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Causal and Diagnostic Reasoning

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Abstract:

Causal and diagnostic reasoning.

This paper deals with reasoning involved in the analysis of singular events as, for instance, outbreaks of diseases. Mackie's theory of singular causality is shown to be a fruitful tool for this kind of analysis. We expand this theory and discuss some issues about the nature of causal complexes (their prototypical character) and about how detailed a causal tree structure must be (the stop problem). It is argued that causal and diagnostic reasoning is driven by constructing mental models.

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Reasoning is not identical with deductions. Even in scientific thinking we draw conclusions based on insufficient premises, and we quite often work with inconsistent theories. A very beautiful description of how scientists handle inconsistent and incomplete information is given by Werner Heisenberg in his characterization of Niels Bohr's early atomic theory: "Bohr must surely know that he starts from contradictory assumptions which cannot be correct in their present form. But he has an unerring instinct for using these very assumptions to construct fairly convincing models of atomic processes. Bohr uses classical mechanics or quantum theory just as a painter uses his brushes and colors. Brushes do not determine the picture, and color is never the full reality; but if he keeps the picture before his mind's eye, the artist can use his brush to convey, however inadequately, his own mental picture to others. Bohr knows precisely how atoms behave during light emission, in chemical processes and in many other phenomena, and this has helped him to form an intuitive picture of the structure of different atoms; a picture he can only convey to other physicists by such inadequate means as electron orbits and quantum conditions. It is not at all certain that Bohr himself believes that electrons revolve inside the atom. The fact that he cannot yet express it by adequate linguistic or mathematical techniques is no disaster. On the contrary, it is a great challenge." (1). Bohr is not facing a problem of logic but a problem of rationality, namely, the <u>problem of inventing or constructing</u> enough mathematical structure to represent those phenomena he already has a relatively clear intuitive picture of - that is, enough structure to make logical deductions possible. This rational activity is not rule- based but a kind of tacitly given skill that characterizes creative work.

Although reasoning cannot be adequately modelled as logical deductions it is a significant part of reasoning to put forward claims and to justify these claims. Bohr acted rationally as a scientist by picking out consistent sets of claims about his picture of light emission from atoms and by drawing logical consequences from these claims. It is of course very common both in scientific and daily life reasoning to construct such sets of claims - belief sets or belief systems as we may call them. Such claims are very often expressed in propositional form. Therefore, it is natural to model some aspects of reasoning as a process of modification of belief systems, where belief systems are represented as sets of propositions or sets of sentences. This is a fruitful idea which has been explored by Harman (2), Gardenfors (3), Doyle (4) and many others. But it is evident form Heisenberg's description that states of belief and knowledge are not the only mental states and processes involved in reasoning. And, as John Searle says, when we try to trace each state of our network of knowledge and belief, we will eventually reach "a bedrock of mental capacities that do not themselves consist in Intentional states (representations), but nonetheless form the preconditions for the functioning of Intentional states".(5)

It is important to understand this system of background capacities, and to understand how they form the basis of more explicitly given states of knowledge and belief. However, there does not exist - to the best of our knowledge - any satisfactory theory about this background; and we are not going to propose one. What we shall do is to present some observations about reasoning which indicate that some more fundamental, non-propositional mental activities are involved. That is to say, we want to present some further arguments showing the need for a more detailed analysis of the background of knowledge and belief.

These observations are about the use of knowledge and belief by experts when they, as experts, aim at solving practical problems . They may not be relevant to the study of other kinds of belief change, as, for instance, the kind of changes we experience in our daily life or when we acquire new results in basic research. Hopefully, these observations may have some value for further formal work on knowledge representation.

To be more concrete, what interests us is the nature of causal and diagnostic reasoning especially as this kind of reasoning appears in clinical medicine. The clinician is interested in classifying and causally explaining a comprehensive group of important singular events, namely diseases. Diseases are important singular events which we want to prevent happening, or, if they actually happen, we want to reduce their consequences. We are interested both in treatment of diseases, when they have appeared, and in finding suitable measures which eventually will prevent them from happening. There are three aspects of causal and diagnostic reasoning in medicine which require a further analysis of background capacities. They are:

1. construction of first-guesses of a diagnosis
2. the stop problem: how far back in a causal chain must one go?
3. causal field (to be defined later): the space in which the explanation takes place.

But more about that later.

Causal and diagnostic reasoning is not only noticeable in clinical medicine. We find a similar type of reasoning in process industry where we are interested in analyzing accidents, breakdowns or malfunctions which might lead to disasters or catastrophes. In this domain we are also seeking a typology of accidents and their causes. Because of this similarity it is desirable to give a general analysis of causal and diagnostic reasoning which applies to both domains. That is what we are aiming at. But there is an important difference between the two domains, however. In process industry one knows the design and purpose of the system, which in some sense makes it easier to diagnose. In medicine you don't have that kind of information, or you at least only have very rudimentary information about the design. We are not going to explore this important difference here.

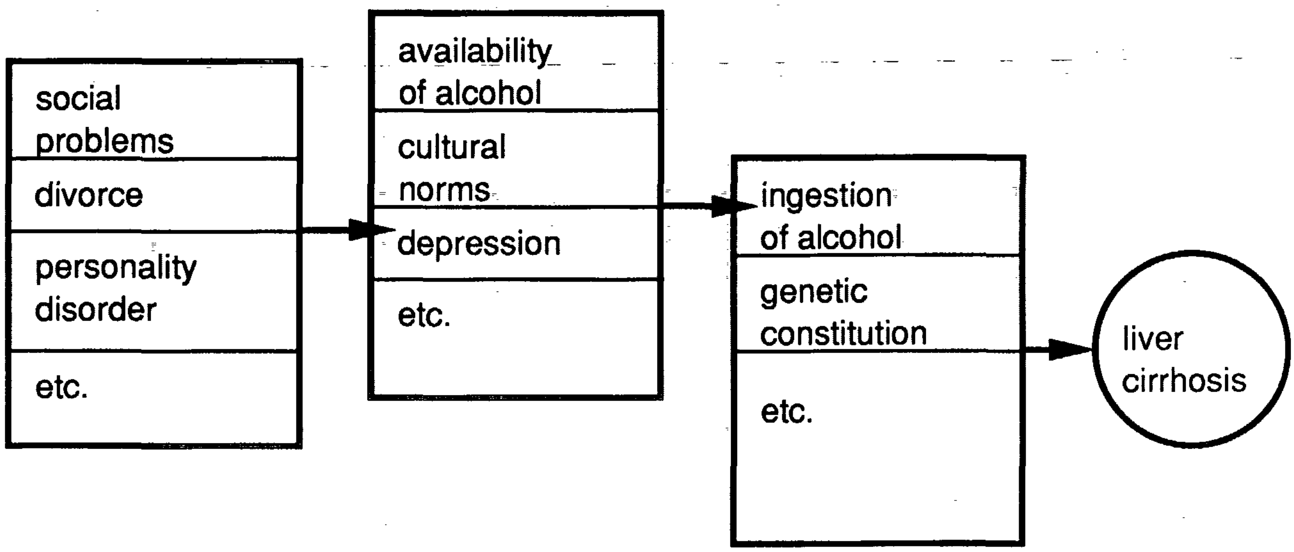
The kind of explicit knowledge needed to diagnose and disentangle causes of various diseases is of two types. First, it is important to have a disease classification, that is, an extensive conception of possible diseases or accidents and means to diagnose events as members of some of these classes. Second, we must have knowledge of the causal network that might lead to diseases or accidents.

