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"SO MUCH WORSE FOR THE FACTS(?)" – 14TH-CENTURY NATURAL PHILOSOPHERS AND THE COMMON EXPERIENCE OF REACTION[1]

INTRODUCTION

At the beginning of the twentieth century, the French physicist Pierre Duhem decided to look into the texts of medieval manuscript codices, covered with dust of centuries, in search of the roots of the ideas developed by such coryphaei of modern science as Copernicus and Galileo. On the basis of these texts he concluded that the firm foundations for the Scientific Revolution of the seventeenth century were laid already in fourteenth-century scholastic natural philosophy. With his monumental work, *Le système du monde*, Duhem introduced into the history of European science the hitherto unexplored area of medieval philosophy of nature (Duhem 1906–1959). Eminent scholars of the next generations, such as Alistair Crombie, Anneliese Maier, Marshall Clagett, and Edward Grant, to mention only a few, shared Duhem's belief that concepts proposed and developed by fourteenth-century natural philosophers anticipated ideas presented in early modern physics (Clagett 1959; Crombie 1959; Grant 1952, 1964, 1966, 1996). On the other hand, there have been many historians of medieval and early modern science who have argued that seventeenth-century physics is in no way a direct consequence of medieval natural philosophy, even though many of

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the ideas and solutions that are to be found in the latter are strikingly similar to concepts forming the core of early modern physics.[2]

In fact, it has not been established yet whether the seventeenth-century Scientific Revolution was an effect of earlier scholastic disputes or not. Results of recent research have revealed important discrepancies between fourteenth-century natural philosophy and early modern physics. This does not mean, however, that the efforts of historians of science to answer the above questions were in vain. Their research resulted in the discovery of many intriguing and sometimes unexpected aspects of medieval natural philosophy. Thanks to their work, many gaps have been filled in the complex picture of the advancement of human ingenuity. The purpose of the present paper is to fill yet another gap in this picture.

Both the researchers who accept the emergence of early modern science as evolutionary and those who reject this characterization have recognized that the use of mathematics in describing and solving problems of physics is a basic criterion for establishing the originality of medieval thinkers – especially in the field of the so-called "science of local motion". Thus, historians of fourteenth-century philosophy focused their interest mainly on the achievements of the Oxford Calculators and their followers in Paris and other medieval universities. As a result, there have been numerous publications on the "science of motion", i.e. the formulation and exploration of the "new rule of motion" and the "mean speed theorem" (known also as the "Merton rule") (Crosby 1955; Jung 2022, 37–78; 2020; Murdoch 1969, 215–54; Podkoński 2019; Sylla 1991).[3] In the present article, however, I shall focus on a different aspect of fourteenth-century natural philosophy, an aspect recognized as innovative already several decades later by the thinkers of the intellectual milieu from which arose Galileo Galilei himself, along with others. In what follows I shall present how fourteenth-century natural philosophers addressed the phenomena of everyday experience that, at first sight, seem to undermine the basic principles of Aristotle's philosophical system. The reader will be shown a scientific view of the world shared by most natural philosophers of the fourteenth century and, as a consequence, will see how a dogmatic attitude about a generally accepted worldview could influence the progress of science.

It was Stefano Caroti who in his excellent pioneering articles on the theory of reaction in the late Middle Ages pointed out that this theory did not appear in scholastic philosophy any earlier than the beginning of the fourteenth century.

[2] The systematic presentation of different attitudes towards this problem can be found in Murdoch (1991, 153–302).

[3] It is worth noting here that Alistair Crombie was of the opinion that the "mean speed theorem" directly inspired Galileo's accounts of free fall motion; see Crombie (1959, 93–97).

Caroti noted also that in the eyes of Italian philosophers of the *quattrocento*, the problem of *reactio* was one of the hallmarks of the new natural philosophy of fourteenth-century Oxford and Paris.[4] Notwithstanding, explanations of *reactio* proposed by scholastic thinkers were usually dismissed by most of these Italians. Their critique was aimed mainly, and in some cases explicitly, at the conclusions of such *Anglici* as William Heytesbury, John Dumbleton, and Richard Swineshead, as well as against the solutions presented by French scholars such as Jean Buridan and Albert of Saxony (Caroti 1997, 231–33; 1996, 257–374; 2006a, 21–43; 2006b, 13–38). Italian thinkers' increased interest in discussions *de reactione* is reflected, for example, in that manuscript codices of Italian origin containing copies of Richard Swineshead's *Book of Calculations* often include also treatises "On Reaction" by such renowned philosophers as Giovanni Marliani and Gaetano da Thiene. Moreover, in the last Italian printed edition of Swineshead's work, published in Venice in 1520 and edited by Pietro Pomponazzi's student Victor Trincavellus, the text of *Liber calculationum* is followed by an extensive discussion *De reactione* authored by Trincavellus himself (Podkoński 2013, 332).

In his articles, Caroti focused on the use of the analytical tools typical of fourteenth-century Oxford natural philosophy. I intend to emphasize a different aspect of fourteenth-century accounts of reaction, namely the fact that these discussions usually include appeals to common experiences that seemingly confirm the processes of reaction *in rerum natura*. On the basis of the explanations of these phenomena by such thinkers as Richard Kilvington, Richard Swineshead, Jean Buridan, and Nicole Oresme, I examine the innovativeness of fourteenth-century natural philosophy in the context of the then commonly accepted Aristotelian worldview.

