Centre for Advanced Study

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Smell has its own memory

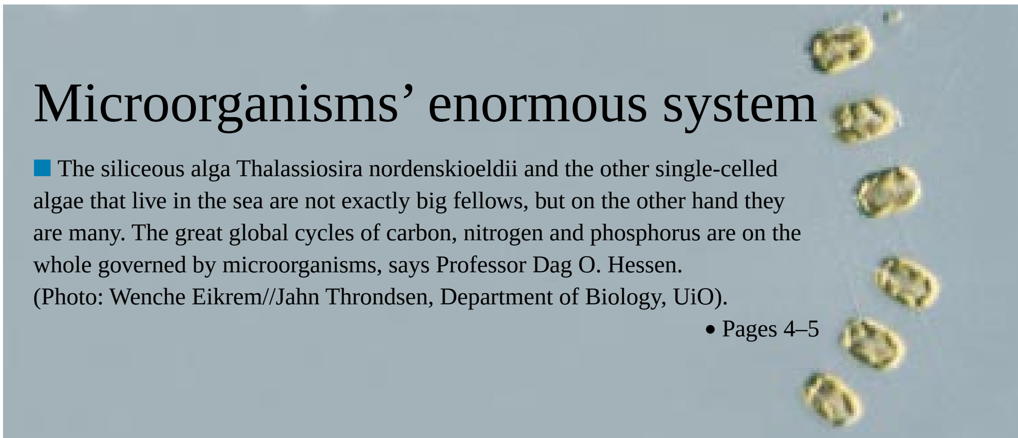
■ If you investigate the memory of adults or elderly people, it turns out that words or pictures as a rule awaken most memories of the time they were between the ages of roughly 15 and 30. But if the same people are exposed to a characteristic smell, they often travel straight back to their childhood. The point is that the sense of smell has a special ability to arouse both feelings and memories relating to childhood, says the psychologist Maria Larsson (picture).

■ Research on the connections between smell and memory has hitherto been largely neglected, but this is something Maria Larsson and her colleagues at the CAS are in the process of putting right. • Pages 2–3

Philosophy back to Nature

■ Analytical philosophy is on its way "back to Nature" again, after many philosophers in the 20th century turned up their noses at biology, psychology and sociology. The French philosopher Pascal Engel is one of the prominent figures in this development. • Pages 6–7

Microorganisms' enormous system



■ The siliceous alga Thalassiosira nordenskioeldii and the other single-celled algae that live in the sea are not exactly big fellows, but on the other hand they are many. The great global cycles of carbon, nitrogen and phosphorus are on the whole governed by microorganisms, says Professor Dag O. Hessen.
(Photo: Wenche Eikrem//Jahn Throndsen, Department of Biology, UiO).

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EDITORIAL

Basic research and market liberalism

The gulf between the *raison d'être* of basic research and the fundamental ideological creed of classical market liberalism is on the face of it enormous. While basic research is a *researcher-initiated, curiosity-driven, long-term* and *patient* activity, the result of which is difficult to predict, research in a market-governed economy is often *market-initiated, interest-governed, short-term and impatient* and with little risk of failure. In this perspective the basic researcher appears as relatively useless – one who cultivates his curiosity without giving anything back to society.

In the light of this it is interesting to note that the EU, as a large-scale market-liberalist project, is now taking active steps to strengthen basic research. Philippe Busquin – the EU's Commissioner for Research – said recently that instead of asking what future basic research has in Europe, one should rather ask what future Europe has without basic research. Over the next four years the EU aims to increase its total research grants from 17.5 to 45 thousand million euro, and in 2010 the goal is that the total grant shall represent 3 per cent of the EU's GNP. In addition a European Research Council is to be established with the responsibility for the administration of funding for basic research. The purpose is to turn the EU into the world's most competitive and dynamic knowledge-based economy, and to reduce the widening knowledge gap between the USA and Europe.

This change of attitude shows that the alleged conflict between market liberalism and basic research is not systemic and absolute. The realisation is that all houses rest on their foundations, and that applied research is produced by basic research. The question now is whether the basic researchers are able to exploit the new market-liberalist development?