It would be natural to require that all this knowledge should be explicitly represented in a huge and exhaustive classificatory system, a system that both include diagnostic criteria and causal structures. As modern disease entities of course are defined by taking disease causes into account modern disease classification systems actually can be considered as being attempts to build such systems. It is also natural to expect that it might be possible to build diagnostic expert systems. And of course it has already been done with some success. Undoubtedly such systems can be improved and in the future be of great help and support to clinicians and engineers in their diagnostic work.

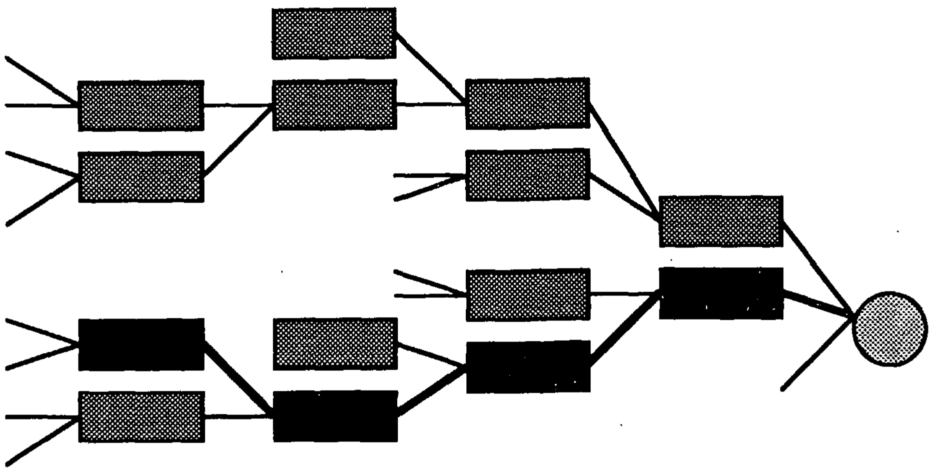
However, it is well known that expert systems cannot take over the role of human experts, and it is surprisingly difficult even for experienced physicians to apply correctly existing explicit classificatory systems. We want to discuss some epistemological features of diagnostic and causal reasoning which might explain some of these difficulties and which must be dealt with if we want to build useful information processing systems that are able to cope with diagnostic and causal reasoning.

Let us give an example in the form of a clinical case: A 44-year-old man is admitted with jaundice and ascites, and it is found that he suffers from cirrhosis of the liver. He readily admits that he has been drinking heavily for a number of years, and he explains that he drinks because of loneliness and depression. It is estimated that his daily consumption of alcohol approaches 200 grams. He is seen by a psychiatrist who explores the past history, and it is revealed that he had an unhappy childhood. His parents divorced when he was 5 years old and his mother had difficulties in coping with him and his two sisters. He did badly at school and was involved in petty criminality. Then, he became a carpenter and worked at building sites where it was normal to drink considerable amounts of beer during the day, but he was never employed by the same firm for more than a few years. He married young, but his wife divorced him when he started to drink heavily during long periods of unemployment. The psychiatrist also concluded from his examination that the patient had a personality disorder.(6)

The complex of causal factors in a case like this one is, of course, very complicated and the following diagram is no more than a suggestion:



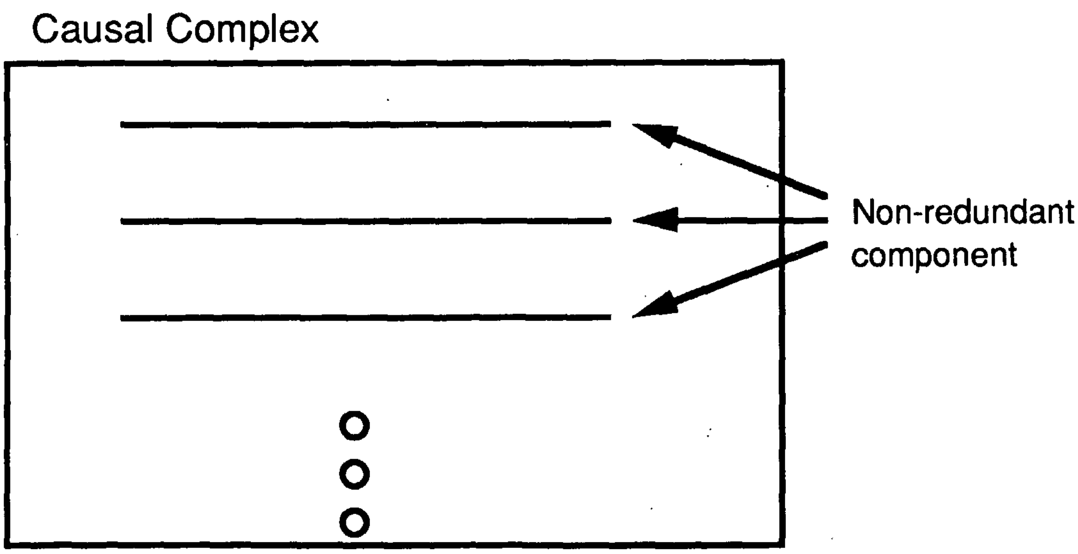
The doctor who treated the patient was in no doubt that the liver disease was caused by alcoholism, as the ingestion of that amount of alcohol may be regarded as a sufficient cause of liver damage. But it is also known that the extent of the damage and the cause of the disease is to some extent determined by the patient's genetic constitution. If the patient's ingestion of alcohol had been less extreme and he had had a stronger genetic constitution he might not have developed cirrhosis of the liver. Furthermore, many other processes may lead to cirrhosis of the liver, as, for instance, various kinds of virus infection, metabolic defects, etc. Consequently, this disease can be caused of many other events. The full causal space of liver cirrhosis will look like this:



General causal tree

All branches in the diagram are possible courses of events, the actual sequence of events is consistent with one, and hopefully only one, branch.

We call each box in the diagram an effective causal complex and each line in the boxes a non-redundant component. A cause is defined as a non-redundant component of an effective causal complex.



This theory of causality is a slightly modified version of J.L. Mackie's theory of singular causality (7). The effective causal complexes are by themselves sufficient for the disease, but not necessary, whereas the non-redundant components are necessary but not sufficient parts of the complexes. The non-redundant components are INUS-conditions in Mackie's sense.

It is possible to say a bit more about the nature of effective causal complexes. Usually, diseases and accidents manifest themselves in a regular manner. Consequently, it is to some extent possible to classify causal complexes and list possible causal trees. That is what clinical medicine aims at, and the usual medical disease classification is the result of this. But, as we shall see below, it is impossible to reach a complete classification of possible diseases or accidents. Causal complexes need not be natural kinds. Usually, they are consequences of human decisions. They are conglomerates of circumstances which, when they happen in the right order, lead to the event. Each of the non-redundant components when considered as part of the complex increases the probability of the event, but they might not do so in other contexts.