1. DIFFERENT UNDERSTANDINGS OF THE CONCEPT OF REACTION IN MODERN SCIENCE AND SCHOLASTIC NATURAL PHILOSOPHY

With respect to the concept of reaction in pre-modern natural philosophy, it is important to point out that fifteenth-century Italian thinkers showed very limited, if any, interest in the science of local motion as developed by Richard Swineshead, William Heytesbury, and other Oxford Calculators – alleged by many historians of science after Pierre Duhem to form the root

[4] The concept of reaction (*reactio*) in this paper refers to a natural phenomenon that involves mutual and simultaneous action of two separate bodies on each other, for example the heating of water by a hot rod plunged into it, which at the same time is cooled by this water.

of early modern physics (Podkoński 2013, 336). For any person acquainted with the basic concepts of Newton's physics it may seem quite contradictory that Italian philosophers of the *quattrocento* were interested in the problem of reaction and not at the same time interested in the science of local motion. After all, in Newton's theory 'reaction' refers to a phenomenon addressed in the third law of motion formulated at the very beginning of the *Philosophiae Naturalis Principia Mathematica*: "To any action there is always an opposite and equal reaction; in other words, the actions of two bodies upon each other are always equal and always opposite in direction." In the scholium to this law Newton provided examples of reaction drawn exclusively from local motions:

> Whatever presses or draws something else is pressed or drawn just as much by it. If anyone presses a stone with a finger, the finger is also pressed by the stone. If a horse draws a stone tied to a rope, the horse will (so to speak) also be drawn back equally toward the stone, for the rope, stretched out at both ends, will urge the horse toward the stone and the stone toward the horse by one and the same endeavor to go slack and will impede the forward motion of the one as much as it promotes the forward motion of the other. If some body impinging upon another body changes the motion of that body in any way by its own force, then, by the force of the other body (because of the equality of their mutual pressure), it also will in turn undergo the same change in its own motion in the opposite direction. By means of these actions, equal changes occur in the motions, not in the velocities – that is, of course, if the bodies are not impeded by anything else. For the changes in velocities that likewise occur in opposite directions are inversely proportional to the bodies because the motions are changed equally. (Newton 1999, 63)

Thanks to this very law it can be explained why, for example, when one pushes a chair by applying some constant force to it, the chair does not move with a specific acceleration (moreover, in some cases does not move at all) – an effect which might be expected on the basis of the second law of motion, taken separately: "A change in motion is proportional to the motive force impressed and takes place along the straight line in which that force is impressed" (Newton 1999, 62).

Still, in scholastic natural philosophy reaction in local motion was generally denied from the outset. For example, Jean Buridan in his question on reaction, included in his commentary on *De generatione et corruptione*, stated authoritatively:

> The first conclusion is that in local motion the mover must not be re-moved by what he does move, since if someone is pulling a weight, he cannot be pulled by this weight. For then he would be moved by contrary motions.[5]

When debating the question of whether reaction is possible, fourteenth- and fifteenth-century scholars generally asked about the possibility of mutual actions between bodies possessing contrary qualities, usually between hot and cold ones; or about mutual actions between bodies characterized by the same quality yet of different intensity as, for example, between something very hot and something lukewarm. In the above-mentioned question by Buridan, for example, we read:

> In all such things the agent and the patient are contrary in some manner, namely, either extremely or moderately, so that one is hot and the other cold, or one is hotter and the other is colder or less cold. And from this it appears at first sight that each of them must act upon the other, because hotness by nature acts upon coldness by corrupting or relieving the cold, and vice versa. Similarly, the hotter and the less hot by nature interact with each other, because the less hot removes the greater hotness, and the greater hotness warms the less hot.[6]

At first sight, then, one could conclude that Buridan intended to confirm that two bodies of unequally intense or contrary qualities will mutually act on one another when in contact. Later in the present paper, however, I shall provide Buridan's own statement where he authoritatively denies such a description of reaction.

It is important to notice here that in Aristotle's natural philosophy we find a concept and a description of reaction only once, in Book I of his *On Generation and Corruption*. In the opening passage of the section described by medieval scholars as "On Action and Passion", Aristotle presented the opinions of his predecessors as follows:

> The traditional theories of the subject are conflicting. For most thinkers are unanimous in maintaining that 'like' is always unaffected by 'like', because (as they

[5] "Prima conclusio est quod in motu locali non oportet movens removeri ab ipso moto, quia trahens aliquod pondus non impellitur ab illo. Tunc enim moveretur contrariis motibus" (Buridan 2010, 145).

[6] "In talibus omnibus agens et passum aliquo modo contrariantur, scilicet vel extreme vel medie, ita quod unum est calidum et alterum frigidum, vel unum calidius et alterum frigidius vel minus calidum. Et ex hoc prima facie videtur quod utrumque debeat agere in reliquum, quia calidum est natum agere in frigidum corrumpendo aut remittendo frigiditatem, et e converso. Similiter magis calidum et minus calidum sunt nata agere inter se, quia minus calidum remittit maiorem caliditatem et magis calidum intendit minorem caliditatem" (Buridan 2010, 146).

> argue) neither of two 'likes' is more apt than the other either to act or to suffer action, since all the properties which belong to the one belong identically and in the same degree to the other; and that 'unlikes', i.e. 'differents,' are by nature such as to act and suffer action reciprocally. For even when the smaller fire is destroyed by the greater, it suffers this effect (they say) owing to its 'contrariety' – since the great is contrary to the small (Aristotle 2001, 7, 323b2-10, 494).

Aristotle mentions here both the mutual (or reciprocal) actions of contrary qualities as well as actions between greater and smaller within the same species. Nevertheless, further on in the same chapter he states unambiguously that it is only the more potent factor that acts during the process of transmutation, the other being totally passive:

> We can now understand why fire heats and the cold thing cools, and in general why the active thing assimilates to itself the patient. For agent and patient are contrary to one another, and coming-to-be is a process into the contrary: hence the patient must change into the agent (Aristotle 2001, 7, 324a10-13, 495).

