Physics of the Stoics-Sambursky (Highlights)

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From the **first century B.C**. on, the centre of gravity of Stoic teachings shifted decidedly to ethics, and **as far as is known today, no further contribution worth mentioning was made by the later Stoa in the field of physical thought.**

The cosmos is filled with an all-pervading substratum called **pneuma**, a term often used **synonymously with air**.

A basic function of the pneuma is the generation of the cohesion of matter **and** generally of the contact between all parts of the cosmos.

As air represents the principle of Cold, the warmth of the human body makes it likely that the stuff **souls are made of is a mixture of cold and hot, of air and fire.** Galen tells us that this mixture is so proportioned that it protects the living organism from extremes of temperature.

Aristotle divided the four elementary qualities of matter into active -- warm and cold, and passive -- dry and moist and regarded the four elements as a result of the four physically possible combinations of these four qualities. The Stoics who attribute one quality only to each of the four elements, defined Air and Fire as active, and Earth and Water as passive elements.

Whereas Poseidonios makes moisture responsible for the coldness of air over marshy ground, his pupil **Cicero** stresses the caloric content of air: "Air must be deemed to be a sort of vaporized water, and this vaporization is caused by the motion of the heat contained in the water."

…one can infer from the passage in Cicero De natura deorum dealing with the nature of heat that the development of the first thermodynamical notions had begun already in the Old Stoa.

Cleanthes' doctrine which describes the function of heat in organic nature

as a special case of thermic processes: "It is a law of Nature that all things capable of nurture and growth contain within them a **supply of heat,** without which their nurture and growth would not be possible; for everything of a hot, fiery nature supplies its own source of motion and activity but that which is nourished and grows possesses a definite and uniform motion. . . .

…it must be inferred that this element of heat possesses in itself a vital force that pervades the whole world.

Pneuma or one of its components was also defined by the collective "pneuma-like matter", and the Stoics attributed to them the property of coherence in the twofold sense of being cohesive and making cohesive.

Without the active interference of air or fire or the two mixed together, the passive elements (earth, water) would disintegrate as they themselves do not possess the "cohesive force"

"cohesive force"= property of active elements

Stoics saw the cause of **sleep in a relaxation of the sensory tension.**

…the tension innate in air and fire endows these elements with cohesion which is acquired by water and earth only through their admixture.

…since pneuma pervades the whole universe, the pneuma-like tonos makes the cosmos into a single cohesive unit

…the tension of the pneuma has a **twofold function**: besides being a **binding force**, it is an agent which **generates all the physical qualities of matter.**

The Stoics generalized their **continuum theory into a field theory;** the pneuma is the physical field which is the carrier of all specific properties of material bodies, and cohesion as such thus gets a more specific meaning by becoming hexis, the physical state of the body.

The structural concept of **hexis, also defined as the "binding spirit" of a body,** represents the highest entity in the hierarchy of inorganic structures as conceived by the Stoics. These entities are divided into **discrete, contiguous and unified**. At the lowest level we have an assembly of bodies in a disordered state, such as a crowd which does not lend itself to numerical determination. The following level is also a discrete state, but here the

elements are arranged in an order which allows for numerical determination, such as a choir or an army in formation. This is a "denumerable" entity. Contiguous structures are composed of conjoined elements, like the links of a chain or the planks of a ship or the stones of a house. What the discrete and contiguous structures have in common is that each of their elements can continue to exist even if the rest are destroyed, which is characterized by a simple additive relationship between the elements.

We must realize that the elements of hexis are not mere localized units but physical properties which interpenetrate and create a totality where each of them shares in the existence of the rest. In our modern terminology: all the qualities which define the physical state of a certain body -- its mechanical, thermic, electric, optical properties -- have their origin in common roots and are therefore interdependent and not additive. Every one of them is affected if all or some of the others change.

The Stoic term for this form of co-existence of the elements of the highest structure was "sympathy" (sympatheia), and it is again significant that analogies from the living organism were given to exemplify this condition: when a finger is cut, the whole body shares in its condition.

It seems that Stoic terminology distinguished between qualities of the lower structures which are produced to a greater or lesser degree by the co-operating effects of their units (e.g. the performance of a choir reached by the common efforts of each of its dancers individually), and the physical properties which are immanent in the "unified" structures. Only these, the hexeis, are distinguished by a "pneuma-like unity" which is ruled by one law.