In spite of the fact that human decisions - or some other forms of contingencies - are involved in causal structures of diseases and accidents there is still some kind of regularity involved. We express this by saying that effective causal complexes are robust classes. By saying that a class is robust we mean that it is more than an arbitrary delimited set. It is a classificatory entity which supports induction or prediction or which is theoretically relevant (e.g. plays an explanatory role). This is not a very precise definition, but the idea is that robust classes, like, for instance, natural kinds, play a decisive role in causal and explanatory contexts because they refer to events that apparently occur regularly or in lawful ways. Examples of robust classes are:

- disease entities
- clouds
- tigers

- alcoholics
- error classes
- designed mechanisms and structures

...

All these kinds of classes are categorically very different. But they share the property of being important concepts in causal reasoning. They all refer to possible "causal mechanisms" which may turn out to be essential to causal analyses. But such "causal mechanisms" need not be natural mechanisms, they may well be social, psychological or even rather unspecified regularities of which we know from experience that they occur with high probability.

The non-redundant components of a causal complex constitute a partial and incomplete description of the complex. They are of a very inhomogeneous s nature and refer to properties and features in the causal field or context of the event to be explained. For instance, they may be of the following kinds:

- alien agents (e.g. bacteria)
- important past decisions (omission of certain precautions) or events
- malfunction of mechanism at a certain level (e.g. low production of insulin)
- environmental conditions
- contextual conditions

...

We don't have a clear overview of the range of possible types of non-redundant components, and neither do we have a theory of how they in fact specify the causal complex. But we do know that they only partially specify the complex, probably in the same way as the meaning of natural kind terms and other forms of concepts only are partially specified by defining properties.

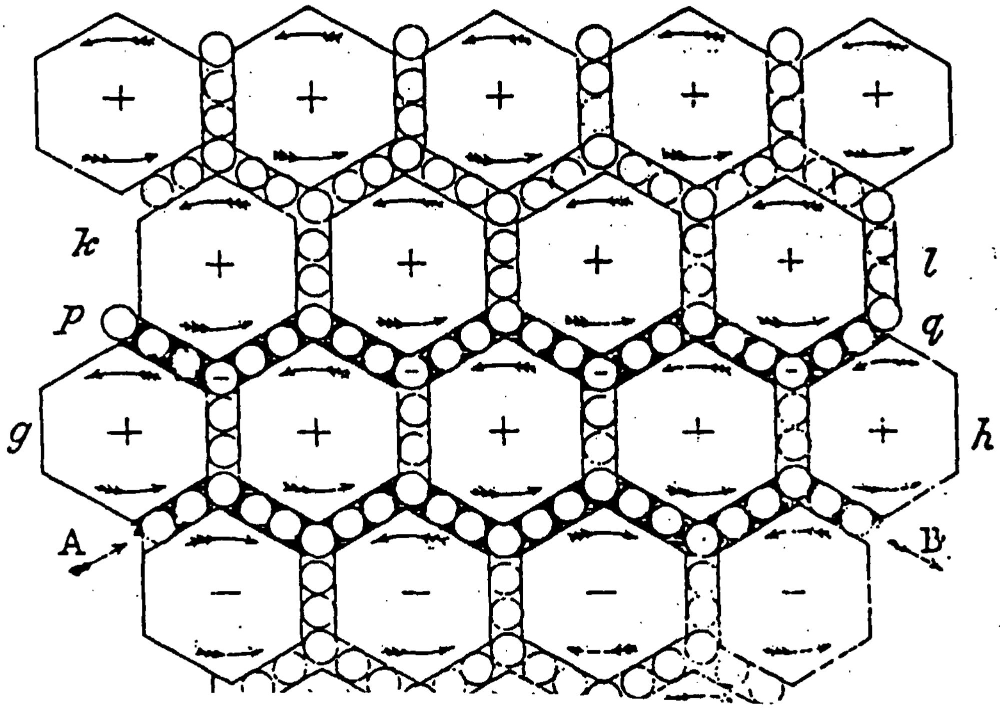
It is therefore tempting to apply philosophical and psychological theories of concept formation to the specification of causal complexes. Many of these theories, e.g. Putnam's philosophical theory of stereotypes

(8), Rosch's theory of prototypes (9), Marvin Minsky's AI theory of frames (10) and Roger Schank's and Robert Abelson's theory of scripts (11), are of course quite different from each other. But they share some remarkable similarities: a concept specifies the typical characteristics of members of a class; it does not have necessary and sufficient conditions; it does not have clear-cut boundaries; but in its ordinary context it can be applied with great precision. The specification of a causal complex is similar. The non- redundant components give a partial description of a typical instance of the complex; if the complex is the actual one, then they are necessary but not sufficient for the specification of the complex; if it is not the actual one, then they are neither necessary nor sufficient for the specification of the complex; the specification of the complex, when taken out of a concrete context, is imprecise, but often very precise when applied to a concrete case. As a consequence of this we pose the thesis that causal complexes are prototypical which means that to specify a causal complex one needs a prototypical picture of the complex beside a list of non-redundant components.

It would be nice if it was possible to construct for each disease or each type of accident a full causal tree. If that were possible we would be able to construct a kind of expert system that could check all possibilities related to a certain disease/accident. Unfortunately, that seems not to be possible. The reason is that the way in which we construct diagnoses and causal trees involve many different kinds of cognitive activities that cannot easily be integrated. The causal space and the causal components do not exist ready at hand. Although there are some general invariant features, it is something that we construct in each particular case. There does not exist a predefined check-list.

When a physician is making a diagnosis he does not calculate all possible effective causal complexes and chooses the one that best fits the observations. Typically, diagnosis making is a skill based activity. The first guess that a physician comes up with is not computed or inferred. Rather, he constructs, based on his past experiences and scientific domain knowledge, a first guess of an effective causal complex. This complex will them guide him in his collection of further data. He constructs or forms a mental model or picture of the effective complex. This picture is not unlike the one Bohr had of light emission. We call it a prototypical identification of the causal complex. It gives rise to a set of beliefs about the cause. These beliefs may be represented as a belief set, but they are not identical with the mental picture. They partially characterize the picture, its structure, its role, and its consequences. Let us give another example from the history of science.

A beautiful example of mental construction is James Clerk Maxwell's honeycomb model of the magneto-electric medium. (12)



According to this picture the ether was composed of mechanical devices in which "idle wheels" were placed between wheels that were intended to revolve in the same direction. The idle wheels represented layers of particles laying between contiguous vortices, represented by the wheels, so that the rotation of each vortex would cause the neighboring vortices to revolve in the same direction. Maxwell represented this medium as a cellular ether, depicted like a honeycomb. This mechanical model was then used as a representation of electromagnetic induction. The model did also explain many other important physical phenomena. For instance, it made the Faraday effect (that a magnetic field can rotate the plane of polarization of light), an effect which played a central role in the development of classical field theory, because, among other things, it led to the idea that induction had something to do with rotations and vortices.

It is historically fair to construe Maxwell's invention of the electromagnetic field equations as a mathematical articulation of this mental picture of what is going on in electromagnetic induction. This picture gave rise to a unifying conceptual system which could guide both mathematical and experimental work. In this respect it is similar to Bohr's mental picture of atoms and light emission. It is our impression that the process of diagnosis or, in general, the search for an effective causal component work in a similar way.

