THE UNNOTICED REGIONAL ONTOLOGY OF MECHANISMS

Ingvar Johansson

(Pre-print version of a paper published in *Axiomathes* **VIII**, pp. 411-428, 1997.)

The first main thesis of this paper is that we can intuit (in the German sense of "anschauen") a kinematics of mechanisms in the same way as we can intuit some truths in Euclidean geometry. There is a *philosophically* almost wholly neglected area in which intuition is possible, actual, and a source of a kind of knowledge which is important both in science and technology. This area makes up a regional ontology (in Husserl's sense[1]) which contains truths about figures-through-time, truths which have the same epistemological status as the truths of the original Euclidean geometry; whatever that status may be. (I do myself regard geometrical truths as Husserlian eidetic laws or laws of essences, and therefore as non-conceptual a priori truths, but the views I put forward in this paper do not rely on such views about synthetic a priori truths.)

The second main thesis is that, even if my remarks about a possible *mechanism geometry* should be wrong, there is nonetheless a surprising lack of studies of mechanism concepts and of mechanism thinking.

1. Contiguity geometry

Analytical geometry revolutionised geometry. The introduction of co-ordinates to define positions in space, and the possibility thereby created, to describe geometrical figures by means of algebraic equations, turned out to be the foundation of a magnificent development of geometry. However, this arithmeticization and algebraicization must not hide the important fact that geometry was a mathematical science long before Descartes invented analytical geometry. Even though large parts of modern geometrical knowledge are possible only within this kind of geometry, it should not be forgotten that some parts were created independently of analytical geometry. Independently of numbers we can intuit what falls under the concepts of point, line, straight line, surface, plane surface, angle, boundary, figure, circle, parallell lines, and some others; and we can intuit axioms like the one that things which spatially coincide with one another are equal to one another (= Euclid's fourth axiom[2]).

Also, I want the reader to keep in mind the fact that a lot of geometrical truths were discovered *before* Euclid distinguished between (in modern terms) axioms and theorems and managed to turn geometry into a deductive system. The following three steps in the development of geometry should be kept distinct:

(1) the discovery of pure geometrical truths
(2) the discovery of axiomatic geometry
(3) the discovery of analytical geometry.

For the purposes of this paper, I do not find it necessary to discuss the epistemological consequences of the discovery of the non-Euclidean geometries. In

[1] [Husserl 1982], §9.
[2] [Euclid 1956], 155.

some sense we can, even today, say that pure geometry, Euclidean as well as non-Euclidean, affords us some kind of non-empirical knowledge. Whether or not physical space-time is Euclidean is of course another matter, and a question which can only be settled empirically. In what follows, non-Euclidean geometrical thinking is wholly left out of account.

Today, geometry also includes areas like projective geometry and topology. But, I claim, there are even more kinds of geometrical truths. I shall sketch something which I would like to call *contiguity geometry*. Some examples will make the basic point clear. If two equally large half circle formed figures are put together, in the same plane, in such a way that their straight lines meet one another, then we get a figure whose *non-common boundary shape* is a circle. Leaving some assumptions tacit, we can write: 'half circle + half circle = circle'.

The last statement is a non-empirical truth about geometrical shapes. It says what is the case when two equally large half circles are contiguous in space in a certain way. Similarly, it is non-empirically true that when two equally large squares are contiguous in such a way that they share one side, then their *non-common boundary shape* is a rectangle. We get: 'square + square = rectangle'. When two right-angled triangles are contiguous with their hypotenuses in common, their *non-common boundary shape* is also a rectangle. We can symbolize it: 'right-angled triangle + right-angled triangle = rectangle'. However, since our language is very meager with respect to concepts which describe geometrical shapes, it is hard to find many truths of this kind which can be *propositionally represented*. But if *pictorial representation* is allowed, then examples can be multiplied indefinitely. All one has to do is to make two shapes contiguous and focus attention on their non-common boundary shape. Two geometrical shapes conjoined and contiguous to each other give rise to a third geometrical shape. And what this third shape looks like can be discovered by means of intuition ("Anschaung").

The relationship which exists between the shapes of the two contiguous figures and their common shape is, I think, discovered by the same kind of intuition which led to the first discoveries of pure geometrical truths. Thus, truths like 'right-angled triangle + right-angled triangle = rectangle' are propositionally represented truths within *contiguity geometry*, but most such truths can (at least today) only be pictorially represented. Whether or not they can be systematised into some kind of theory is a question whose answer is far beyond the aim of this paper. I am *not* trying to become a Euclid of contiguity geometry.

I have so far only talked about *two* contiguous figures, but of course one may also investigate the non-common boundary shape of three or more figures. *I would like to define contiguity geometry as the study of properties and relations which accrue to two (or more) contiguous geometrical figures.*[3] Common shape is not the only property which can be studied. There is another contiguity-geometrical property which may be called *unbroken attachment*; its opposite may be called *broken attachment*. Two two-dimensional contiguous figures may either have only one line in common, in which case they have an unbroken attachment; or they may have more than one line in common, in which case they have a broken attachment. Two figures which have a broken attachment must, somewhere, have an empty space enclosed between them.

