In the drop of water the disordered motion of droplets inside it is **dynamically ordered** inside the spherical form of the drop generated by the dynamic interactions of the droplets at the drop surface. For Aristotle it is geometry emerging from dynamics! The exact contrary as to Democritus and Newton mechanics!
 - In this sense, Aristotle speaks also about form as «intrinsic limit» (πέρας) and «intrinsic threshold» (ὄυδος) of a physical process, giving another example very significant for QFT: the spontaneous growth of a crystal (see Aristotle, *Phys.*, 212a, 34 and Aquinas' commentary, *In Phys.*, IV, vii, 479-482). All this is synthesized in the famous Aristotle's denotation of a natural form as *entelechia*, ἐντελέχεια, literally, “what-has-an-end-in-itself”, translated into Scholastic Latin as *actus, forma ut actus* (form as act) for emphasizing the dependence of a natural form (i.e., a form in a matter) on an acting causality, and hence on a causal agent.

Aristotle's characterization of formal causality III

3. The “catastrophic”, “not proportioned” effect of a *small change* of the initial agent and material causes. This confirms that the Aristotelian concept of “formal causality” is deeply bound to what we now define in physics as **dynamic instability**, typical of “non-linear systems”, as far as violating the essential proportional character of the Newtonian “second law” ($f = ma$), so to make the system non-integrable, even though differentiable.
- The term I used of “catastrophe” is a technical term in contemporary physics for denoting such phenomena, of strong dependence on small changes of the initial conditions, even though it does not want to be a quotation of the so-called “catastrophe theory” of R. Thom (1990), absolutely insufficient in our case, because of the energy openness of the system, as we already emphasized. In this case indeed the system does not satisfy the **structural stability** condition (i.e., no Lyapunov energy function can be defined) as the true inventor of the theory, V. Arnol'd (1990) emphasized and M. Viana (2000) formally demonstrated. The stability here concerned is indeed **far from equilibrium**, proper of non-linear thermodynamics (i.e., Prigogine's, **dissipative structures**: See Basti 2012, §§ 2.6-2.7 for an introductory discussion and the bibliography here quoted. As we see in the next classes, QFT constitutes the fundamental physics of all these phenomena. Anyway, to conclude, this is the Aristotelian quotation connecting the formal causality to the strongly non-linear (thermo-)dynamic systems.
 - “Small changes cause larger ones, not in themselves, but when they occur with a change of ‘principle’. Indeed, principles are small in their dimensions, but large for their potentialities and, accordingly, this is what makes them principles: being the cause of several things and having nothing higher than themselves” (Aristotle, *De Gen. An.*, V, 788a, 10-15).