The next step of diagnosis is them to spell out the details of this proposed complex and prove that it fits the symptoms of the patient. This part of the process is mainly rule based and knowledge based. But the search for rules and knowledge is guided by the mental model of the complex. You do not just require diagnostic tests and further information about the patient. That would give you a huge and unmanageable amount of data. But the mental model of the effective complex that may be involved constitutes a provisional hypotheses of the disease. Rules and knowledge will be gathered with the purpose of testing this temporary hypothesis in the same way as Maxwell's mathematical and experimental work was an articulation of the honeycomb model. If the model does not fit the date you construct a new one and let this new hypothesis govern your search for further information. As the provisional hypothesis is prototypical identified we usually only need to find enough evidence to prove that this hypothesis fits the symptoms better than a few other possible hypotheses.

It is of course possible to formulate some rules of thumb that can be of some guidance for a physician when he is involved in constructing a first guess of a possible effective complex. But generally such rules are of very little use unless you already are a skilled physician. There are so many <u>tacit assumptions and capacities</u> involved in diagnosis making which can only be learned by actually doing clinical work.

The tacit dimension of medical diagnosing is very nicely illustrated by Polanyi. He consider a medical student attending a course in X-ray diagnosis of pulmonary diseases:

At first the student is completely puzzled. For he can see in the X-ray picture of a chest only the shadows of the heart and the ribs, with a few spidery blotches between them. The experts seem to be romancing about figments of their imagination; he can see nothing that they are talking about. Then as he goes on listening for a few weeks, looking carefully at ever new pictures of different cases, a tentative understanding will dawn on him; he will gradually forget about the ribs and begin to see the lungs. And eventually, if he perseveres intelligently, a rich panorama of significant details will be revealed to him... He has entered a new world. He still sees only a fraction of what the experts can see, but the pictures are definitely making sense now and so do most of the comments made by them. He is about to grasp what he is being taught: it has clicked. (13).

It has clicked for the experienced physician . He has achieved a tacit understanding of his field and this tacit understanding governs his cognitive activity as a diagnosis maker. He is able to use the seemingly unstructured clinical information as clues for the construction of mental models of possible effective complexes. In many cases he is able to pick out the right effective complex right at the beginning and does not have to check a huge number of possibilities before getting to the right diagnosis. This is a skill-based cognitive ability which is more like a kind of construction than it is similar to computation or deduction. We find it a very important task for cognitive science to develop formal analyses of such constructive activities.

There are other tacit dimensions of diagnosis making. Sometimes it is not sufficient to stop at the first effective complex. Usually, it is necessary to extend the causal analysis further back. That is done by selecting a non-redundant component of the complex and then looking for a complex that implies the selected component. For instance, during the treatment of the alcoholic the doctor will be interested in reducing the man's drinking. In this case it is necessary to find the causes of the abuse of alcohol, for instance, by analyzing the social and psychical conditions of the patient. The process of extending the causal chain backwards, as well as the construction of the various branches, takes place inside a causal field.

The notion of a causal field was introduced by Mackie. He does not give a completely sharp definition but explains the concept by giving some examples. Mackie expresses his idea in the following way: "a cause is required to differentiate, within a wider region in which the effect sometimes occurs and sometimes does not, the sub-region in which it occurs: this wider region is the causal field." (14). Consider the following example discussed by Mackie: "What caused this man to develop skin cancer?" As it stands this question is ambiguous. It may mean:

1. Why did this man develop skin cancer now when he did not develop it before?

The causal field in this case, according to Mackie, is the career of this man: "It is within this that we are seeking a difference between the time when skin cancer developed and times when it did not."(15) We are looking for factors or events which might have caused the cancer. We are trying to construct a causal tree in which one of the branches is consistent with our knowledge of main events in the past history of the diseased man. Radiation is an effective component in such a tree, and if the man has been exposed to radiation it is likely that it will be picked out as the cause.

But the question may mean something else, for instance:

2. Why did this man develop skin cancer, whereas other men who were also exposed to a similar amount of radiation did not?

In this case Mackie defines the causal field as the class of men thus exposed. Radiation cannot be an active component in this case. It is a background constraint which does not appear in the causal tree.

Mackie is basically right in introducing the notion of causal field. But his definition is not satisfactory. We want to redefine the notion without loosing Mackie's basic intuition. As many other philosophers have observed a causal factor is something which if it had not occurred then neither would the effect. So, it is necessary to consider <u>counterfactual situations</u> if we want to define a cause. This is an insight that goes back at least to David Hume who writes: "We may define a cause to be an object followed by another, and where all the objects, similar to the first, are followed by objects similar to the second. Or, in other words where, if the first object had not been, the second never had existed." (16). It has been explored further by many philosophers.

Consider the various branches in a causal tree. They all correspond to possible courses of events. It is part of the causal explanation to pick out one, and hopefully only one, of these branches as representing the actual course of events. But a full causal tree represents many possible episodes. So, a causal tree represents a whole group of possible scenarios only one of which corresponds to the actual course of events. But when we are seeking for a causal explanation we rarely consider the full causal tree but only the most important branches - the branches which, given the context, are most likely to lead to a causal explanation. The causal field constraints and delimits the range of possible scenarios. Therefore, we propose the following definition of a causal field:

The causal field is constituted by the body of properties and features which (1) must be present in all counterfactual situations, and (2) which are comprehensive and detailed enough to characterize the phenomenon or event of which we want to find the cause.

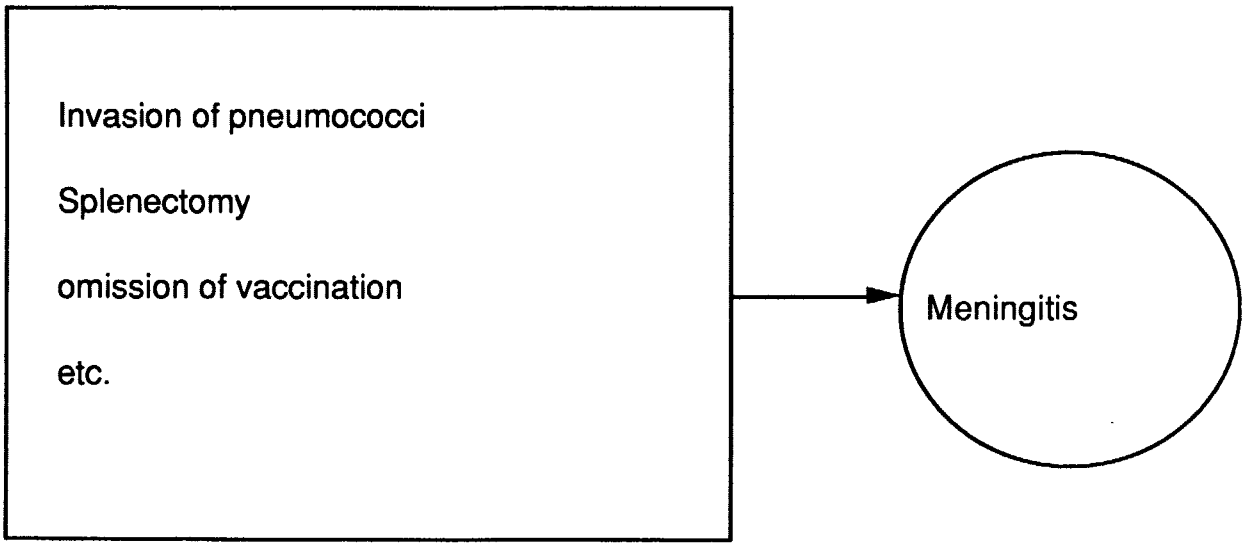
Usually, the causal field is implicitly given. It is like a paradigm i Kuhn's sense, or, maybe, a system of frames in the AI sense . It is based on a huge amount of background knowledge of a rather complex nature. It considerably narrows the space of possible effective complexes and causal trees. The causal field forms the background for constructing mental models of effective complexes. It defines a stance towards the problem in the way that you focus on some branches rather than others. During the training as a physician or as an engineer students are usually not taught how to delimit a causal field, but to an astonishing degree experts agree about what constitutes the causal field when analyzing a given problem. Consequently, the ability to delimit and work inside a relatively stable and fixed causal field, when searching for a diagnosis, is a kind of tacit faculty which forms the background of more explicitly given knowledge.