Diogenes identifies soul and intelligence with air, and the variations in the former (soul) are explained by the difference in proportion of hot and cold, dry and wet in air.

…each of the physical properties of a body, according to this principle, would be defined by a specific sort of pneuma, characterized by a definite mixture of fire and air.

a third case of "mixture"= **Theory of total blending**

(krasis for liquids, mixis for non-liquids)

…from the Stoic point of view, **represents the most important category of blending**. Here a complete interpenetration of all the components takes place, and any volume of the mixture, down to the smallest parts, is jointly occupied by all the components in the same proportion, **each component preserving its own properties under any circumstances**, **irrespective** of the ratio of its share in the mixture. The properties are preserved in all cases where -- as opposed to the case of fusion -- the components can be separated out again from the mixture by physical contrivances.

The Stoic view was that the medium of the more abundant actually assists both the expansion of the weaker one throughout such large volumes and its homogeneous occupation of the whole space offered to it.

…the Stoics, taking a radical position with regard to continuity, conceived of mixture as a complete interpenetration of the components which existed simultaneously in the given proportions down to the most minute elements of volume. This conception of total mixture was understood by them in the sense that every element of volume, however small, would be homogeneous with regard to the mixing of the components, and that from no point on would this homogeneity dissolve itself into a mosaic-like structure with bits of the components lying side by side.

Mutual interpenetration of soul and body, of physis and plants, of hexis and inorganic matter, have all one common feature -- the total mixture of a very tenuous and rare component, the pneuma, with a much bulkier one

Anaxagoras developed his **theory of seeds** which in a certain way can also be regarded as a precursor of the total mixture doctrine of the Stoics. **The infinitely divisible seeds of each form of matter contain something of all the opposite qualities**, though in different proportions.

…the most significant difference between Anaxagoras' theory and that of the Stoics is to be found in the much wider conception of the latter (Stoics), where the idea of interpenetration is linked up with the **tensional qualities** of the pneuma and thus, as we shall see later, with the notion of the **field of force**.

The four Stoic categories, on the other hand, are a vertical classification according to which every object is determined by four successive steps of increasing specification such that every category includes the preceding one. They thus represent a kind of methodological guide for the complete ontological definition of an object. There is a highest notion, comprising all **the four categories…substratum, quality, state and relative state.**

Shapeless and passive matter is the primary substratum of the cosmos and as such without any qualities. It is the all-pervading **pneuma** which, by totally mixing with matter, **imbues it with all its qualities**, and thus represents the second category. The third category, **the state**, is given by the fact that to each specific quality of the body there is attributed a **specific mixture of the pneuma** defined by a certain proportion of its two components, air and fire. **The sum total of all pneumata permeating the body then defines its physical state.** There is a lack of consistency in the extant sources with regard to terminology. Thus we find no direct reference to hexis as a physical state, but Alexander once mentions the "physical property of a body", which is much the same as hexis, and calls it "pneuma in a certain state."Hexis, however, is mentioned expressly in connection with the fourth category, and the passage in Simplicios referring to it is of great significance for the understanding of the whole subject.

Simplicios informs us of a subdivision of the **fourth category:** the Stoics distinguished between **two kinds of relations**, the relative state and the relative. The first (relative state) denoted a state defined by that of another thing outside it, such as the relation father-son or left and right-hand neighbour. The relative referred to things capable of change (the examples given are sweet and bitter), whereby the relation is given through comparison of two states of this change (e.g. two degrees of sweetness). Simplicios quotes hexis as another example of the relative which throws into relief the dynamic notion of Stoic physics, because hexis is the key term of the physical continuum which embraces an infinity of different states. Each of these states can evolve from another by a continuous transition produced through the "change of the former quality," a change which corresponds to that of the spectrum of all pneuma tensions permeating the body involved. Simplicios further reports the discussions on how far the two subdivisions of the fourth category are interrelated, and whether the first implies the second or vice

versa, or whether they are independent of each other.

…on this point the views of the earlier Stoics differ from those of the later. However, it is evident that, as far as the description of the physical world is concerned, the subcategory relative state completes the set-up described above. The relative state determines the relation between the physical states of two different bodies and, taking into account the fact that each of these bodies can itself undergo changes corresponding to a continuum of states, it is obvious that all the possible combinations resulting from this fact together form the totality of physical occurrences.