In fact, the process of reaction as described and discussed by later medieval authors seems to contradict, from the outset, at least two basic principles of Aristotelian natural philosophy:

> 1. the "greater inequality ratio" law (*proportio maioris inaequalitis*) – according to which any change in the sublunary world (i.e. local motion, alteration, or augmentation) is possible if, and only if, the agent is more potent than that on which it acts (i.e. the 'patient');
> 2. the rule "no contraries at the same time in the same thing" (*nulla contraria simul in eodem*) – which seems to be broken when one accepts simultaneous actions of both factors involved in a reaction process. Obviously, in the case of reaction there must be assumed the simultaneous activity of two contrary qualities in the same part of one or the other thing, or within the medium between these agents. (Caroti 1997, 232–33)

A rejection, or rather reinterpretation, of the latter rule was in a sense necessary, and thus acceptable, since according to Aristotle himself in mixed bodies there somehow coexist active contrary qualities.[7] The *proportio maioris inaequalitatis*

[7] In Aristotle we read "it is evident that the combining constituents not only coalesce, having formerly existed in separation, but also can again be separated out from the compound. The constituents, therefore, neither (a) *persist actually*, as 'body' and 'white' persist: nor

law nevertheless was recognized as the one that should be strictly observed, even though is seems to contradict common experience, as Jean Buridan puts it:

> Certain thinkers have stated that a reaction could not take place because action does not result from the [proportion of] equality or from the proportion of a lesser inequality, but only from the proportion of greater inequality. For an agent must dominate over the patient. It is simply impossible that each of the two would be greater or stronger than the other. Therefore it seems impossible that both should act on one another. This opinion is not valid, however, because we can experience the opposite.[8]

It is worth noting here that it is the common experience that lets Buridan to undermine – as it seems – the validity of the opinion that reaction is impossible.

2. CASES OF COMMON EXPERIENCE IN 14TH-CENTURY ACCOUNTS OF REACTION

It must be said here that references to cases of common experience, that is, to universally observable phenomena, is a special feature of discussions of reaction taking place in the fourteenth-century. Appeals to common experience, or in other words real-life instances of reaction, in most cases served as a point of departure for questioning the problem of reaction also in the context of the Aristotelian system. We may find mentions of common experiences in other contexts in fourteenth-century philosophical texts, as for example in discussions of the rules of

(b) are they *destroyed* (either one of them or both), for their 'power of action' is preserved" (Aristotle 2001, I.10, 327b27-32, 505). Walter Burley, an early fourteenth-century philosopher, commenting on this very passage stated unambiguously that a mixed body can produce contrary effects. See Burley's *Utrum elementa maneant actu in mixto* (2007, 323): "Nam a qualitatibus mixtis possunt procedere consimiles operationes, quales procedunt a qualitatibus elementorum. Nam mixtum per suas qualitates potest calefacere, frigefacere, humidicare et desiccare; et consimiles operationes procedunt a virtutibus consimilibus. Ideo dicitur quod elementa manent in mixto in virtute, quia mixtum habet virtutes consimiles virtutibus omnium quattuor elementorum, non quia substantiae elementorum manent in mixto nec etiam qualitates elementorum, sed quia virtutes consimiles."

[8] "Quidam dixerunt quod non posset fieri reactio propter hoc quod ab aequalitate vel a proportione minoris inaequalitatis non fit actio, sed solum a proportione maioris inaequalitatis. Oportet enim agens dominari super passum. Modo impossibile est quod quodlibet aliquorum duorum sit maius sive fortius altero. Ideo videtur impossibile quod utrumque agat in reliquum. Tamen illa opinio non valet, quia contrarium experimur" (Buridan 2010, 145).

local motion.[9] Such cases, however, always appeared among many other, more or less speculative, *a priori* examples that served either to confirm or to deny some thesis derived directly from Aristotle's own solutions or speculations. The problem of reaction is unique in the context of medieval natural philosophy, since it was perhaps the only issue that was not based directly on Aristotle's considerations, but derived from observations of natural phenomena.

The chapter "On Reaction" in Richard Swineshead's *Book of Calculations* actually begins by enumerating such cases. At the beginning of this treatise, Swineshead states presumptively that there can be no dispute that two different (elementary or mixed) bodies can act upon one another at the same time as regards qualities not considered contrary, for instance that fire can act upon water with its heat (reducing or destroying the coldness of water) while water acts upon fire with its humidity (reducing or destroying the dryness of fire). Following this brief declaration, Swineshead introduces his considerations about reaction taken strictly, that is, on the reaction between contrary qualities. He begins with the following cases of common experience:

> It is also argued that reaction is possible according to the same qualities, and this [is confirmed] through experience:
> 1. First, in the case of a red-hot iron rod plunged into water, where the iron rod cools and the water is heated.
> 2. Likewise, it is obvious from the case of cold water poured into boiling water, because the boiling ceases, and the poured water is heated.

[9] In one of Kilvington's questions on the *Physics*, *Utrum in omni motu potentia motoris excedat potentiam rei motae?*, we find the following example: "Item, posito quod aliquis homo trahat unam fabam per unam cordam currendo ita velociter sicut potest, tunc si alius homo tantae potentiae ad currendum sibi iniungatur ad trahendum illam fabam praedictam, illi duo homines non trahent velocior quam unus illorum per se; ergo velocitas motus non sequitur excessum" (Kilvington 2020, 236). Richard Swineshead in the treatise "De reactione" included a similar example: "Unde motus non sequitur absolute proportionem potentie ad resistentiam: sed cum ceteris paribus scilicet cum applicatione et aliis talibus sicut in exemplo capiatur fortis homo qui certa velocitate trahat navim et contingit accipere aliquem debilem qui cum aliqua applicatione sufficeret ipsum iuvare per certam latitudinem motus: et cum alia applicatione per maiorem et cum alia per minorem: ut constat" (Swineshead 1520, 27ra). He also used one based on experience: "forma illa est in quantitate minori in illa materia densiori quam in rariori: et sic melius applicatur: et ad suum contrarium ut in ipsum agat. Similiter est de lata tabula descendente in aere si comprimeretur et fieret rotunde figure vel quantitatis minoris sine ablatione forme tota illa tabula velocius descenderet: ut apparet experimentaliter. Cuius causa est: quia melius applicaretur ad partes medii: ita quod minor pars medii sibi obiiceretur quam prius: ita quod minorem resistentiam habet a medio quam prius habuit: et tamen totum in rei veritate non est maioris potentie: quia non est aliud argumentum ad hoc probandum nisi quod velocius movetur quam prius" (Swineshead 1520, 27ra).