The causal field depends of course on our medical knowledge and technology and our conception of disease and health. It also varies with the concrete context and the goal of the diagnosis. Some of it can be explicitly formulated, but like a scientific paradigm some important aspects of it are mainly tacitly given. It does not only restrict the set of possible effective complexes to a manageable size, but it usually defines <u>natural stop rules</u> for the causal analysis.

Let us look at a simple example:

A 23-year-old man is admitted as an emergency, suffering from fever and neck stiffness. He is found to have meningitis and the spinal fluid contains pneumococci. Five years previously, his spleen was removed after a traffic accident, and it is known that splenectomy increases the risk of pneumococcal septicaemia and meningitis. Usually, splenectomized patients are vaccinated against pneumococci, but this was not done in this particular case.

In this case we have at least three necessary components of an effective complex leading to the disease: invasion of pneumococci, splenectomy, and omission of vaccination.



Each of the three factors can be proclaimed as the cause of meningitis. But most clinicians would probably say that the meningitis was caused by the pneumococci. That choice is natural from a therapeutic point of view as we can eliminate this component. But from a preventive point of view it would be more reasonable to regard the omission of vaccination as the cause. And furthermore if the patient would sue the hospital for being badly treated it would be necessary to extend the causal chain further backwards to find causes of why the doctors neglected to vaccinate the patient after surgery. The causal tree can be extended arbitrarily and the selection of the cause is the result of a choice which reflects our interests and background knowledge.

There are other interesting aspects of the stop problem. Consider a general causal tree as the one on page 6.We have already seen that it is possible to extend it backwards relatively arbitrary, and we have seen that it is to some extent arbitrary which component of an effective complex is selected as the cause. It is also possible to construct new branches in the causal tree. The causal field does not completely determine whether a logically possible branch is also causally relevant or not. Furthermore, when searching for non-redundant components of a causal complex one does not have clear-cut criteria of how fine-grained the analysis must be. In principle you may continue the analysis until the atomic level.

Consequently, when trying to give a causal explanation of a singular event there are several decisions to be taken. The analysis can in principle be continued in several directions and one have to decide where to stop the analysis. There are at least the following stop problems:

1. How many branches are relevant for the problem.

2. How far backwards in the tree is it necessary to go.

3. How many non-redundant factors must be taken into account in the characterization of the causal complex.

4. How detailed must the analysis of the causal complex be.

Although the causal field and our experience in general, as an expert, narrow the range of possible answers enormously there does not exist necessary and sufficient conditions for asking these questions. They must be decided in each case, and it is an important task to study the basis of such decisions.

We hope that these observations of how causal and diagnostic reasoning works have made it clear that there are mental activities involved in this which are quite different from explicit belief states and logical revisions of such states. We don't want to postulate a dual architecture theory of mind (17). But we do want to claim that there are several mental activities involved in causal reasoning which have very little to do with deduction and computation. Rather they form the background both of explicit beliefs and deductive and computational manipulations of such beliefs. We construct mental pictures of possible causal complexes, we have skills as experts, we make tacit assumptions about causal fields, we have stances, we decide to focus on some aspects of the phenomena rather than others, etc. We don't see how existing formal (mainly computational) models should be able to catch these phenomena.

Let us conclude with a few rather speculative remarks about which properties models of these capacities must have. It is essential to be able to model the capacity of constructing mental pictures and to describe the background, the mental awareness, and the tacit knowledge on which these constructions are based. For example, we must answer the questions: Which mental capacities make it possible for medical students to "see" pulmonary diseases from radiograms. What has physicians and engineers learned that makes it possible for them to come up with astonishing precise guesses of diagnoses/causal complexes, and do it in an apparently effortless way? How can we explain that physicians share causal fields without being able to describe these fields explicitly? What governs their stance toward a problem? At the face of it these phenomena seem to be based on capacities which are quite independent of explicit belief sets and deductions from such beliefs. Neither are they like computations of best alternatives from some measure of goodness or utility. Rather they are preconditions for explicit beliefs, deductions and computations. Of course, experts have explicit beliefs, and they can perform rather complicated deductions and computations. But only on the background of these other capacities.

In an interesting paper "Geometrical Approaches to visual processing"(18) Dodwell stresses that the operation of a perceptual system requires several levels of processing. He identifies three levels:

- The detection of signals in a noisy environment

- The organization of visual features into patterns

- The cognitive understanding and use of perceptual categories

When we perceive visually we select abstract features from the environment, we organize them into meaningful patterns, and we understand these patterns by incorporating them into our network of belief and knowledge. We suggest that the mental process of making a diagnosis or giving a causal explanation of a singular event is quite similar. It also involves selective abstraction of features from the environment, the organization of these features into a mental picture of possible causal complexes, and, finally, a conceptual and logical elaboration of this into a causal explanation.

This threefold activity characterizing causal and diagnostic reasoning is also involved in other kinds of reasoning, we believe. Consequently we postulate that,in general,reasoning involves a threefold activity consisting of the following components:

- selective abstraction of features

- organization of these features into a mental picture

- conceptual and logical elaboration of this into a coherent system of propositions.

We shall call this activity constructive because it goes far beyond mere computation and deduction but is still something we are able to do relatively effortlessly. Maxwell and Bohr were involved in such constructive activities, clinicians and engineers as well as other creatures which are able to reason have the capacity to construct coherent systems of beliefs in this way. What we need is an epistemological and psychological analysis of such constructive capacities of the human mind.

Acknowledgements.
I would like to thank Henning Boje Andersen, Niels Ole Bernsen and Jens Rasmussen for many useful comments and suggestions.

Notes:

(1) Heisenberg, W. (1972) Physics and Beyond. Encounters and Conversations. Harper Torchbooks, New York. p.36-7.

(2) Harman, G. (1986) Change of View. The MIT Press. Cambridge, MA.

(3) Gardenfors, P. (1988) Knowledge in Flux: Modeling the Dynamics of Epistemic States. The MIT Press, Cambridge, MA.

(4) Doyle, J. (1989) Constructive Belief and Rational Representation. Computational Intelligence. 5, No 1, 1 - 11.

(5) Searle, J. (1983) Intentionality. Cambridge University Press, Cambridge. p. 143.

(6) The medical cases are taken from Wulff, H.R., Pedersen, S.A., Rosenberg, R. (1986) Philosophy of Medicine: An Introduction. Blackwell Scientific Publications. Oxford.