…the four categories were constructed in the first instance to fit methodologically the conceptual set-up of a physical theory,

The vital **function of the hegemonikon** as the central seat of consciousness, unifying all the activities of the soul and maintaining and regulating its contact with the external world, clearly **defines a dual direction of communication**: from the centre of the body to the various organs on its surface, and vice versa. It is through the incessant movement of pneuma to and fro between the hegemonikon and the surface of the body that this two-way communication is established…

…**What kind of motion did the Stoics have in mind when they talked about movement of pneuma within the body?** Modern physics distinguishes between two types of motion: particle movement, i.e. transport of matter, and **wave motion**, i.e. propagation of a state. There can be little doubt as to the Stoic attitude in this respect; **their conception of continuity and the idea of tension inherent in the pneuma make it highly probable that they visualized movement of pneuma as something akin to the second type of motion (wave motion)**, the expansion of a disturbance in an **elastic medium.**

…the gist of the Stoic theory was that the "optical pneuma" emitted from the hegemonikon to the eye, excites the air adjoining the pupil and that from there the object is contacted through the stressed air. The significant part of this hypothesis is the picture of a cone of air in a state of tension with its apex in the pupil of the eye and its base at the object. "The object seen is reported through stressed air, as if in contact by a stick."

…the Stoics regarded the movement of the pneuma as some sort of

propagation of a state. In one of them the "seven parts of the soul" growing out of the hegemonikon and extending through the body are compared to the tentacles of an octopus -- a picture somewhat similar to that of the stick quoted above. The arms of the octopus are in fact a prolongation of its central part and their stretched or unstretched position reflects and indicates the actual condition of the animal.

Chrysippos: "In the same way as a spider in the centre of the web holds in its feet all the beginnings of the threads, in order to feel by close contact if an insect strikes the web, and where, so does the ruling part of the soul, situated in the middle of the heart, check on the beginnings of the senses, in order to perceive their messages from close proximity."

Each of the two opposite senses of the tensional motion has a specific function, as we have noted already. The motion towards the centre, in co-ordinating all the different sensations, produces the unity of consciousness, whereas the motion towards the periphery, maintaining the contact with the outside world, differentiates between the various qualities of sensation on the level of consciousness

Since matter is conceived as strictly continuous, the medium performs its tensional fluctuating motions within matter itself, being united with it in total mixture. The dynamic concept of hexis by which the physical state of a body is defined is thus akin to what we would call today a field of force.

The Stoic notion of continuity, applied to the phenomena of the physical world, has therefore led, by the intrinsic logic of scientific thought, to the concept of forces acting in accordance with the principle of continuity, these forces being the cause of the cohesion of matter as well as of its specific physical qualities.

The Stoics were the first to postulate continuous forces between parts of matter by introducing their dynamic theory of the physical state.

…in Stoic physics this regulative power was given to the pneuma which was supposed to extend throughout the whole world and to create coherence by mixing with all matter.

It was the **elasticity** and the great **pervasiveness of air,** facilitated by its tenuity which, combined with the **activity of heat**, gave the pneuma all the qualities needed for a continuous medium and for a source of the cohesion of matter.

We must remember that, although the Stoics believed in the corporeal nature of the pneuma, they came to regard it as something not akin to matter, but rather to force. **Pneuma= Force**

It was their conception of a continuous field of force interpenetrating matter and spreading through space, and thus being the cause of physical phenomena, which formed the central idea of pneuma.

The idea of the existence of forces continuous in space and time merged in Stoic doctrine with the conception of the ever-present and all-permeating Deity.

Pneuma became a concept synonymous with God, and either notion was defined by the other.

This way of looking on God and the active force of the pneuma as two aspects of the same agent clearly brings out the gist of the physical world of the Stoics. The cosmos is formed and ruled by forces which activate matter in a similar way to the activation of the living body by the soul.

Chrysippos defined **Fate** (heimarmene) as a **pneuma-like force** (dynamis pneumatike), one comes to realize that pneuma derived its central position in Stoic physics from its **dual significance.** It was **divine power** (viz. Force) impressing a definite state upon matter on the one hand, and **causal nexus** linking the successive states of matter on the other, and in both these aspects it revealed itself as a spatially and temporally continuous agent.