> 3. The same is also evident from the case of a cold hand placed on a warm bosom, because the hand is warmed while the bosom is cooled.
> 4. Likewise, if two knives cut their blades at the same time, each acts upon the other, dividing a part of the other.[10]

Richard Kilvington in the question "Whether all contrarieties are mutually active and passive?" (Utrum omnia contraria sint activa et passiva ad invicem?), in treating the problem of reaction, provides a short list of similar cases of common experience:

> The truth of this question is evident inductively from experience, because I assume that some [amount of] water acts on a great fire; we observe through our senses that something is reduced in the fire. The same can be observed if some small fire is placed into a great amount of water. And the same is clearly seen when a red-hot iron rod is plunged into cold water; water cools the iron and the iron heats the water.[11]

Jean Buridan in the previously mentioned question on reaction also provides the following cases of common experience:

> This is proved by many experiences: Firstly, if water is thrown into fire, it extinguishes the fire while being consumed by the fire and evaporated [at the same time]. Secondly, if a small vessel full of cold water is placed into a cauldron full of hot water, it will be seen that the coldness of the water in the vessel is removed, since it becomes warm, and also the heat of the water in the cauldron is reduced. The same [is observed] when you pick up a cold apple with your hand. You will immediately sense that your hand becomes colder and the apple is warmed by your hand. And when a red-hot iron rod is placed into cold water, it will considerably heat up this water and be cooled by this water.[12]

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[10] "Arguitur etiam quod est reactio possibilis secundum easdem qualitates, et hoc per experimenta: (1) primo per ferrum ignitum aquae impositum ubi ferrum frigescit et aqua calefit. (2) Item patet de aqua frigida in aquam bullientem infusa, quia cessat ebullitio et aqua imposita calefit. (3) Idem patet etiam de manu frigida posita in sinu calido, quod manus calefit et sinus frigefit. (4) Item, si duo cultelli secundum acutiam simul percutiantur, uterque in reliquum agit partem alterius dividendo" (Swineshead 1520, 25va).

[11] "Veritas istius quaestionis patet inductive per experimentum, quia pono quod una aqua agat in magnum ignem; videmus ad sensum quod aliquid remittitur in igne. Idem etiam apparet si ponatur unus modicus ignis in magna aqua. Et idem etiam apparet manifeste si ferrum ignitum ponatur in aqua frigida: aqua frigefaceret ferrum et ferrum calefaciet aquam" (Kilvington n.d., *Utrum in omni generatione*…, f. 116va).

[12] "Et hoc probatur multis experimentis. Primo, si aqua proicitur in ignem, ipsa extinguit ignem et ab igne consumitur et evaporatur. Secundo, si vasculum plenum aqua frigida ponatur in caccabo

Even though all these experiences seem to confirm the statement that reaction is a process occurring *in rerum natura*, each of these thinkers tries hard in each case to deny a reciprocal action of opposite primary qualities, or at least to explain these phenomena in a way that avoids contradicting the Aristotelian law of *proportio maioris inaequalitatis*. Interestingly enough, in order to reach such goals they saw no problem with modifying the Aristotelian philosophical system by introducing new distinctions or concepts.

For example, Richard Kilvington suggests that in some cases described as reaction, the final effect is not caused by the action of the less potent factor on the more potent one, but simply by the fact that the agent weakens by itself while acting upon the patient:

> But it should be said in the beginning that the contraries are not mutually active and passive in such a sense that each acts upon another so that the agent acts more strongly, and the less potent patient acts by its qualities upon the agent; but it is called 'reacting', because the agent is weakened by acting. And that is why it appears as if the less potent part [of the agent] was reacted upon by the patient, but this is not so, and this [part] is weakened by the action of the principal agent.[13]

In another passage of the same text Kilvington explains that the phenomenon that appears to be a reaction can be explained by stating that the less potent factor acted on the more potent before the latter begins to act – as in the case of two men pulling a rope in opposite directions; the weaker one can pull the stronger one only if he pulls the rope more quickly than his opponent:

> It must be said that the reason is that the reactant begins to act first…. For example, if there are two men, one of whom is stronger and the other weaker, and they have a rope which they are trying to pull in opposite directions, and the weaker begins to pull before the stronger, for some time he would be able to pull the rope and

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pleno aqua calida, videbitur frigiditatem aquae huius vasculi remitti et ipsam fieri tepidam et etiam caliditatem aquae remitti, videlicet caccabi. Ita de pomo frigido posito in manu tua. Statim senties quod frigefiet manus tua et pomum calefit a manu tua. Et si ferrum ignitum ponitur in aquam frigidam, calefaciat notabiliter illam aquam et frigefiet ab illa aqua" (Buridan 2010, 146).

[13] "Sed forte dicitur in principio quod contraria non sunt sic activa et passiva ad invicem quod utrumque agat in reliquum sic quod agens fortius agat et debilius passum aget per suas qualitates in agens, sed pro tanto dicitur reagere, quia agens in agendo debilitatur. Et sic apparet quod pars debilior [agentis] repatietur a passa, et non est sic, sed solum debilitetur per actionem principalis agentis" (Kilvington n.d., *Utrum in omni generatione*…, f. 113va).