(7) Mackie, J.L. (1975) Causes and Conditions. From Sosa, E. (ed) (l975) Causation and Conditionals. Oxford University Press. Oxford.

(8) Putnam, H. (1975) The Meaning of 'Meaning'. In Putnam, H. (1975) Philosophical Papers, Volume 2. Cambridge University Press. Cambridge.

(9) Rosch, E. (1078) The Principles of Categorization. In Rosch, E. and Lloud B.B. (eds.) (1978) Cognition and Categorization. Lawrence Erlbaum.

Hillsdale, NJ.

(10) Minsky, M.L ((1975) Frame-System Theory. In Johnson- Laird, P.N. and Wason, P.C. (eds) (1977) Thinking: Readings in Cognitive Science. Cambridge University Press. Cambridge.

(11) Schank, R.C. and Abilson, R.P (eds.) (1977) Scripts, Plans, Goals and Understanding. Lawrence Erlbaum. Hillsdale, NJ.

(12) See, for instance, Harman, P.M. (1982) Energy, Force, and Matter. The Conceptual Development of Nineteenth-Century Physics. Cambridge University Press. Cambridge.

(13) Polanyi, M. (1958) Personal Knowledge. Towards a Post- Critical Philosophy. Routledge & Kegan Paul. London. p. 101.

(14) Mackie, J.L., op.cit. note 7, p. 22.

(15) ibid.

(16) Hume, D. An Inquiry Concerning Human Understanding. Sec. VII.

(17) Maybe that would be the only way of explaining the nature of causal reasoning; but we don't want to discuss that here.

(18) Dodwell, P.C. (1984) Geometrical Approaches to Visual Processing. In Dodwell, P.C. and Caelli, T. (eds.) (1984) Figural Synthesis. Lawrence Erlbaum. Hillsdale NJ.

1/78 "TANKER OM EN PRAKSIS" - et matematikprojekt. Projektrapport af: Anne Jensen, Lena Lindenskov, Marianne Kesselhahn og Nicolai Lomholt. Vejleder: Anders Madsen

2/78 "OPTIMERING" - Menneskets forøgede beherskelsesmuligheder af natur og samfund. Projektrapport af: Tom J. Andersen, Tommy R. Andersen, Gert Krenøe og Peter H. Lassen Vejleder: Bernhelm Boss.

3/78 "OPGAVESAMLING", breddekursus i fysik. Af: Lasse Rasmussen, Aage Bonde Kræmmer og Jens Højgaard Jensen.

4/78 "TRE ESSAYS" - om matematikundervisning, matematiklæreruddannelsen og videnskabsrindalismen. Af: Mogens Niss Nr. 4 er p.t. udgået.

5/78 "BIBLIOGRAFISK VEJLEDNING til studiet af DEN MODERNE FYSIKS HISTORIE". Af: Helge Kragh. Nr. 5 er p.t. udgået.

6/78 "NOGLE ARTIKLER OG DEBATINDLÆG OM - læreruddannelse og undervisning i fysik, og - de naturvidenskabelige fags situation efter studenteroprøret". Af: Karin Beyer, Jens Højgaard Jensen og Bent C. Jørgensen.

7/78 "MATEMATIKKENS FORHOLD TIL SAMFUNDSØKONOMIEN". Af: B.V. Gnedenko. Nr. 7 er udgået.

8/78 "DYNAMIK OG DIAGRAMMER". Introduktion til energy-bond-graph formalismen. Af: Peder Voetmann Christiansen.

9/78 "OM PRAKSIS' INDFLYDELSE PÅ MATEMATIKKENS UDVIKLING". - Motiver til Kepler's: "Nova Stereometria Doliorum Vinariom". Projektrapport af: Lasse Rasmussen. Vejleder: Anders Madsen.

10/79 "TERMODYNAMIK I GYMNASIET". Projektrapport af: Jan Christensen og Jeanne Mortensen. Vejledere: Karin Beyer og Peder Voetmann Christiansen.

11/79 "STATISTISKE MATERIALER". Af: Jørgen Larsen.

12/79 "LINEÆRE DIFFERENTIALLIGNINGER OG DIFFERENTIALLIGNINGSSYSTEMER". Af: Mogens Brun Heefelt. Nr. 12 er udgået.

13/79 "CAVENDISH'S FORSØG I GYMNASIET". Projektrapport af: Gert Kreinøe. Vejleder: Albert Chr. Paulsen.

14/79 "BOOKS ABOUT MATHEMATICS: History, Philosophy, Education, Models, System Theory, and Works of". Af: Else Høyrup. Nr. 14 er p.t. udgået.

15/79 "STRUKTUREL STABILITET OG KATASTROFER i systemer i og udenfor termodynamisk ligevægt". Specialeopgave af: Leif S. Striegler. Vejleder: Peder Voetmann Ckristiansen.

16/79 "STATISTIK I KRÆFTFORSKNINGEN". Projektrapport af: Michael Olsen og Jørn Jensen. Vejleder: Jørgen Larsen.

17/79 "AT SPØRGE OG AT SVARE i fysikundervisningen". Af: Albert Christian Paulsen.

18/79 "MATHEMATICS AND THE REAL WORLD", Proceedings af an International Workshop, Roskilde University Centre, Denmark, 1978. Preprint. Af: Bernhelm Booss og Mogens Niss (eds.)

19/79 "GEOMETRI, SKOLE OG VIRKELIGHED". Projektrapport af: Tom J. Andersen, Tommy R. Andersen og Per H.H. Larsen. Vejleder: Mogens Niss.

20/79 "STATISTISKE MODELLER TIL BESTEMMELSE AF SIKRE DOSER FOR CARCINOGENE STOFFER". Projektrapport af: Michael Olsen og Jørn Jensen. Vejleder: Jørgen Larsen

21/79 "KONTROL I GYMNASIET-FORMÅL OG KONSEKVENSER". Projektrapport af: Crilles Bacher, Per S. Jensen, Preben Jensen og Torben Nysteen.

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25/80 "EKSAMENSOPGAVER", Dybdemodulet/fysik 1974-79.

26/80 "OM MATEMATISKE MODELLER". En projektrapport og to artikler. Af: Jens Højgaard Jensen m.fl.

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32/80 "POLYMERE STOFFERS VISCOELASTISKE EGENSKABER - BELYST VED HJÆLP AF MEKANISKE IMPEDANSMÅLINGER MÖSSBAUEREFFEKTMÅLINGER". Projektrapport af: Crilles Bacher og Preben Jensen. Vejledere: Niels Boye Olsen og Peder Voetmann Christiansen.

33/80 "KONSTITUERING AF FAG INDEN FOR TEKNISK - NATURVIDENSKABELIGE UDDANNELSER. I-II". Af: Arne Jakobsen.

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35/80 "HISTORISKE STUDIER I DEN NYERE ATOMFYSIKS UDVIKLING".
Af: Helge Kragh.

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Fire artikler.
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ENERGY SERIES NO. 2.
Af: Bent Sørensen.

38/81 "TIL EN HISTORIETEORI OM NATURERKENDELSE, TEKNOLOGI OG SAMFUND".
Projektrapport af: Erik Gade, Hans Hedal, Henrik Lau og Finn Physant.
Vejledere: Stig Andur Pedersen, Helge Kragh og Ib Thiersen.
Nr. 38 er p.t. udgået.