Something is happening. An initiative has been taken for the formation of a European network between Institutes of Advanced Studies in a number of countries – *NetIAS*. The purpose is to see what possibilities for co-operation exist between the institutes involved, with a view to brining about co-ordinated approaches to the EU's 7th Framework Programme. The Centre for Advanced Study welcomes this initiative and will play an active part in the preparatory work. The market is ripe for more basic research.

Willy Østreng
Scientific Director, CAS

The sense of smell is a ticket to childhood

Human beings generate most lasting memories between the ages of 15 and 30, if the memories are connected with sight or hearing. But those memories that have to do with smell instead, often function as a ticket straight back to childhood. The scent of cinnamon, cloves or vanilla can often bring adult human beings right back to the celebration of Christmas at Grandma's.

The French author Marcel Proust's great work Remembrance of things past is world famous, to a great extent on account of the story of the mature adult Marcel eating a madeleine dipped in lime-blossom tea. He thereby travels mentally straight back to his childhood and his upper-class Aunt Léonie, who used to serve madeleines every Sunday before mass. The psychologist Maria Larsson, who is an associate professor at the University of Stockholm, is able to shed light on why Proust's narrative has moved many people so strongly. The point is that she knows more than most people about the connection between smells and memory.

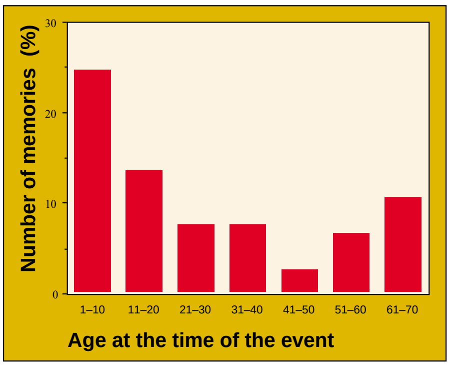
"It's been known for many years that the so-called 'memory peak' lies in the age range from roughly 15 and 30 years when it's a matter of visual and verbal impressions. Researchers can for example ask people in their seventies what memories they associate with a selection of words or pictures, and in such cases it turns out that they report most memories from when they were in that age range. This may be an expression of the fact that the period from 15 to 30 is very dynamic for most people – they move away from home, for instance, they get married for the first time, and altogether develop their own identity. That period is also very important for the development of preferences when it comes to such things as music and literature," says Maria Larsson.

Smell brings back memories of childhood

However, when it comes to memories associated with smell, the picture is quite different. Maria Larsson's research in the Department of Psychology at the University of Stockholm has in fact revealed that the olfactorily activated memories to a high degree stem from an earlier period in life. "If we expose mature adults to different characteristic smells, such as cinnamon or vanilla, they often go straight back to the period between the ages of 5 and 10. Suddenly they're children again," says Maria Larsson.

Maria Larsson began studying the connections between smell and memory about 15 years ago, after having registered that this was an area in which precious little research had been done. "At that time a great deal of research had already been done on the role of sight and hearing in the memory, but the connections between the sense of smell and the memory on the other hand had been virtually ignored. Today we know a lot about how the sense of smell functions on the molecular and chemical levels, for example how the olfactory receptors in the nose function, and which proteins code for different olfactory experiences. But there's still a lot of unploughed ground when it comes to understanding the connections of the sense of smell to the memory mechanisms in the brain," she adds.

Maria Larsson makes it clear that great individual variations were discovered in her



Distribution of memories activated by smell through the life cycle, with data from Maria Larsson's investigation. Episodic memory is not fully developed until the age of about five, and a closer study shows that the period between the ages of 5 and 10 is the most active when it comes to the establishing of memories of smells. (Willander and Larsson, 2003)

Gerard Bruno in the cake shop called Kristine's Franske Fristelser (Christine's French Temptations) in Oslo is happy to serve genuine madeleines – tasty symbols of the fact that olfactory impressions can activate powerful childhood memories.

investigation. "We gave the subjects of the experiment approximately 20 smells, and a number of them were not able to bring to memory anything at all. 'I know it smells of vanilla but nothing is happening'. Other subjects of the experiment reacted immediately and said for instance: 'It smells of vanilla, and it reminds me of eating porridge at my grandmother's.' But the tendency was clear: the subjects of the experiment went farther back in time with olfactory memories than with visual and auditory memories. So in many ways this is a Proustian study: it deals with the possibilities of smells to activate remembrance of things past," she says.