> the stronger man, even though at the same time the stronger would try to pull the rope as strongly as he could.[14]

Further on Kilvington attempts the solution that changes of intensity of heat, for example, are not dependent upon changes in its contrary quality, coldness. Sometimes, he argues, it is possible that the intensity of heat increases due to the remission of humidity, and sometimes the reduction of the intensity of heat is not caused by the introduction of more intense coldness into the same subject. Moreover, according to Kilvington, even if the intensity of heat in a given body increases, it does not necessarily mean that its coldness decreases or vice versa.[15] Such is the reason why tepid water added to hot water makes the latter colder, he states, since coldness – a primary quality of water itself – is always present in tepid water and thus cooperates with the coldness present in hot water: "In any medium where there is more heat than coldness, the coldness in that *mixtum* can act in spite of the heat of the same *mixtum*, obviously, since a less hot thing through its coldness can act in one hotter."[16] We find a similar explanation of the same common experience case in Richard Swineshead's treatise "On Reaction": "Regarding a second experience (*experimentum*) it may be said that there is much coldness even in hot water, which loses its heat by cooperating with the coldness introduced with the cold water."[17]

Swineshead describes the whole process more detailedly (however not more clearly), yet concludes finally that in such cases a reaction does not occur. Instead, he suggests that due to the fact that cold water is divided into many minute portions, our senses are simply deceived:

> The [cold] water that is added does not remove all the heat, but is divided into many parts that mix with parts of the hot water, and thus the whole combined water is

[14] "Dicendum est quod causa est quia reagens prius incipit agere…. Verbi gratia, si essent duo homines, quorum unus esset fortior et alius debilior, et haberent cordam quam niterentur trahere ad diversas differentias positionis, et debilior prius inciperet trahere quam fortior, per aliquod tempus traheret cordam et fortior, licet per totum tempus nitatur fortior trahere cordam ita fortiter, sicut potest" (Kilvington n.d., *Utrum in omni generatione*…, f. 117va).

[15] "Remissio caliditatis non supponit intensionem frigiditatis sicut manifeste patet in actione ignis in terra" (Kilvington n.d., *Utrum in omni generatione*…, f. 116va).

[16] "In aliquo medio ubi plus est de caliditate quam de frigiditate, frigiditas in illo mixto potest agere non obstante caliditate eiusdem mixti, quod patet, quia unum remissius calidum potest agere in fortius calidum per suam frigiditatem" (Kilvington n.d., *Utrum in omni generatione*…, f. 116vb–117ra).

[17] "Pro secundo experimento dicitur quod in aqua calida est multa frigiditas, quae cum frigiditate inducta per aquam frigidam caliditatem illius aquae remittit" (Swineshead 1520, 28va).

> colder than the first [hot] one was at first…. It may be said that that the added water is not immediately warmed by the hot water, but it is divided into small parts, and for this reason its coldness cannot be felt well, and thus that water appears to the senses to be hot, although, however, it is not hot in reality.[18]

As regards the example of a red-hot iron rod plunged into water, Swineshead provides us with two, even more imaginative but clearer explanations. In the first description Swineshead employs the same assumption that he used with respect to the above case of hot water, namely that much natural, primary coldness remains even in a red-hot iron. This statement he proves with the fact that a red-hot iron rod will become cooler "by itself" even if left in some hot place. Therefore, it is surely not the coldness of water which acts on this iron rod, cooling it down.

> First … this red-hot iron is not hot but cold, as it seems – on a basis of the fact that although it were to be left in a quite hot place, its heat would still diminish. This would not be the case unless its intrinsic coldness dominated over the hotness. Thus it might be said that this intrinsic coldness diminishes its heat, and due to the combination of this heat with the heat of the air introduced into the water through the iron rod, the water is warmed. And so properly there is no reaction, even if it seems so to the senses.[19]

It is worth noting that Swineshead again suggests here that it is only the evidence of our senses that lets us presume that there occurs a process of reaction, while there is no reaction, properly speaking.

In the second explanation Swineshead first accepts the assumption that the iron rod can be described properly as hot, but further on he refers to the previously mentioned idea that some amount of hot air is introduced into water with this red-hot iron rod. Such a hot, or "ignited" air is hidden in the pores of the iron and the successive portions of air are released when one plunges the rod into water,

[18] "Aqua infusa non remittit totam caliditatem illam sed dividitur in partes multas et coniungitur cum partibus aquae calidae: et sic tota aqua coniuncta fit frigidior quam primo erat prima…. Potest dici quod illa aqua infusa non statim calefit ab aqua calida: sed dividitur in parvas partes, ratione cuius eius frigiditas non potest bene sentiri: et sic ad sensum apparet illa aqua calida, quae tamen in re non est calida" (Swineshead 1520, 28va).

[19] "Primo … illud ferrum ignitum non est calidum sed frigidum, sicut apparet – eo quod licet in loco quodammodo calido poneretur, eius caliditas remittetur. Quod non foret nisi esset dominium frigiditatis intrinsecae super caliditatem. Et tunc potest dici quod ista frigiditas intrinseca remittit caliditatem eius propriam et secundum eius caliditatem una cum caliditate aeris circumstantis ingredientis cum illo ferro in aquam calefacit illam aquam. Et sic non est reactio proprie nisi quo ad sensum tantum" (Swineshead 1520, 28rb).

making it appear to be boiling – while, nevertheless, according to Swineshead the water is not warmed at all. Thanks to this, quite an imaginative, so to say, explanation of the phenomenon, he can finally state that the iron rod does not act on water.