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Af: Jens Højgaard Jensen.

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Projektrapport af: Arne Jørgensen, Bruno Petersen og Jan Vedde.
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Projektrapport af: Niels Thor Nielsen.
Vejleder: Bent C. Jørgensen.

45/82 Er aldrig udkommet.

46/82 "EKSEMPLARISK UNDERVISNING OG FYSISK ERKENDESE-
1+11 ILLUSTRERET VED TO EKSEMPLER".
Projektrapport af: Torben O.Olsen, Lasse Rasmussen og Niels Dreyer Sørensen.
Vejleder: Bent C. Jørgensen.

47/82 "BARSEBÄCK OG DET VÆRST OFFICIELT-TÆNKELIGE UHELD".
ENERGY SERIES NO. 5.
Af: Bent Sørensen.

48/82 "EN UNDERSØGELSE AF MATEMATIKUNDERVISNINGEN PÅ ADGANGSKURSUS TIL KØBENHAVNS TEKNIKUM".
Projektrapport af: Lis Eilertzen, Jørgen Karrebæk, Troels Lange, Preben Nørregaard, Lissi Pedesen, Laust Rishøj, Lill Røn og Isac Showiki.
Vejleder: Mogens Niss.

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Projektrapport af: Preben Nørregaard.
Vejledere: Jørgen Larsen og Rasmus Ole Rasmussen.

50/82 "HERSLEV - MULIGHEDER FOR VEDVARENDE ENERGI I EN LANDSBY".
ENERGY SERIES NO. 6.
Rapport af: Bent Christensen, Bent Hove Jensen, Dennis B. Møller, Bjarne Laursen, Bjarne Lillethorup og Jacob Mørch Pedersen.
Vejleder: Bent Sørensen.

51/82 "HVAD KAN DER GØRES FOR AT AFHJÆLPE PIGERS BLOKERING OVERFOR MATEMATIK ?"
Projektrapport af: Lis Eilertzen, Lissi Pedersen, Lill Røn og Susanne Stender.

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55/82 "MATEMATISKE MODELLER" - Litteratur på Roskilde Universitetsbibliotek.
En biografi.
Af: Else Høyrup.

Vedr. tekst nr. 55/82 se også tekst nr. 62/83.

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En undersøgelse af matematisk økologi.
Projektrapport af: Troels Lange.
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Skjulte variable i kvantemekanikken?
Projektrapport af: Tom Juul Andersen.
Vejleder: Peder Voetmann Christiansen.
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Projektrapport af: Per Hammershøj Jensen og Lene Vagn Rasmussen.
Vejleder: Jørgen Larsen.

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Projektrapport af: Annette Post Nielsen.
Vejledere: Jens Høyrup, Jens Højgaard Jensen og Jørgen Vogelius.

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En biografi 2. rev. udgave.
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Projektrapport af: Per Hedegård Andersen, Kirsten Habekost, Carsten Holst-Jensen, Annelise von Moos, Else Marie Pedersen og Erling Møller Pedersen.
Vejledere: Bernhelm Booss og Klaus Grünbaum.

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Specialeopgave i fysik af: Bent Hove Jensen.
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Vejledere: Jørgen Larsen og Jens Bjørneboe.

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Specialrapport af: Hans Hedal, Frank C. Ludvigsen og Finn C. Physant.
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Projektrapport af: Henrik Coster, Mikael Wennerberg Johansen, Povl Kattler, Birgitte Lydholm og Morten Overgaard Nielsen.
Vejleder: Bernhelm Booss.

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81/84 "FREKVENSAFHÆNGIG LEDNINGSEVNE I AMORFT GERMANIUM".
Specialerapport af: Jørgen Wind Petersen og Jan Christensen.
Vejleder: Niels Boye Olsen.

82/84 "MATEMATIK - OG FYSIKUNDERVISNINGEN I DET AUTOMATISEREDE SAMFUND".
Rapport fra et seminar afholdt i Hvidovre 25-27 april 1983.
Red.: Jens Højgaard Jensen, Bent C. Jørgensen og Mogens Niss.

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PEACE RESEARCH SERIES NO. I
Af: Bent Sørensen
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Af: Jens Højgaard Jensen, Mogens Niss m. fl.

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Specialerapport af: Per Hedegård Andersen, Carsten Holst-Jensen, Else Marie Pedersen og Erling Møller Pedersen.
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Projektrapport af: Biger Lundgren, Henning Sten Hansen og John Johansson.
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Projektrapport af: Niels Jørgensen og Mikael Klintorp.
Vejleder: Stig Andur Pedersen.

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Af: Mogens Niss.

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Af: Ganesh Sengupta.

102/85 OPSTILLING OG ANALYSE AF MATEMATISKE MODELLER, BELYST VED MODELLER OVER KØERS FODEROPTAGELSE OG - OMSÆTNING".
Projektrapport af: Lis Eilertzen, Kirsten Habekost, Lill Røn og Susanne Stender.
Vejleder: Klaus Grünbaum.

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Af: Tage Christensen.

"A SIMPLE MODEL AF AC HOPPING CONDUCTIVITY".
Af: Jeppe C. Dyre.
Contributions to the Third International Conference on the Structure of Non - Crystalline Materials held in Grenoble July 1985.

106/85 "QUANTUM THEORY OF EXTENDED PARTICLES".
Af: Bent Sørensen.

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- flodblindhed som eksempel på matematisk modellering af et epidemiologisk problem.
Projektrapport af: Per Hedegård Andersen, Lars Boye, CarstenHolst Jensen, Else Marie Pedersen og Erling Møller Pedersen.
Vejleder: Jesper Larsen.

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Af: Peder Voetmann Christiansen

119/86 "DET ER GANSKE VIST - - EUKLIDS FEMTE POSTULAT KUNNE NOK SKABE RØRE I ANDEDAMMEN".
Af: Iben Maj Christiansen
Vejleder: Mogens Niss.

120/86 "ET ANTAL STATISTISKE STANDARDMODELLER".
Af: Jørgen Larsen

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122/86 "ON THE MECHANISM OF GLASS IONIC CONDUCTIVITY".
Af: Jeppe C. Dyre.

123/86 "GYMNASIEFYSIKKEN OG DEN STORE VERDEN".
Fysiklærerforeningen, IMFUFA, RUC.

124/86 "OPGAVESAMLING I MATEMATIK".
Samtlige opgaver stillet i tiden 1974-jan. 1986.

125/86 "UVBY,β - systemet - en effektiv fotometrisk spektralklassifikation af B-,A- og F-stjerner".
Projektrapport af: Birger Lundgren.

126/86 "OM UDVIKLINGEN AF DEN SPECIELLE RELATIVITETSTEORI".
Projektrapport af: Lise Odgaard & Linda Szkotak Jensen
Vejledere: Karin Beyer & Stig Andur Pedersen.

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Projektrapport af: Pernille Sand, Heine Larsen & Lars Frandsen.
Vejleder: Mogens Niss.

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Projektrapport af: Niels Jørgensen & Mikael Klintorp.
Vejleder: Jeppe Dyre.