We know what the world tastes like

The results of her investigation reflect the fact that the sense of smell is a very old system in the historical development of both animal species and human beings. "In humans the sense of smell is very well developed early in life, indeed, it's already being developed in the womb in fact. Experiments have been conducted that show that if the mother eats a great deal of liquorice or garlic for example, the new-born child will also prefer these smells. In the first years of life altogether the child uses the systems of both smell and taste very actively, so as adults we know exactly what sand tastes like for instance, or the edge of a wooden table, or a cloth. The point is that we've tasted it, and that's a taste we still remember!"

Maria Larsson adds that one of the most important functions of the sense of smell – perhaps the most important – is to act as a warning system for toxic or hazardous substances in the food or the surroundings otherwise. "The sense of smell in combination with the sense of taste is also linked to a powerful ability to create aversions. If for example you eat something and become ill, this often leads to a lasting aversion to that particular food. It's enough to have been ill on one occasion, and because of this you may have developed an aversion that can last for 10 to 15 years. This mechanism is naturally extremely important for the possibility of survival, so we see it in so to speak the whole of the animal kingdom.

The connection of smell with emotions

Olfactory impressions also have a special capacity to arouse feelings, Maria Larsson points out. "The two cerebral structures, the *amygdala* and the *hippocampus* play an important role for the storing of memories, and the olfactory nerve has very direct connections to both structures. The amygdala reacts strongly to emotionally charged events, be they positive or negative, and there are in fact only two synapses (points of contact between nerve cells) between the olfactory nerve and the amygdala. The impulses from the other sensory systems must by comparison travel long roundabout ways in the brain before reaching the amygdala", she explains.

Maria Larsson's interest in smell and memory was aroused when indications started coming in to suggest that early stages of neurophysiological disorders, such as Alzheimer's disease, often involved weakening of the sense of smell. "It's possible that weakening of the olfactory function may be an early warning of a risk of developing Alzheimer's disease. This is an area in which more research ought to be done in the years ahead," says Maria Larsson.

Facts about memory

■ Human memory consists of at least four or five different systems. Psychologists differentiates between three non-conscious systems:

Procedural memory is found in animal species, with the possible exception of the amoebae, and takes care of the motor skills.

The primitive form of learning *conditioning* is particularly important for the linking of emotions to situations.

Priming is a memory system under which the presentation of a stimulus, like a word or a smell, makes it easier to recognise the word or smell again later.

There are also two conscious memory systems:

Semantic memory manages factual knowledge and has close connections with linguistic ability.

Episodic memory may be described as a mental time machine and stores memories with information about "what, where and when". This system is younger and more complex than the others, and is perhaps unique to human beings. This system is usually not mature until a child has reached roughly the age of five – not until then can the child recall events and at the same time relate them to particular places and times.

In addition we have a system for short-term storage, our *working memory*, which is responsible for an individual's simultaneous capacity and ability to pay attention, and it is brought into play in situations in which we distinguish smells from one another.

- Women have more sensitive noses than men, and are far better at putting words to olfactory experiences.
- Human beings have a tendency to prefer the smell of people with a different genetic origin. This is an evolutionary advantage, because this tendency may reduce the risk of inbreeding.
- About one third of the brain – some researchers claim up to 50 per cent – works with visual information. By comparison the olfactory centre constitutes only about 1 per cent of the brain.

■ Maria Larsson is taking part in the CAS Project *Towards a comprehensive model of human memory*, which is being led by Professor Svein Magnussen and Professor Tore Helstrup of the Department of Psychology at the University of Oslo.