[3] I take ‘contiguity’ to imply ‘not overlapping’.

The contiguity-geometrical property of unbroken attachment is explored by at least one well-known group of people, namely by jig-saw puzzle solvers. Since, at the moment one plays with them, the bits of a jig-saw are assumed to be both rigid and non-destructible, they instantiate for the puzzle solving mind ideal geometrical figures. A necessary condition for two bits to belong together is that they can have an unbroken attachment. Another condition, of course, is that contiguous bits have to fit into the overall picture of the jig-saw, which means that the bits shall neither *collectively* have any broken attachment.

A child trying to build a little house with building bricks, can be said to be concerned with all three kind of contiguity-geometrical properties mentioned. Most of the bricks must have unbroken attachments in order not to fall, but the bits taken collectively should also leave empty spaces for imagined rooms, doors, and windows. The house as a whole shall of course have a nice over-all boundary shape.

With respect to *aggregates* of geometrical figures (like the building bricks above), one may talk of *possibility truths* as well as of *impossibility truths*. Some boundary shapes are possible to create by the given aggregate of geometrical figures and some boundary shapes are impossible to create by making the figures contiguous.

The figures in my examples above, are meant to be thought of as two-dimensional or three-dimensional. In a one-dimensional space, contiguity geometry has no interest at all. In such a space there is only two possible shapes, being a point and being a line, and only one possible kind of attachment, (end-)point to (end-)point. The more dimensions the more shapes become possible, and, consequently, the more complex does the corresponding contiguity geometry become. In the next section, time is brought in as an additional dimension, whereby contiguity geometry takes on the form of *kinematical* contiguity geometry and of *mechanism geometry*.

2. Mechanism geometry

What can an old-fashioned (i.e. non-topological and Euclidean) geometrical figure do in time? Answer: It can either move or be at rest, and if it moves it can have a motion which is either translational, rotational, or a combination of translation and rotation. Such a figure is, if three-dimensional, an *absolutely rigid and massless body*. It is indestructible, and it can change neither shape nor size, but it can move. When it moves a four-dimensional space-time shape is created. We shall not, however, look at one single such body, but continue with contiguity geometry; we shall look at two (or more) contiguous geometrical figures of which at least one is moving.

My first three examples of time-extended contiguity geometry are (i) the axle, (ii) the encircled cylinder, and (iii) the nut-and-bolt (see Figure 1).

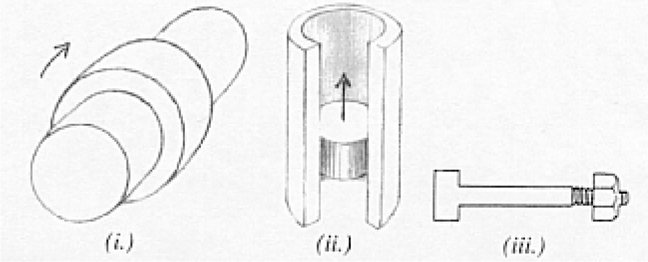

Figure 1

The one who understands the axle can intuit the outer geometrical figure (two-dimensionally, a ring) as rotating around the inner figure (two-dimensionally, a circle). This intuition is in the pictorial representation represented by the ring and the rod in their unbroken attachment *plus* the arrow. Note that the intuition and the picture are not identical. The arrow represents two things simultaneously, both the temporality and the direction of the movement of the ring. My claim now is simply that it is a non-empirical truth that these two geometrical figures (or absolutely rigid and massless bodies) can be in complete and unbroken attachment during the whole time period in which the outer figure is rotating around the inner figure. In space-time we can imagine a corresponding ideal shape, i.e. a shape really extended in time.

I am pretty sure that some intuition like the one described was at work when the wheel was invented, but I am also sure that this was not the whole of the inventive intuition. Of course, the wheel must be intuited also in relation to a third figure, the ground, but that is not what I am thinking of primarily. In order for something to be a wheel, there has to be some kind of *force* or cause which can make the thing with the wheel move. But in the kind of intuition that I am trying to describe in this paper, *all causes have been abstracted away*. Physicists have since long made a distinction between kinematics and kinetics in the study om motion. Kinematics is the study of motion without references to masses or forces, whereas in the kinetics (or dynamics) of movement the causes of movements are studied. Analogously, what I am concerned with can be called *kinematical contiguity geometry*; another possible label is *mechanism geometry*. I am concerned with mechanisms, but mechanisms regarded wholly apart from operating forces, friction, and similar things. When forces are taken into account, too, we get mechanism kinetics, or mechanisms in the ordinary sense.

The intuition of the axle contains a non-empirical possibility truth of mechanism geometry. It says that it is possible for the wheel to rotate around the rod at the same time as they are in complete and unbroken attachment.