…Pneuma, it is true, had gradually become the "fifth element", identified with aether, and was probably in the course of time detached from its origins and regarded as a simple substance.

To say that pneuma under certain circumstances is "wetter and colder" and sometimes "drier and hotter", comes very near to the Newtonian conception of a simple substance "intermixed with various vapours and exhalations".

Cosmic sympathy implies of course absolute non-existence of any vacuum within the cosmos…

…the Stoics regarded the cosmos as a finite body surrounded by an infinite void. This enabled the cosmos to expand or contract according to its various cosmic phases as described in the Stoic theory of conflagration (ekpyrosis).

Through this **hexis, all parts of the cosmos are bound together into a "closed universe"** which is not affected by the void outside it, and thus the character of a single coherent entity is given to the universe…

Dissolution of the body sets in after the soul has left it, and the same applies to the pneuma in general: a slackening of its intensity of penetration leads to a relaxation of the binding forces of the hexis.

In a given mixture of pneuma and matter the actual ratio of the components of the pneuma -- fire and air -- determines a definite differentiation and corresponds to a definite shape.

Hexis, the physical structure of a body, **is** nothing else but **the superposition of all the mixtures of pneuma corresponding to the various qualities of the body.**

…the Stoics insisted that "nothing is the same as that which some other thing is," and that "no hair or grain of sand is in all respects the same as another hair or grain"

The very fact that **ordered experience is possible** was taken as a **proof** for the existence of Cause.

…Sextus Empiricus in the name of the Sceptical School: "If cause were non-existent everything would have been produced by everything at random."

…Absence of cause would result in lack of permanence in all phenomena -- a horse could be formed from a man, a plant from a horse, things proper to summer could happen in winter, and vice versa, etc.

…medical practice leads straight to the core of the problem of causality.

The physician is confronted in his aetiology with the difficulties arising from the multiplicity of causes and from the time lag between the dominant cause and the effect. On the one hand there is the dependence of symptoms and their intensity on various kinds of food as well as on the constitution of the patient…

…Contiguity is therefore an essential attribute of causality, and causes are bodies acting upon other bodies either in spatial contact with them or through the medium of the pneuma…

The nature of this action can always be described as movement, as there are always motions involved in it, either the tensional motion of the pneuma or locomotion of other bodies.

"Every cause is a body which is the cause to a body of something incorporeal happening to it."

They realized that in every given instance one has to reckon with a multiplicity of causes, since the complex texture of natural phenomena reduces the conception of one single body acting upon another to a mere abstraction.

"In view of the multiplicity of causes, they (the Stoics) equally postulate about all of them that, whenever the same circumstances prevail with regard to the cause and the things affected by the cause, it is impossible that sometimes the result should be this and sometimes that; otherwise there would exist some uncaused motion."

According to the Stoic conception, **every transition from the state A, characterized by a certain constellation of bodies, to another state B**, happens by way of motions that represent the effects of the causes leading to that transition. As all these motions are on the one hand linked by the causal nexus to A and on the other hand do inevitably lead to B, a situation C different from B could only arise if there were at least one motion different from the others.

…We have seen that the Stoics regarded **cause as a body** and **effect as a**

movement affecting another (or the same) body.

…The elimination of one single link from the causal chain would, by necessity, lead to the destruction of the chain as a continuous whole. The concatenation of causes establishes an interdependence whose disconnection would amount to a dissolution of the cosmos.

…**Effects are propagated in space and time and, together with the bodies from which they emanate and which they affect, form the totality of causation.**

…the doctrine of **causality expands into determinism,** the doctrine of heimarmene. In the pre-Stoic period, heimarmene was mainly used to denote human fate, but the Stoics introduced it as a term signifying causality, the ordered system of causal occurrences.

"Heimarmene is a natural order of the Whole by which from eternity one thing follows another and derives from it in an unalterable interdependence."

If there were a man whose soul could discern the links that join each cause with every other cause then surely he would never be mistaken in any prediction he might make. For he who knows the causes of future events necessarily knows what every future event will be."