> It may be said otherwise, admitting that the iron is hot. And then it may be said that the ignited substance of the air is placed into the water along with this iron. The parts of this air, being light, tend to move upwards, and they ascend. And so, as long as parts of this air remain in the water, that water appears to be hot, and yet in fact this water is not hot, and thus the iron does not act on the water.[20]

What is more, with respect to this red-hot iron itself – it cools down in the water due to the same activity of the air (or a 'vapor'), and not of the water:

> In iron and in every such mixed body there are pores filled with air or a subtle vapor that is acted upon by a hot agent, and the exhalation is mediated by this fine vapor that is heated and ignited. And such an exhaled vapor is cooled when the iron is placed into water – and thus we state that the whole has undergone a reaction, which is false.[21]

Since neither the red-hot iron acts on water, nor water acts on this iron, consequently, this case cannot be taken as a case of "reaction". Interestingly enough, the only "action" here is the release of hot air from iron, clearly observable when it is plunged in water.

What is more, Swineshead later provides a detailed explanation of why our sense of touch is always deceived in such cases:

> There are so many, insensibly spaced pores in mixed bodies that we say that there is a reaction throughout [a given part] because the exhalation surrounds the entire surface. And so the hot vapor enters the pores of the flesh from all sides, in which pores the nerve of touch is situated. This nerve is easily acted upon and that is how

[20] "Aliter potest dici admittendo quod ferrum sit calidum. Et tunc dicitur quod materia aeris est inflammata ingrediens cum ferro in aquam, cuius partes, eo quod leves sunt, appetunt ascendere versus sursum, et ascendunt. Et sic, quamdiu manent partes illius aeris in aqua, apparet illa aqua calida, et tamen in rei veritate illa aqua non est calida, et sic non agit ferrum in aquam" (Swineshead 1520, 28rb).

[21] "In ferro et in omni tali mixto sunt pori repleti aere sive vapore subtili, qui ab agente calido suscipiunt actionem. Et fit exhalatio mediante vapore subtili sic ignito et calefacto. Et talis vapor exhalans frigefit cum ferrum ponitur in aquam – et sic dicimus totum repati, quod est falsum" (Swineshead 1520, 28rb).

> we sense. Hence it is said that due to the difformity in the iron and in the mixed water there may be an action in one part and reaction in another – as has been said. Nor can one really experience in them an action throughout.[22]

As we can see, Richard Swineshead unambiguously suggests that all the common experiences of reaction are cases when our senses are deceived, and not the real processes where mutual action occurs.

I think it is worthwhile to try to find the rationale for the explanations by which Kilvington and Swineshead deny sensory experience as a reliable source of true knowledge about natural phenomena (thereby undermining the Aristotelian position that sensory experience is a valid source of knowledge). Of course, one could simply adopt the attitude of Victor Trincavellus in his question "On Reaction" appended to his own edition of Richard Swineshead's *Book of Calculation*, who openly declares that the evidence of the senses is the source of true knowledge, and anyone who denies the validity of sensory experience is harshly characterized by him as the one afflicted with intellectual *imbecillitas*:

> For it is the rule and the test of true discourses that they agree with sensory experience. Wherefore, when reason and sensory experience are at variance, it is better to adhere to sensory experience than reason, because any reason which contradicts sensory experience is sophistical and vain. And to abandon [the testimony] of sensory experience for the sake of reason proves nothing but the weakness of intellect.[23]

But I think it would be unfair to attribute *imbecillitas intellectus* to Kilvington or Swineshead. In my opinion, the tendency shared by fourteenth-century natural philosophers to deny the occurrence of reaction reveals the fact that they were generally not interested in developing any new natural science, even though at first sight it might seem like they accepted common experience as a starting point for their considerations. We must not forget that a commentary on Aristotle's *De generatione* was the very first teaching task for a young

[22] "Tot sunt pori in mixtis insensibiliter distantes, quod dicimus per totam [partem datam] esse reactionem propter hoc, quod exhalatio totam superficiem circumdat. Et sic ex omni parte vapor calidus ingreditur in poros carnis, in qua est nervus tactus. Qui nervus de facili transmutatur et sic sentimus. Unde per hoc dicitur quod ratione difformitatis in ferro et in aqua mixta secundum aliquam partem potest esse actio et secundum aliquam reactio, ut dictum est. Nec potest aliquis vere experiri ibi esse actionem per totum" (Swineshead 1520, 28rb).

[23] "Regula enim et experimentum sermonum verorum est ut concordent sensatis. Unde discordantibus ratione et sensu magis adhaerendum est sensui quam rationi, quia ratio quae sensui contradicit sophistica est et vana. Et dimittere sensum propter rationem non arguit nisi intellectus imbecillitatem" (Trincavellus 1520, f. 72rb).

magister regens at a medieval university in the fourteenth century. An even more decisive factor here, then, is that all these scholars were expected to teach and expound the Aristotelian texts, not to undermine the theories presented in these or prove them false.

This attitude is reflected well, for example, in Richard Kilvington's question "Utrum in omni generatione tria principia requirantur?" (Whether three principles are required for every generation?) – from the same set of questions in which the above-mentioned question *Utrum omnia contraria*… is included – where he provides two alternative solutions for the main problem. He dismisses the second one, however, only since it "departs" too far from Aristotle's solution:

> Another understanding of this question could be given, however, which is closer to the meaning of terms but more distant from Aristotle's understanding…. But I omit this understanding of the question because it departs from Aristotle's understanding [and] I take the former understanding of the question.[24]

Therefore, in the cases when some common experience seemed to undermine Aristotle's statements the only thing fourteenth-century scholars could (and tended to) do was to explain such phenomena using the Aristotelian conceptual apparatus, modifying it a bit where necessary, while not denying the basic dogmas of the system.