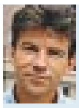
Plankton, food webs and the carbon cycle:

Small organisms govern large cycles

The great global cycles of carbon, nitrogen and phosphorus are to a great extent governed by microorganisms. To understand the largest one must take one's point of departure in the smallest, and the central idea of the research group for *Food-webs, stoichiometry and population dynamics* is precisely to start with the basic composition of elements in individual cells – in order to understand the principles of energy transfer in food webs and how the sum of these processes contributes to the global carbon cycle.

By Professor Dag O. Hessen

On an annual basis roughly 300 pentagrams (= 300 x10^{15} grams = 300 x 10^9 tonnes) of carbon (C) are in circulation in the global carbon cycle. By far the largest proportion of this relates to the balance between carbon uptake via photosynthesis and the respiration (cell breathing) that takes place in so to speak all cells – plant cells included. In addition comes a considerable exchange of inorganic carbon compounds between types of rock, soil and water – and then we must not of course forget the contribution created by man through the combustion of coal, oil and gas. These emissions of fossil carbon dioxide (CO_2), corresponding to nearly 6 thousand million tonnes of carbon per year, are nevertheless modest in relation to what "Nature herself" contributes through respiration (cell breathing) and liberation from oceans, totalling more than 200 thousand million tonnes of carbon each year.



■ Professor Dag O. Hessen at the University of Oslo is the leader of the CAS Research Group *Food-webs, Stoichiometry and Population Dynamics.*

This has misled more people than the international petroleum lobby into claiming that the greenhouse effect created by man has no significance – that Nature is the sinner instead. Rubbish, of course, because there is an approximate balance between those processes that naturally add CO_2 to the atmosphere and those that remove it. This means that our 6 thousand million tonnes, plus nearly 1 thousand million tonnes on account of deforestation, come *in addition*.

If one pours 1050 millilitres into a bottle every day and removes 1000, then the level of liquid will continue to rise. This picture has its weaknesses, since not all CO_2 from fossil fuel remains in the atmosphere, but it is nevertheless clear that global photosynthesis cannot take care of all this extra CO_2. With "business as usual" we shall increase the CO_2 level from a pre-industrial level of 280 ppm (parts per million) in the atmosphere to over 400 in the course of the next 50 years.

A global fertilising experiment

The carbon cycle is not alone in being changed. Two other important greenhouse gases are methane and dinitrogen oxide (N_2O, "laughing gas"). The methane concentration will be almost trebled. Laughing gas, an intermediate in the nitrogen cycle, is rapidly increasing in the atmosphere as a consequence of the dramatic intrusions we have made in the natural nitrogen cycle. Incidentally our conversion of free, atmospheric nitrogen (N_2) through the fertiliser industry and combustion is now just as great as the natural processing of nitrogen. Our interference with this cycle is in thus in one sense considerably more dramatic than for the carbon cycle.

Phosphorus (P), however, is the element with respect to which we have *really* interfered with the course of nature. There is many times more phosphorus in circulation now than there was in pre-industrial times, essentially on account of the fertiliser industry. Carbon and nitrogen are spread globally as gas, but even though phosphorus does not

The ocean is a gigantic reservoir of carbon. The great global cycles of both carbon, nitrogen and phosphorus are on the whole governed by microorganisms. (Photo: Trym Ivar Bergsmo, Samfoto)

occur in the form of gas, this element too can be spread over enormous distances in the form of phosphorus-rich dust particles from agricultural areas, and it can also be carried with ocean currents of course. In other words, a large-scale global fertilising experiment is taking place in that three of the most important elements for life on Earth – C, N and P – have all had their circulation artificially increased in the atmosphere and biosphere.