…The most important difference between the antecedent and the operative cause according to Clemens Alexandrinus is that the effect of the first persists after the cause has ceased to exist…

…the operative cause and its effect co-exist only in strict simultaneity, so that the effect sets in with the cause and ceases together with it.

…the negation of free will would obviously destroy the foundations of ethics…

The whole causal chain leading up to a certain situation and ending in a definite act on the part of a man confronted by that situation is divided by Chrysippos into two parts. **The first part** comprises **all** the **external events** and includes as a last link their presentation to the conscious human mind. These links in their totality form the antecedent causes whose deterministic nature is obvious and indisputable. **The attitude taken by the mind to the situation presented to it**, the appetitus which is either an irrational impulse or a reasoned choice and which results in the subsequent act **forms the second**

part of the chain which constitutes the operating causes, sometimes also called "perfect and principal causes".

Cicero quotes Chrysippos as pointing at the cylinder and spinning-top which cannot begin to move unless they are given an impulse; but once the impulse has been given, the cylinder goes on rolling and the top spinning according to their own nature (suapte natura). A similar illustration is quoted by Aulus Gellius : "If you roll a cylindrical stone over a sloping steep piece of ground, you do indeed furnish the beginning and cause of its rapid descent, yet soon it speeds onward, not because you make it do so, but because of its nature and because of the ability of its form to roll."

"Just so the order, the law and the necessity of fate set in motion the classes and beginnings of causes, but the impulse of our design and thought and the actions themselves are determined by each individual's own will and the characteristics of his mind."

…the initial conditions represent the antecedent cause, whereas the equation itself and especially the physical constants entering it represent the principal cause.

Both are part and parcel of the deterministic scheme and the body's fate depends on both of them, but there is a difference between them. The initial conditions are the last link of the whole history of the world which led to this particular state of the body.

The stone in Chrysippos' second simile was doubtless subject to various tribulations before "zero hour", when it started rolling down the slope. Being put into a certain situation is the result of an extremely complicated chain of causal happenings comprising the whole history of the physical world preceding that situation. It is clear that the part played by the stone itself in this antecedent chapter is insignificant compared with all the other events which finally created the initial conditions. But if we come to regard the particular behaviour of the stone during its descent down the slope, we realize that the course of its motion is determined by the principal or perfect causes among which the physical properties of the body play an important part. In the case of the stone, it is, as Chrysippos expresses it, its "modus" and "formae volubilitas"; in the case of a vibrating string it is its modulus of elasticity and its density; in the case of the spinning top -- its moment of inertia; in a moving

fluid -- its viscosity, and so on. All these parameters, although they are themselves inseparably bound up with the whole "fate" of world events, are nevertheless characteristic quantities of the body itself, and it is through them that the body's own share in its determined course becomes manifest.

Both the "personal parameters" of man and the "initial conditions" are part of an all-embracing fate. But by the very fact that the personal parameters participate in the determined chain of events independent of external conditions, the arbitrariness of fate is alleviated. Psychologically **this participation appears in the consciousness of the human mind as free will.**

The Stoic belief in "artificial" divination, i.e. in divination from inference based on signs and events in the physical surroundings, in animal life, etc., stemmed from their attitude towards "natural" divination, i.e. the alleged faculty of certain inspired persons to foresee the future. In this they followed in the footsteps of the Pythagoreans and Plato, who had defined divination as "the mutual association of Gods and men"

"Since the universe is wholly filled with the Eternal Intelligence and the Divine Mind, it must be that human souls are influenced by their contact with divine souls."

…already in pre-Stoic times **the gift of prophecy** was sometimes regarded not merely as a transcendental faculty, restricted to a certain class of selected people, **but also as an art based on rational foundation**, and therefore

accessible to every intelligent being.

This second kind of divination, the artificial or inductive one, became of great importance in Stoic epistemology…

Cicero clearly defines **inductive divination** as **"the art of those who follow up new things by inference, having learned the old ones by observation"**

…even though we may not discern the causal nexus itself, we still discern **the signs and tokens** of those causes…

"According to the Stoics, God is not present at every little fissure in the liver or in every song of a bird . . . but the universe in the beginning was so instituted that **certain events are preceded by certain signs** . . ." In other words, the law of causality supposes an immanent and pre-established order in the world by which the succession of single events and the interconnection of phenomena, including those related through divination, is determined once

and for all. It follows, therefore, that the postulation of determinism (i.e. fate) implies the assumption of the validity of the method of induction (i.e. divination).