In the next example - Figure 1, picture ii - we find another such simple non-empirical possibility truth. It is possible for the cylinder to move in a vertical movement and at the same time be in unbroken attachment with the surrounding body. Also, of course, there are non-empirical *im*possibilities. It is impossible to move the cylinder in any other direction than the vertical one. When this intuition is combined with thoughts of forces, we get a mechanism which is part of several inventions, e.g. the water pump and the cylinder of the internal-combustion engine. If the cylinder is exchanged for different kinds of prisms, then a lot of other, but structurally similar, intuitions and inventions become possible.

In the nut-and-bolt case, picture iii, we find a more complex but structurally similar non-empirical truth. The only possible movement for the nut, if we keep the bolt non-moving, is the combination of a rotational and a translational movement which is typical for screws. Today, it is a very well-known kind of movement, but once upon a time it was a peculiar invention. As an invention it includes thoughts of forces, but also a kinematic intuition to the effect that two contiguous figures, which have such shapes, can be in unbroken attachment while having the screw movement.

Intuitions of the kind described can equally easily be found in relation to contiguous bodies which are completely external to each other in space. Think of cog-wheels. In Figure 2, picture iv, there is a representation of the ordinary circular cog-wheel, which is an essential part in an enormous lot of different kinds of mechanisms and machines. When all forces are abstracted away, we can intuit the pure space-time shape which is created by the two moving geometrical shapes. This intuition *does not* say that one of the wheels is pushing the other. It merely says that they can move continuously while being in unbroken attachment to each other by some cog. There is, by the way, also an *im*possibility truth connected with the cog-wheel. The wheels cannot possibly move in the same direction if the wheels shall stay contiguous and the cogs never be spatially coinciding. The conjunction of these two truths may very well be called *the cog wheel axiom*.

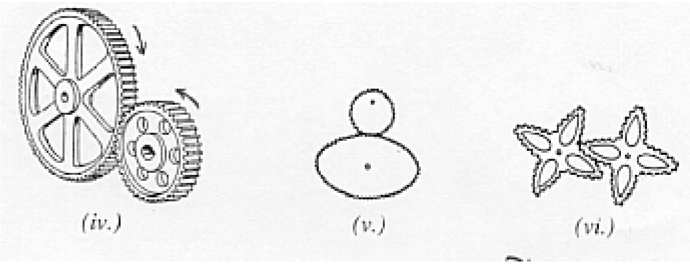

Figure 2

The pictures v and vi are inserted only as intuition exercises for the reader. Can these wheels rotate while being unbrokenly contiguous? In the next pictures (Figure 3, vii and viii) we find the right angled bevel gear and the worm gear, respectively. They are just as non-empirically possible as the ordinary cog wheel is, but to see this possibility seems to require a lot more from our ability to intuit space-time shapes than the ordinary cog wheel does.

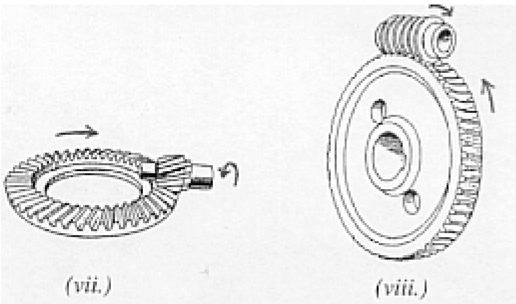

Figure 3

I have defined contiguity geometry as the study of properties and relations which accrue to two (or more) contiguous geometrical figures. *Mechanism* geometry, I would like to define as the study of properties and relations which accrue to two (or more) contiguous geometrical figures *during a time period*. All geometrical bodies are indestructible, colourless, and massless; and they cannot be subject to any forces. When they are regarded apart from time, as in ordinary geometry, they are of course non-changeable or rigid. Their shape cannot possibly change. However, when time is brought in, as in mechanism geometry, then changes of shape of the geometrical bodies become possible. The geometrical figures which are to be investigated need then *not necessarily* be treated as rigid (as in the examples in pictures i to viii). They can equally well be treated as *malleable*. A malleable geometrical body is a figure which is massless and indestructible but which can change shape while retaining both its identity and its size or volume. Shape changes can be investigated in mechanism geometry, just like movements.

Once again I will pick an example from the history of inventions; an example which will make it obvious in what way mechanism geometry differs from topology. Let us take a quick look at Archimedes' famous water screw (see Figure 4, picture ix).

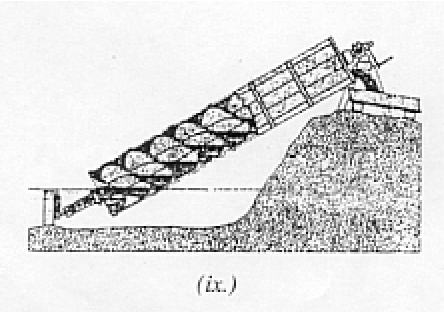

Figure 4

Usually, when we look at it, we think of water which is lifted by the *force* of the screw's movement. But in order for us to step into mechanism geometry, this force has to be abstracted away. The water should be thought of as a *completely malleable* geometrical body and the screw should be regarded as an *absolutely rigid* body. We then have a malleable geometrical shape which is contiguous to a rigid geometrical shape. Wholly without any empirical investigations, we can now see that it is possible for the malleable figure to move and to *change shape* in such a way that it can follow the movement of the screw at the same time as it moves from the lower basin to the upper one. This truth tells us as much or as little about the real world as the truths of ordinary geometry do. It is a truth about ideal entities, but it is still a truth.