129/86 "PHYSICS IN SOCIETY"
Lecture Notes 1983 (1986)
Af: Bent Sørensen

130/86 "Studies in Wind Power"
Af: Bent Sørensen

131/86 "FYSIK OG SAMFUND" - Et integreret fysik/historieprojekt om naturanskuelsens historiske udvikling og dens samfundsmæssige betingethed.
Projektrapport af: Jakob Heckscher, Søren Brønd, Andy Wierød.
Vejledere: Jens Høyrup, Jørgen Vogelius, Jens Højgaard Jensen.

132/86 "FYSIK OG DANNELSE"
Projektrapport af: Søren Brønd, Andy Wierød.
Vejledere: Karin Beyer, Jørgen Vogelius.

133/86 "CHERNOBYL ACCIDENT: ASSESSING THE DATA.
ENERGY SERIES NO. 15.
AF: Bent Sørensen.

134/87 "THE D.C. AND THE A.C. ELECTRICAL TRANSPORT IN AsSeTe SYSTEM"
Authors: M.B.El-Den, N.B.Olsen, Ib Høst Pedersen, Petr Viscčor

135/87 "INTUITIONISTISK MATEMATIKS METODER OG ERKENDELSES-TEORETISKE FORUDSÆTNINGER"
MASTEMATIKSPECIALE: Claus Larsen
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Projektrapport af Frank Colding Ludvigsen
Vejledere: Historie: Ib Thiersen
Fysik: Jens Højgaard Jensen

137/87 "HOPMODELLER FOR ELEKTRISK LEDNING I UORDNEDE FASTE STOFFER" - Resume af licentiatafhandling
Af: Jeppe Dyre
Vejledere: Niels Boye Olsen og Peder Voetmann Christiansen.

138/87 "JOSEPHSON EFFECT AND CIRCLE MAP."
Paper presented at The International Workshop on Teaching Nonlinear Phenomena at Universities and Schools, "Chaos in Education". Balaton, Hungary, 26 April-2 May 1987.

By: Peder Voetmann Christiansen

139/87 "Machbarkeit nichtbeherrschbarer Technik durch Fortschritte in der Erkennbarkeit der Natur"

Af: Bernhelm Booss-Bavnbek
Martin Bohle-Carbonell

140/87 "ON THE TOPOLOGY OF SPACES OF HOLOMORPHIC MAPS"

By: Jens Gravesen

141/87 "RADIOMETERS UDVIKLING AF BLODGASAPPARATUR - ET TEKNOLOGIHISTORISK PROJEKT"

Projektrapport af Finn C. Physant

Vejleder: Ib Thiersen

142/87 "The Calderón Projektor for Operators With Splitting Elliptic Symbols"

by: Bernhelm Booss-Bavnbek og
Krzysztof P. Wojciechowski

143/87 "Kursusmateriale til Matematik på NAT-BAS"

af: Mogens Brun Heefelt

144/87 "Context and Non-Locality - A Peircan Approach
Paper presented at the Symposium on the Foundations of Modern Physics The Copenhagen Interpretation 60 Years after the Como Lecture. Joensuu, Finland, 6 - 8 august 1987.

By: Peder Voetmann Christiansen

145/87 "AIMS AND SCOPE OF APPLICATIONS AND MODELLING IN MATHEMATICS CURRICULA"

Manuscript of a plenary lecture delivered at ICMTA 3, Kassel, FRG 8.-11.9.1987

By: Mogens Niss

146/87 "BESTEMMELSE AF BULKRESISTIVITETEN I SILICIUM"
- en ny frekvensbaseret målemetode.

Fysikspeciale af Jan Vedde

Vejledere: Niels Boye Olsen & Petr Viščor

147/87 "Rapport om BIS på NAT-BAS"
redigeret af: Mogens Brun Heefelt

148/87 "Naturvidenskabsundervisning med Samfundsperspektiv"

af: Peter Colding-Jørgensen DLH
Albert Chr. Paulsen

149/87 "In-Situ Measurements of the density of amorphous germanium prepared in ultra high vacuum"

by: Petr Viščor

150/87 "Structure and the Existence of the first sharp diffraction peak in amorphous germanium prepared in UHV and measured in-situ"

by: Petr Viščor

151/87 "DYNAMISK PROGRAMMERING"

Matematikprojekt af:
Birgit Andresen, Keld Nielsen og Jimmy Staal

Vejleder: Mogens Niss

152/87 "PSEUDO-DIFFERENTIAL PROJECTIONS AND THE TOPOLOGY OF CERTAIN SPACES OF ELLIPTIC BOUNDARY VALUE PROBLEMS"

by: Bernhelm Booss-Bavnbek
Krzysztof P. Wojciechowski

153/88 "HALVLEDERTEKNOLOGIENS UDVIKLING MELLEM MILITÆRE OG CIVILE KRÆFTER"

Et eksempel på humanistisk teknologihistorie
Historiespeciale

Af: Hans Hedal

Vejleder: Ib Thiersen

154/88 "MASTER EQUATION APPROACH TO VISCOUS LIQUIDS AND THE GLASS TRANSITION"

By: Jeppe Dyre

155/88 "A NOTE ON THE ACTION OF THE POISSON SOLUTION OPERATOR TO THE DIRICHLET PROBLEM FOR A FORMALLY SELFADJOINT DIFFERENTIAL OPERATOR"

by: Michael Pedersen

156/88 "THE RANDOM FREE ENERGY BARRIER MODEL FOR AC CONDUCTION IN DISORDERED SOLIDS"

by: Jeppe C. Dyre

157/88 " STABILIZATION OF PARTIAL DIFFERENTIAL EQUATIONS BY FINITE DIMENSIONAL BOUNDARY FEEDBACK CONTROL: A pseudo-differential approach."

by: Michael Pedersen

158/88 "UNIFIED FORMALISM FOR EXCESS CURRENT NOISE IN RANDOM WALK MODELS"

by: Jeppe Dyre

159/88 "STUDIES IN SOLAR ENERGY"

by: Bent Sørensen

160/88 "LOOP GROUPS AND INSTANTONS IN DIMENSION TWO"

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Dirichlet feedback control problems"

by: Michael Pedersen

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AF: Karin Beyer, Sussanne Blegaa, Birthe Olsen,
Jette Reich , Mette Vedelsby

163/88 "EN MATEMATISK MODEL TIL BESTEMMELSE AF PERMEABILITETEN FOR BLOD-NETHINDE-BARRIEREN"

Af: Finn Langberg, Michael Jarden, Lars Frellesen

Vejleder: Jesper Larsen

164/88 "Vurdering af matematisk teknologi
Technology Assessment
Technikfolgenabschätzung"

Af: Bernhelm Booss-Bavnbek, Glen Pate med
Martin Bohle-Carbonell og Jens Højgaard Jensen

165/88 "COMPLEX STRUCTURES IN THE NASH-MOSER CATEGORY"

by: Jens Gravesen

166/88 "Grundbegreber i Sandsynligheds-regningen"

Af: Jørgen Larsen

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Af: Jørgen Larsen

167b/88 "BASISSTATISTIK 2. Kontinuerte modeller"

Af: Jørgen Larsen

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Fysikspeciale af:

Birger Lundgren

Vejleder: Jens Martin Knudsen
Fys.Lab./HCØ

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Peder Voetmann Christeansen

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Fysikprojekt af:

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