A very good example of such an attitude is Jean Buridan's discussion of the *proportio maioris inaequalitatis* law in his question "Whether it is possible to have an action from the [ratio] of equality or even from the ratio of lesser inequality?" (Utrum possibile est esse actionem ab aequalitate vel etiam a proportione minoris inaequalitatis?). Buridan ingeniously introduces here a distinction between "passivity" and "resistive capacity":

> In order to act and be acted upon it is not necessary that the active factor be greater in its activity than the passive [factor] in its passivity, since prime matter is the most passive, insofar as it is by itself; and yet a weak agent acts in prime matter…. When philosophers say that the potency of the mover or the agent must exceed the potency of what is moved or acted upon, this comparison must not be understood as a comparison between the capacity of the active factor to act and the passivity of the passive factor. But … such a comparison must be drawn between the capacity

[24] "Alius tamen poterit esse intellectus istius quaestionis magis attendens ad virtutem sermonis et magis remotior ab intellectu Aristotelis…. Sed isto intellectu quaestionis ideo hic omisso quia recedit ab intellectu Aristotelis [et] sumo intellectum quaestionis priorem" (Kilvington n.d., *Utrum omnia contraria*…, f. 33vb). I would like to thank Elżbieta Jung for pointing out this fragment.

> to act of the active factor and not the passivity of the passive factor, but its capacity to resist.[25]

It is symptomatic that Buridan justified himself by claiming that the distinction between "passivity" and "resistance" was introduced by Aristotle himself:

> In Books V and IX of the *Metaphysics* Aristotle distinguished three kinds of potency. The first of which is active potency, the second passive potency, the third he calls the habit of passivity, that is, the resistive capacity. It is called the habit of passivity since it resists that its subject be moved or acted upon by another, or that it be acted upon much or quickly…. Resistance tends to stop and rest.[26]

The distinction introduced by Buridan is his own interpretation of the relevant passages of Aristotle's treatise. We do not encounter such a term as *habitus impassibilitatis* in the *Metaphysics*. Yet, this distinction allowed Buridan and others, such as Nicole Oresme and fifteenth-century Italian thinkers, to save and explain the phenomena of reaction without denying the law of *proportio maioris inaequalitatis*. For example, in Nicole Oresme we find the following:

> The same power (*virtus*) is sometimes weaker in acting and stronger in resisting and sometimes vice versa, for example, the hotness of fire is strong and quick acting, and yet it is weak in resisting. And in the same manner it is also more evident with respect to the humidity of water, but humidity is strong in resisting and weak in acting; and in the same manner with respect to the dryness of earth, whence if cold earth is touched it is evident that its coldness is acting and its dryness is not. Therefore, to the [main] hypothesis I say that if [something] hot and [something] cold approach each other, then both are stronger in acting and weaker in resisting; thus either of them can be acted upon by the other, since action and speed are not determined according to

[25] "Ad agendum et ad patiendum non oportet quod potentia activa sit maior in agendo quam passiva in patiendo, quoniam materia prima est summe passiva, quantum est ex se; et tamen parvum agens agit in primam materiam…. Quando dicunt philosophi quod potentia moventis seu agentis debet excedere potentiam moti vel passi, illa comparatio non debet intelligi comparatio [inter] potentiam activam in agendo et potentiam passivam in patiendo. Sed … comparatio debet attendi inter potentiam agentis in agendo et potentiam passi non in patiendo, sed in resistendo" (Buridan 2010, 151–52).

[26] "Aristoteles quinto et nono Metaphysicae distinguit triplicem potentiam. Quarum prima est potentia activa, secunda potentia passiva; tertiam ipse vocat habitum impassibilitatis, id est potentia resistiva. Quae dicitur habitus impassibilitatis, quia resistit, ne subiectum suum moveatur aut patiatur ab alio, aut ut non multum seu velociter patiatur…. Resistentia inclinat ad pausandum et quietandum" (Buridan 2010, 152).

> the ratio of potency [of acting] to resistance, but according to the ratio of the potency of acting (*potentiae ad agendum*) to the ability to resist (*posse resistere*).[27]

It is important to stress here again that such a solution was still a result of the effort to preserve the dogmas of Aristotelian philosophy, in this case the law of *proportio maioris inaequalitatis* on the one hand, and the validity of common, sensory experience, on the other.[28]

CONCLUSIONS

For a modern reader it is obvious that the fundamental issue that forced all the above-mentioned thinkers to find more or less acceptable explanations for the common experience of the mutual reaction between hot and cold substances was the fact that they all accepted Aristotle's theory of elements, where "coldness" and "hotness" are recognized as different, independent, and primary qualities. As it was shown above, such a theory – when confronted with sensory experience – generates more doubts than explanations. For example, Richard Swineshead seems to be perfectly content with his description of water "boiled" with the ignited air released from the red-hot iron rod plunged into it. He never confronts this phenomenon, however, with a case of water boiled in a cauldron with fire. Moreover, he never explains why, shall we say, after the entirety of ignited air has been released from the rod (i.e. after the water ceases to "boil"), both water and iron will be equally hot. Clearly, he was not interested in explaining the phenomena, but rather in preserving the validity of Aristotle's theory. In my opinion, it is also confirmed by the fact that further on in the same text, i.e. in the treatise "On Reaction" in his *Book of Calculations*, Richard Swineshead refers to the similar

[27] "Eadem virtus quandoque est debilis ad agendum et fortis ad resistendum et quandoque e converso, verbi gratia caliditas ignis est fortis et velocioris actionis, et tamen est debilis ad resistendum. Et eodem modo patet etiam manifestius de humiditate aquae, sed humiditas est fortis ad resistendum et debilis ad agendum; et eodem modo de siccitate terrae, unde si tangatur terra frigida patet quod frigiditas eius agit et siccitas non. Tunc ad propositum dico quod si calidum et frigidum sint approximata, tunc utrumque est fortius in agendo et debilius in resistendo, et sic quodlibet potest pati a quolibet, quia actio et velocitas non attenditur penes proportionem <potentiae> ad resistentiam, sed penes proportionem potentiae ad agendum ad posse resistere" (Oresme 1996, 94–95).