There are mechanism-geometrical truths both about *rigid* figures (i.e. figures which can change neither shape nor size) and about *malleable* figures (i.e. figures which can change shape but not size). However, there are also mechanism-geometrical truths about figures which can change both shape and size. Let me call such figures *gaseous*. Ordinarily, we think of gases both as malleable and as expandable and contractible without losing their identity. Of course, there is a link between the ideal concept of a rigid geometrical body and the ordinary concept of solid, and between the ideal concept of malleable geometrical body and the ordinary concept of liquid, just as there is this link between the ideal concept of gaseous geometrical body and the ordinary concept of gas.

Earlier, when I laid bare the mechanism geometry of the encircled cylinder, I mentioned in passing the cylinder of the internal-combustion engine. Now, I can expand this example a little. Normally, we think of such a cylinder as consisting of a gas which (when being ignited) explodes and, thereby, forces the cylinder shaped piston to move downwards, and, in turn, by another mechanism, move a rod. Once again: In order to step into mechanism geometry, we have to think all forces away. What is left when this act of abstraction has been performed, is the non-empirical possibility truth that a gaseous geometrical body *can* change shape and size in such a way that it, during every moment in the time period in question, fills all the space there is between the moving rigid geometrical body and the non-moving surrounding rigid geometrical body.

Obviously, there are an infinite number of possible combinations of rigid, malleable, and gaseous figures in a mechanism geometry, but I shall not delve into any more examples. My aim in this paper is not to *do* mechanism geometry, but to show that there exists a regional ontology which deserves such a name since it contains non-empirical truths of its own.[4] At the beginning of this section, I talked as if the concepts of *kinematic contiguity geometry* and *mechanism geometry* might be synonymous, but they are not. The study of ideal malleable and gaseous bodies cannot be restricted to their kinematics. Kinematical contiguity geometry is merely one part of mechanism geometry.

3. Mechanisms in science

All my examples of mechanisms so far have been examples of artificial mechanisms, i.e. mechanisms invented by man. But nature contains in itself a myriad of different mechanisms; some of them may be called nature's evolutionary inventions. Mechanisms are mechanisms independently of origin. This being so, I want to make some remarks on the existence of mechanisms in natural scientific theorizing. In these remarks, though, *my distinction between the kinematics and the kinetics of mechanisms is of no relevance, except when explicitly mentioned.*

In the medical sciences mechanisms abound all the way from the macro level to the micro level of molecular biology. The mechanisms which even we laymen talk about (the blood circulation system, the attached lymph system, the central and the peripheral nervous system, the digestive and secretion systems and the immune system) have been analyzed into more detailed physiological mechanisms, and these, in turn, the molecular biologists try to analyse into molecular mechanisms.

Likewise, mechanisms abound in the whole of ecology, biology, and zoology; and the same goes for the earth sciences and disciplines like meteorology. All of them make heavy use of mechanisms both in explanations and predictions. But, and this is a noteworthy fact, the same cannot be said of modern physics. In particular, it happens to be the case that none of the three most prominent physical theory constructions of this century (the theory of special relativity,[5] the theory of general relativity, and the quantum mechanical theories) contain descriptions of mechanisms. The theory of special relativity consists only of equations by means of which it is possible to transform length values and mass values from one inertial frame into another such frame, and these transformations are not associated with any mechanisms at all. In general relativity theory, each solution to the general equation gives a holistic description of space-time and its mass-energy distribution; the theory depicts no mechanism whereby a certain space-time structure becomes connected with a certain mass-energy distribution, or vice versa. Quantum mechanics is, by many non-positivists and realists, regarded as a theory which cries for a mechanism which makes it really understandable. As is well known, however, no such good mechanism has yet been discovered or invented. The most important parts of twentieth century physics have, no doubt, developed without making use of mechanism explanations.

In fact, mechanisms were conspicuously absent even from the theories which constitute the birth of classical physics. Galilei's law for freely falling bodies, Newton's laws of motion, and his gravitational law, were all phenomenological laws. They relate

---

[4] This paper is a development of thoughts first put forward in [Johansson 1989], chapter 14; in the book there is no real concept of mechanism geometry, although the founding idea is there.

[5] In special relativity, geometrical shape is *not* a frame-invariant property. Nonetheless, however, this theory does not affect my thoughts about a mechanism geometry any more than the non-Euclidean geometries do. Much can be said here, but for the moment I have to rest content with stating my view.

different magnitudes to each other but describe no mechanisms. Newton's gravitational law momentarily relates masses which can be at any distance from each other in space; whereby philosophy got the problem of action at a distance. Action at a distance, of course, necessarily excludes every kind of contiguity geometry and ordinary mechanisms. There are, though, two famous classical theories which contain talk of mechanisms: the statistical interpretation of thermodynamics (whereby temperature is regarded as an effect of the kinetic energy of molecules) and Faraday's formulations of the electromagnetic field theory (in which there are real fields with different patterns of field strengths). Sometimes, also physics has developed by making use of mechanism explanations.