The Stoic position is that of the empirical scientist who has to allow for errors of observation. "Signs badly guessed and badly interpreted turn out to be **false not because something is wrong** with the order of things but **because of the ignorance of the interpreters.**"

…it must be again emphasized that the whole problem of divination occupied the Stoics not so much for practical reasons but was of primarily **theoretical or scientific interest to them**, for the very reason that **they had to accept the validity of divination in a deterministic world** and at the same time saw in it a confirmation of determinism by inductive inference.

"the assertion that chance is a cause obscure to the human mind is not a statement about the nature of chance but means that chance is a specific relation of men towards cause, and thus the same event appears to one as chance and to another not, depending on whether one knows the cause or does not know it".

He quotes the Stoic definition of "the possible" as follows: **"The possible event is something that is not prevented by anything from happening even if it does not happen."**

…hexis represents the highest type of all possible structures, i.e. an entity which exhibits "communication" (diadosis) between the individual members and the whole.

The interdependence of virtues is one of the basic assumptions of Stoic ethics. **Although every virtue is clearly distinguishable from the others, they interact in such a way that a man possessing one virtue possesses all the others.**

"The knife is the cause for the meat to be cut, and the meat the cause for the knife to cut." Cutting and being cut are mutual causes, they are two aspects of the same event.

"They seem to understand **hexis as the range of variation of a state and diathesis as the extreme case.**" In the same way virtues were regarded by the Stoics as diathesis, not because of their stability, but because they represent an extremal case, a singularity.

The Stoic continuum, being a medium for transmission of physical actions and for exchange of forces, was incompatible with the existence of static and definite surfaces interrupting the free flux of phenomena.

"There is no extreme body in nature, neither first nor last, into which the size of a body terminates. But there always appears something beyond the assumed, and the body in question is thrown into the infinite and boundless."

Instead of the surfaces of two adjacent bodies touching each other, we now have a picture of the infinite sequences which envelop the surfaces, merging into one another and thus forming a narrow zone where the extremities of these bodies enter into a mixture. In this way the corporeality of the contact is maintained and any conceptual difficulty is removed which might arise from the notion of two-dimensional surfaces entering the description of physical phenomena which are taking place in three dimensions.

"Man does not consist of more parts than his finger, nor the cosmos of more parts than man. For the division of bodies goes on infinitely, and among the infinities there is no greater and smaller nor generally any quantity which exceeds the other, nor cease the parts of the remainder to split up and to supply quantity out of themselves." Here the most important sentence is the first one. It seems to be a literal quotation from the writings of Chrysippos. The infinite sets "man" and "cosmos" are compared with their respective subsets "finger" and "man", and it is clearly stated that the subset is equivalent to its set in the sense defined by the modern theory of sets.

…Great and small for him were opposite qualities like hot and cold, etc., and he wanted to express the relative nature of qualities because **owing to the infinite divisibility of things one never reaches a part so small that it does not contain seeds of all the opposite qualities.**

"If we are asked whether we have any parts and how many, and of what

and of how many parts these consist, we will have to make a distinction. On the one hand we can posit large parts and say that we are composed of head and trunk and limbs -- this was all that was asked and inquired about. On the other hand, if the question is carried further to the least parts, nothing of this kind can be assumed, but we must say that we are neither composed of such and such parts nor of so many, nor of finite or infinite ones."

The continuum cannot be regarded as an aggregate of fixed elements, nor can it be said that it is composed of parts. Chrysippos saw it rather as a "medium of free becoming" in the sense in which the modern intuitionists like Brouwer and H. Weyl tried to define its ever incomplete and always fluid character.

The continuum is not a static entity which can be defined as a sum of separate subaggregates or sequences be they finite or infinite; **it is a dynamic whole which is always in the state of becoming.**

Zeno speaks of Time as "the interval of movement which holds the measure and standard of swiftness and slowness", and Chrysippos, amplifying on it, defines **Time as "interval of movement** in the sense in which it is sometimes called measure of swiftness and slowness, **or the interval proper to the movement of the cosmos**, and it is in Time that everything moves and exists".