[28] It is worth noting here that in this very respect fourteenth-century natural philosophy is incompatible with the seventeenth-century science of motion, according to which it is obvious, and confirmed by common experience, that motion can occur when there is a *proportio aequalitatis* between factors (as it would be formulated in medieval terms).

case of a common experience, namely to the fact that "the red-hot iron rod does more damage than a flame of the same dimensions." Yet here he refers to the concept, presumably invented and introduced by himself, of the "amount of form" (*multitudo formae*); and explains that it is due to the fact that there is greater amount of the form of fire condensed in the red-hot iron rod than in an equally large flame.[29] One can conclude, then, that in this context Swineshead assumes that red-hot iron rod is hot because of fire, not of the "ignited" air. Therefore, it is safe to conclude that his explanations of similar common experiences are just provided *ad hoc*, and thus cannot be recognized as constituting a basis for a new, consistent theory that could eventually replace the Aristotelian worldview.

Even though Richard Swineshead's *Liber calculationum* enjoyed some interest among the coryphaei of early modern science and was recognized by them as a worthwhile text, we must not overlook the fact that this treatise was conceived as nothing more than a detailed, thorough presentation of natural philosophy developed mostly in an *a priori*, speculative manner, and based on Aristotelian principles and rules. Swineshead's treatise was not a direct part of his university teaching activities, but nevertheless he never left the boundaries of Aristotle's worldview, even if he had reached their limits in many points (Podkoński 2020, 125–57). Still, Swineshead, as all the other fourteenth-century thinkers mentioned, considered natural philosophy a purely theoretical science. Consequently, he saw no need to transcend these boundaries and build a new science on the basis of common sensory experience. As it seems, one of the main factors that provided the impetus for the development of early modern science was rather the union between the theoretical and the practical within the new science of ballistics developed at the turn of the seventeenth century by Niccolo Fontana (Tartaglia) and Galileo (Hall 1952). What was new in fourteenth-century natural philosophy, then, were only the new tools and methods of interpreting and explaining Aristotle's texts and statements in order to preserve, or rather to provide logical and conceptual coherence, to his system.

[29] "Et ideo causa quare ferrum ignitum plus ledit quam flamma eiusdem quantitatis vel aequalis est hoc causa: quia plus est de forma in illa quantitate ferri quam in illa quantitate flammae sibi aequali. Si enim ex isto ferro generetur ignis summus et ex tanta flamma similiter, tunc in fine fieret ferrum illud valde maioris quantitatis quam illa flamma, eo quod nunc est materia ferri densior quam materia flammae. Et tunc aeque rara, eo quod in utroque tunc esset summa forma ignis et in omni parte equali esset aequaliter de forma, igitur in illa materia quae est materia ferri esset plus de forma quam in materia flammae. Et per consequens, si utraque forma in utraque materia uniformiter foret generata, in illa materia ferri plus esset de forma quam in materia flammae. Illud etiam ferrum ignitum plus lederet quam flamma equaliter habens de forma" (Swineshead 1520, 27ra-b).

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"SO MUCH WORSE FOR THE FACTS(?)" – 14TH-CENTURY NATURAL PHILOSOPHERS AND THE COMMON EXPERIENCE OF REACTION

Summary

The article presents a selection of considerations by fourteenth-century Oxford and Paris scholars on the phenomena of common experience that seemingly confirm the occurrence of processes of reaction *in rerum natura*. All of the philosophers involved, however, attempted to explain these phenomena in a way that allowed them to defend Aristotle's statement that it is impossible that there be any such reaction, between either elementary or mixed bodies (*mixta*). On the basis of the explanations provided by these thinkers, one can arrive at the conclusion that they were simply unable to leave the boundaries of the Aristotelian worldview, at least with respect to the issue of mutual action of elementary bodies. In the final section of the article the plausible reasons for their attitude towards these phenomena of common experience are provided.

Keywords: natural philosophy; medieval philosophy; Aristotelianism; fourteenth century philosophy; *reactio*

„TYM GORZEJ DLA FAKTÓW(?)" – CZTERNASTOWIECZNI FILOZOFOWIE PRZYRODY WOBEC POTOCZNEGO DOŚWIADCZENIA ZJAWISKA REAKCJI

Streszczenie

Wiele spośród analiz czternastowiecznych oksfordzkich i paryskich filozofów przyrody odnosi się do dających się zaobserwować w przyrodzie zjawisk, które wskazują na zachodzenie procesów reakcji, rozumianej jako jednoczesne oddziaływanie ciał o przeciwnych jakościach, na przykład gorącego i zimnego, w efekcie czego ciało gorące staje się chłodniejsze, a jednocześnie ciało zimne jest ogrzewane. Jednak wszyscy myśliciele, których rozważania są przedstawione w niniejszym artykule, starali się wyjaśnić takie zjawiska tak, by pozostać w zgodzie z twierdzeniami Arystotelesa odnośnie do procesów reakcji. Stagiryta autorytatywnie zaprzeczył możliwości zachodzenia reakcji, zarówno między ciałami elementarnymi, jak i złożonymi (*mixta*). Na podstawie wyjaśnień zjawisk potocznego doświadczenia zaproponowanych przez tych czternastowiecznych filozofów przyrody można wyprowadzić wniosek, że nie byli oni w stanie przekroczyć granic światopoglądu naukowego Arystotelesa, przynajmniej w odniesieniu do wzajemnego oddziaływania bytów rzeczywiście dających się zaobserwować w przyrodzie. W podsumowaniu artykułu sformułowane zostały najbardziej prawdopodobne wyjaśnienia, dlaczego myśliciele ci w taki, a nie inny sposób opisywali w swoich tekstach dostępne potocznemu doświadczeniu zjawiska przyrodnicze.

Słowa kluczowe: filozofia przyrody; filozofia średniowieczna; arystotelizm; filozofia czternastowieczna; *reactio*