The conclusion which follows from my brief remarks is simple: Sometimes a natural science can make progress without mechanism intuiting, but sometimes such intuiting is needed.

4. Mechanisms in the philosophy of science

For positivists who claim that science should only look for correlations among observables, mechanism thinking can only be an intermediary heuristic device in the hunt for fundamental correlations. For reductionists, who think that in the end all the sciences will be reducible to physics, mechanism intuiting is important only if it is important in physics. But since modern physics seems to do well without hypotheses about mechanisms, philosophers of science need not waste time on trying to analyse what mechanism intuiting really is about. Within philosophy of science, both positivists and reductionists will be interested mainly in the formal-logical structure of science. That is part and parcel of their positions.

Since positivists and reductionists for a long time dominated the philosophy of science in this century, it is not surprising that the concept of mechanism has no central place in the philosophy of science. Somewhat surprisingly, though, I find the fact that non-positivist and non-reductionist philosophers of science, who even owe some of their reputation to their stress on the concept of mechanism, have nonetheless made no real attempt to get a really clear idea of what can constitute a mechanism. Therefore, I shall make some brief comments in relation to three such philosophers of science: Mario Bunge, Rom Harré, and Roy Bhaskar.

In 1964 Bunge published his paper *Phenomenological Theories*,[6] in which he attacked what he called 'black boxism'. A black box theory (or phenomenological theory), is a theory in which there is no talk of mechanisms which connect input variables to output variables. In a translucid box theory (or representational theory) there is some kind of representation of such a mechanism. 'Black boxism' is the view that science should *only* be concerned with black box theories. According to Bunge, both phenomenological and representational theories are important in science, but the representational ones give deeper explanations; black box *theories* are important now and then, but black boxism is devastating for science.

The same stress on mechanisms reappears on several occasions in Bunge's two volume treatise, *Scientific Research*.[7] Never, however, does Bunge try to tell the reader what a mechanism is. In passing, he distinguishes between mechanical and

---

[6] [Bunge 1964], 234-254.

[7] [Bunge 1967], see in particular vol. I, chapters 5.4 and 8.5.

non-mechanical mechanisms and between visualizable and non-visualizable mechanisms, but all the time he takes it for granted that everyone knows what a mechanism is. There is not even a hint at the existence of something like a mechanism geometry.

A few years later than Bunge, Rom Harré mounted his attack on positivist and conventionalist philosophy of science in his book *The Principles of Scientific Thinking* (1970). Harré talks about three great myths in the philosophy of science, the myth that events are the prime objects of knowledge, the myth that only sentences can be vehicles of rational thought, and the myth of deductivism that logical order matches natural order and that mathematics is an ideal of knowledge. Instead, he proposes some "counter principles" which he thinks ought to replace the myths. These principles are implicitly about mechanisms:

(a) The world is a collection of semi-permanent structures, and there is knowledge both of how these structures behave (conditional law statements), and of what they are (categorical descriptions of structure, etc.). These two fields of knowledge are linked together by the idea of powers, i.e. behaviour is seen as the exercise of capacities things have in virtue of their natures.
(b) The vehicles for thought are not wholly propositional but 'pictorial' as well, so that considerations affecting the judgement of likeness and unlikeness become important as principles of rationality.
(c) A Theory is a complex of
  (i) a representation or description of a permanent structure which is responsible for the phenomena explained by the theory;
  (ii) a set of conditional statements describing how that structure reacts, in particular circumstances.
  (iii) if the structure responsible for the pattern of phenomena is unknown then an iconic model of it must be constructed.[8]

When Harré explicitly speaks of mechanisms, he refers to ordinary examples like the clockwork, bouncing molecules, viruses which cause diseases, other physiological mechanisms, the mechanism of natural selection, and so on. Often, however, he adds an adjective and talks of '*causal* mechanisms' or '*generative* mechanisms'. In section 2 above, I distinguished between mechanism *kinematics* and mechanism *dynamics* (or kinetics) and tried to analyse the former one. Harré does not notice the possibility of such a distinction, but, in fact, he is only interested in the dynamics of mechanisms, i.e. of powers and causal laws. Here is another quotation.

Causal laws are saying ultimately how a cause generates its effect. To establish this element in causal law the proponent of the law can be called upon to describe the manner and mechanism of the generation of the effect by the cause. To do this he must advert to the inner constitutions, structures, powers, encompassing systems, and so on, of which natural generative mechanisms are constituted, and of which the connection between cause and effect usually consists.[9]

It then turns out to be the case that Harré has very specific views about what the ultimate constituents of causal relations can be like. He argues for the view that "The ultimate entities are point sources of mutual influence".[10] According to Harré, all generative mechanisms in nature must be grounded in powers which reside in mathematical points in space. In a mathematical point there can be no contiguity geometry, and, really, Harré reduces mechanisms to point powers.

---

8 [Harré 1970], 1-2.
9 [Harré 1970], 104.
10 [Harré 1970], 296.

'Natural science is a fact, but how is it possible?', Roy Bhaskar asks in his *A Realist Theory of Science*.[11] It is possible, he says, because experiments are possible, and experiments are possible because reality is stratified into experiences, events, and mechanisms; all equally real. Mechanisms generate events, and some events can be experienced. Usually, in nature many mechanisms cooperate and/or counteract in the production of events. In experiments, mechanisms are *isolated*. Despite the important role the concept of mechanism plays in Bhaskar's philosophy of science, he never analyses it. He simply relies on Harré's concepts of powers and generative mechanisms.

Conclusion: Neither Bunge nor Harré nor Bhaskar, do realise the important part played by four-dimensional shapes in ordinary mechanism intuiting.

5. Mechanisms in technology

I started with technological examples, and, now, after our detour into science and the philosophy of science, we shall return to technology. In a science like physics, one often distinguishes between theoretical physics and experimental physics, but no similar distinction seems to exist within technology. However, there have been some attempts to create what I would like to term *theoretical technology*. Now, if somewhere in technology there is something like a mechanism geometry with non-empirical truths, it surely should be found among these attempts at technological theory foundation. If I may trust a very superficial glance at the history of technology, there is only one man whose thoughts I have to present a little, Franz Reuleaux.

In 1875 Reuleaux published a book he called *Lehrbuch der Kinematik: Theoretische Kinematik. Grundzüge einer Theorie des Maschinenwesens*, and in 1900 there followed a second volume called *Lehrbuch der Kinematik: Die praktischen Beziehungen der Kinematik zu Geometrie und Mechanik*; in 1963 there appeared an English translation called *The Kinematics of Machinery: Outline of a Theory of Machines* (which I have not read; the translations below are my own). Long before Reuleaux there had been attempts at classifications of different machines and different kinds of machine elements. A Swedish inventor living around the turn of the seventeenth century, Christoffer Polhem, had even tried to create a mechanical alphabet. But no one had set himself the task which Reuleaux makes his own, namely to outline "a truly deductive treatment of machines".[12]

To start with, Reuleaux treats the bodies as absolutely rigid ("vollkommen widerstandsfähig") and he takes no account of their masses; he is only interested in their geometrical properties.[13] Later, he came to speak of a theorem of sufficient rigidity ("Satz von der ausreichenden Widerstandsfähigkeit").[14] In one sense he disregards what I have called mechanism kinetics, but in another not. He is often interested in what ways mechanisms can transmit forces, but he is never interested in what way forces do arise. Sometimes he talks about his treatise as "Zwanglauflehre", but he says that the best word for it is *phoronomy*, i.e. geometry of motion.[15] (According to Reuleaux, it was Kant who first proposed a separation between

[11] [Bhaskar 1975].
[12] [Reuleaux 1875], viii.
[13] [Reuleaux 1875], 44-45.
[14] [Reuleaux 1900], 151.
[15] [Reuleaux 1875], 59.

phoronomy and the old geometry for figures at rest.[16] I can add that Husserl mentions phoronomy in *Ideen*.[17])

The kind of geometry of motion which Reuleaux wants to study is a special kind of movement. He is not primarily concerned with the movement of one single body as in the cycloid movement, which was studied in phoronomy. The basic kinematical units of machines are, he says, *pairs of elements* ("Elementenpaaren").[18] A machine can be analysed into one or several mechanisms, and these, in turn, can be analysed into pairs of elements. But then the machine analysis ends. Similarly, the kind of study which I have called contiguity geometry cannot be done with only one shape; two shapes are needed in order for questions of over-all shape and unbroken attachment to arise.

With regard to rigid bodies, there are according to Reuleaux three kinds of *encompassing pairs* ("Umschlusspaare"), i.e. pairs of elements where one element encompasses the other. I can now say that my first three examples of mechanism geometry are almost identical with Reuleaux's three basic "Umschlusspaare".[19] As Reuleaux notes, if one varies the screw angle of the nut and bolt, one may regard such a variation as having its extremes in the axle (where there is only a rotational movement) and the prism or cylinder (where there is only a translational movement). When he has treated the rigid bodies, he does not introduce any concepts which correspond to those that I called malleable and gaseous bodies, respectively. But he makes an augmentation and introduces *the flexible mechanical elements* ("die bildsamen kinematischen Elemente"), i.e., elements which can transmit forces in only one direction like bands of leather, of metal, and of other stuffs.[20] However, I shall stop my presentation here and present the two conclusions I have drawn.

(1) Reuleaux's work has the flaw that he never explicitly abstracts all causality away and isolates mechanism geometrical truths. But he came close to doing it.

(2) In the second volume of his great treatise, Reuleaux says that he has "strictly a priori deduced" the three "Umschlusspaare" spoken of.[21] Be that as it may, Reuleaux did not succeed in becoming the Euclid of machine theory. But perhaps this is objectively impossible. Perhaps, contiguity geometry and mechanism geometry do not lend themselves to a systematisation in which a lot of geometrical truths become derivable as theorems from a set of fundamental axioms.

6. Mechanisms in Ontology

In a very recent paper, "Aspects of the Mereology of Artifacts",[22] P.M. Simons and C.W. Dement writes the following:

---

16 [Reuleaux 1900], vi.

17 Husserl writes: "It is well known that the basic means of natural scientific theorizing are the purely mathematical disciplines such as the material disciplines of geometry or phoronomy, the formal (purely logical) disciplines such as arithmetic, analysis, etc. It is manifestly clear that these disciplines do not proceed empirically, that they are not grounded by observation and experiments on experienced figures, movements, and so forth." [Husserl 1982], 45.

18 [Reuleaux 1875], 46.

19 [Reuleaux 1875], 94 and [Reuleaux 1900], 155-56.

20 [Reuleaux 1875], 165.

21 [Reuleaux 1900], 729.

22 [Poli & Simons], 255- 276.

The level of civilisation is literally measured by the kind of artifacts of which a culture is capable, from the first palæolithic hand axe to the space shuttle and the supercomputer. It is all the more surprising then that there has been little interest in the general ontological status of artifacts. Perhaps it is assumed that there is little to say beyond the bare dictionary definition, or perhaps that the very variety and heterogeneity of artifacts inhibits such a general study. They lack as a class that simplicity and amenity to formal treatment that attracts the formally inclined, and largely fail to give rise to the kinds of tingling intellectual puzzles that customarily attract philosophers.

Nevertheless, so important a class of entities should not remain outside the general ontological purview.[23]

I sympathize whole-heartedly with what is said in this quotation, and with the authors' attempt do ontology in this area. My thoughts about a regional ontology of mechanisms ought to be of interest also for that kind of undertaking, but I want to make two comments in relation to Simons & Dement's paper. First, they do not write about the kind of mechanism intuition that I have tried to highlight. Second, mechanism intuition is at work not only in relation to artifacts; it is important in relation to nature, too. Reuleaux, by the way, also notes this obvious fact, and he ends his technological treatise with a section called "Kinematics in the Animal Kingdom".

7. Concluding remarks on the study of mechanism intuiting

Ordinary geometry, as is well established, grew out of practical earth measurements. It took quite a time for the human mind to make (or perhaps: found it worthwhile to make) the kind of abstraction which is necessary in order to go from ordinary solid things to the non-destructible colourless and massless absolutely rigid bodies of geometry. In a lot of ways, however, this kind of thinking in terms of ideal figures has proved to be fruitful; both theoretically and practically. The primary aim of the sections above was to highlight the fact that it is equally possible, in relation to the mechanisms spoken of in technology and the natural sciences, to abstract the corresponding mechanism dynamics away and get a mechanism geometry about ideal figures moving and/or changing in time.

Ordinary geometry has made its way even into intelligence tests. In most tests in which a general intelligence is supposed to be measured, some of the problems to be solved are in a wide sense geometrical. Psychologists concerned with these kinds of tests have since long discussed whether or not the general intelligence should be seen as consisting of various factors. One of the pioneers, C. Spearman, distinguished between one general factor and some specific superimposing factors. Another one, L.L. Thurstone, made by means of statistical factor analysis, a distinction between spatial ability, perceptual speed, numerical ability, verbal meaning, memory, verbal fluency, and inductive reasoning. In this half of the century, J.P. Guilford has proposed a "structure-of-intellect model" where he gets 120 intellectual abilities by crossing some more fundamental ones.[24] Quite recently, it has been argued in an international best-seller, H. Gardner, *Frames of Mind - The Theory of Multiple Intelligences*,[25] that there are seven distinct different intelligences.

I am not mentioning intelligence tests in order to step into the discussion of their validity and reliability, but in order to make a general point of relevance for the topic

---

[23] [Poli & Simons], 255.

[24] [Guilford 1967].

[25] [Gardner 1984].

of this paper. As soon as it is assumed that there are different factors in a general intelligence, or that there exist different kinds of intelligences, then it becomes possible for me to ask where in the intelligence concept at hand the ability to intuit mechanisms has been placed.

Gardner, in the book mentioned, distinguishes between the following intelligences: linguistic, musical, logical-mathematical, spatial, bodily-kinesthetic, intrapersonal, and interpersonal. Only two of them are of interest here, the logical-mathematical intelligence and the spatial intelligence, and one may note that these intelligences have obvious similarities with some of the factors distinguished by his forerunners. These distinctions, by the way, conform well with the introductory remark I made about analytical geometry in relation to the original Euclidean geometry. In analytical geometry, I think, one mostly makes use of the logical-mathematical intelligence, whereas in Euclidean geometry some kind of spatial intelligence is also central. A typical problem in a test of the spatial intelligence (or ability) is the following. One is presented with some pictures of somewhat complicated three-dimensional figures; two of these pictures depict an identical body but seen from different perspectives. The problem consists in identifying these two pictures.

So far so good. Now, if what I have called mechanism intuiting should be part of any of the intelligences or intelligence factors mentioned, it ought to be part of the spatial one. However, problems concerned with mechanisms are absent in Gardner's discussion of the spatial intelligence. And what is true of Gardner's presentation seems, according to a quick survey of mine,[26] to be true both of most such discussions and of intelligence tests. At least they are true of H.J. Eysenck's widely known self-assessment books.[27] In these books, many of the problems test one's ability to see figures *in space* from different perspectives, but *no* problem tests one's ability to imagine figures moving and/or changing *in time*. The ability to see mechanisms is not tested at all. I am *not* saying that there must be a spatio*temporal* intelligence which is different from the spatial intelligence; I am saying that it seems to be the case that test psychologists have never entertained the idea that there *may exist* a special *mechanism intelligence*. Therefore, we simply do not know today whether or not a spatial and a spatiotemporal intelligence (or intelligence factors) coalesce.

The kind of ability I am focusing attention to is an ability to *intuit* mechanisms. It is a spectator's ability, and it must not be conflated with abilities to *use* mechanisms. The latter abilities are agent abilities.

Like philosophers of science, the test psychologists seem not to have realised the peculiarity of mechanism intuiting. As an exercise, the reader can try to understand the mechanism depicted in Figure 5 (picture x). It is the famous so-called lever escapement which was invented in the middle of the eighteenth century, and which was an important step in the development of the clock.

Our modern world, with its natural science and technology, could probably not have come into existence if man had lacked the ability to intuit mechanisms. Mechanisms abound in the natural sciences and in technology, but they are not really discussed among philosophers of science, nor are the non-empirical truths of mechanism

[26] My survey conforms at least with [Eysenck 1972].

[27] [Eysenck 1962] and [Eysenck 1966.]

geometry discussed by philosophers or theoretically minded technologists. And mechanism intuiting is not discussed among test psychologists. Curious![28]

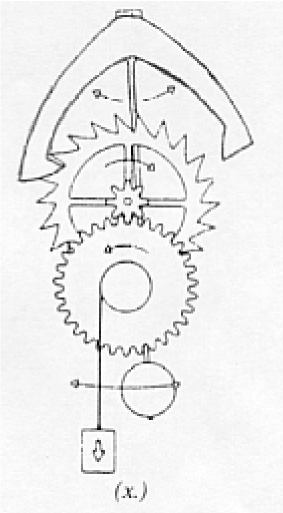

Figure 5

Bibliography

[Bhaskar 1975]	R. Bhaskar, *A Realist Theory of Science*, Leeds Books.
[Bunge 1964]	M. Bunge (ed.), *The Critical Approach to Science and Philosophy*, Free Press of Glencoe, New York.
[Bunge 1967]	M. Bunge, *Scientific Research* vols. I&II, Berlin, Springer.
[Euclid 1956]	Euclid, *The Thirteen Books of Euclid's Elements* vol. 1, New York, Dover.
[Eysenck 1962]	H.J. Eysenck, *Know Your Own I.Q.*, Harmondsworth, Penguin.
[Eysenck 1966]	H.J. Eysenck, *Check Your Own I.Q.*, Harmondsworth, Penguin.
[Eysenck 1972]	H.J. Eysenck (ed.), *Encyclopedia of Psychology* (3 vols.), London, Search Press.
[Gardner 1984]	H. Gardner, *Frames of Mind - The Theory of Multiple Intelligences*, London, Heinemann.
[Guilford 1967]	J.P. Guilford, *The Nature of Human Intelligence*, New York, McGraw-Hill.
[Harré 1970]	R. Harré, *The Principles of Scientific Thinking*, London, Macmillan.
[Husserl 1982]	E. Husserl, *Ideas pertaining to a Pure Phenomenology and Phenomenological Philosophy*, Dordrecht, Kluwer.
[Johansson 1989]	I. Johansson, *Ontological Investigations*, London, Routledge.
[Poli & Simons 1996]	R. Poli and P. Simons, *Formal Ontology*, Dordrecht, Kluwer.

[28] I would like to thank P. Simons, Leeds, England, and, in Sweden, L-G Johansson, Linkoping, and the whole seminar at the Department of Philosophy and Philosophy of Science, Umea, for valuable comments.

[Reuleaux 1875] F. Reuleaux, *Lehrbuch der Kinematik: Theoretische Kinematik. Grundzüge einer Theorie des Maschinenwesens*, Braunschweig, Friedrich Vieweg.

[Reuleaux 1900] F. Reuleaux, *Lehrbuch der Kinematik: Die praktischen Beziehungen der Kinematik zu Geometrie und Mechanik*, Braunschweig, Friedrich Vieweg.

Ingvar Johansson
Department of Philosophy and of Philosophy of Science
Umeå University
S-901 87 Umeå
Sweden
e-mail: Ingvar.Johansson@philos.umu.se