The sea is a gigantic reservoir of carbon

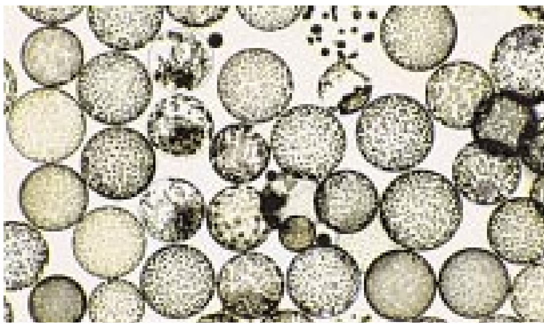
The content of C in the form of CO_2 in the atmosphere is in fact relatively modest. In total the atmosphere contains 750 thousand million tonnes of carbon, only a little more than is found in terrestrial plants (560 thousand million tonnes), half of what is stored in the soil (1500 thousand million million tonnes), while the great reservoir is to be found in the oceans, which contain as much as 38.000 thousand million tonnes of C!). This means that factors which even to a relatively modest degree change uptake and liberation from forests, soil and sea may have great significance for the concentration of CO_2 in the atmosphere – and thereby the climate. What one for the moment knows much less about is what effect a changed climate will have in its turn and how it will contribute to further liberation of CO_2 and methane from soil and water.

So, from the big to the small. The three fundamental elements we have been talking about are absolutely crucial building blocks in cells. An average alga cell hovering about in the sea and doing what it does best – binding carbon via photosynthesis – consists of carbon, nitrogen and phosphorus in relative mass ratios of roughly 50:7:1. This means that an alga cell can bind 50 grams of carbon per gram of phosphorus, or 7 grams per gram of nitrogen. Plants on land have even more extreme element ratios. According to *Liebig's Law of the Minimum* there will always be one element that sets limits to growth and thereby the uptake of other elements. If phosphorus is the limiting element, more of it will necessarily give more in the way of algae (or grass, or forest …). Now even a well nourished alga cell cannot manage to bind more than a few thousandths of a gram of carbon, but this modest contribution is compensated by their number. A millilitre of water can contain many thousand algal cells, and on an annual basis algae (plant plankton) bind a good 50,000 million tonnes of carbon. A corresponding quantity is bound in vegetation on land. The amount of carbon that is bound is determined to a high degree by available nitrogen and phosphorus – which have, as we know, increased in the course of the past 50 years. But it is an ill wind that blows nobody any good: The global fertilising with nitrogen and phosphorus is in other words contributing to increased binding of carbon. How much carbon is bound is determined by the relative ratios of these three elements in the plants.

Maxima in minimis

The next link in this chain is the fate of the carbon that is bound by the plants. How much is stored in sediment and soil, how much ends up in higher levels of the food web, and how much is conducted back to the atmosphere through respiration in the form of CO_2? One of the great uncertainties when it comes to quantification of the global carbon cycle, and thereby climate prognoses, is how much of the plants' carbon uptake is conducted back to the atmosphere through respiration. There is a great deal to suggest that this contribution is greater than has been supposed, and that plants' access to carbon in relation to phosphorus and nitrogen is crucial here. In other words, an understanding of the individual cells' regulation of the elements is important for the carbon cycle. The ratios of elements in plant cells can also regulate how much carbon or energy is transferred from one link to another in food chains. To make a long and complicated story short, a high content of carbon in the cells – in relation to nitrogen and phosphorus – will lead to rather inefficient food webs, great "loss" of carbon to the atmosphere, and thus less effective carbon storage in long-term stores such as soil and seabed. The brief grounds for this are as follows: animals have systematically a greater need for phosphorus and nitrogen than plants have. If they must gobble up a large amount of carbon that they cannot use, they will have to get rid of this surplus carbon, either by increased metabolism (to CO_2) or as another form of excretion. Since terrestrial plants have systematically more in the way of carbon and less in the way of nitrogen and phosphorus than algae, there will be more carbon that cannot be used here. This contributes to the fact that food webs on land are generally less "efficient" than in water. In addition phosphorus is a key element in the genetic materials (DNA and RNA), where RNA in particular is dependent on an adequate phosphorus supply to ensure rapid cell growth. Nitrogen for its part is the central element in proteins. Thus it is obvious that the relative ratios of these three elements will also have great importance for the dynamics in an ecosystem, which can be shown by means of both experiments and models.

This is the essence of what our group at the Centre has been working on, and what is stimulating is precisely this logical journeying from the level of the cell to the global. It shows the significance of reductionism for a holistic picture, and is probably in many ways what Linné called *Maxima in minimis* – the largest in the smallest.



A millilitre of water in the ocean can contain many thousand algal cells. The green algae Halosphaera sp is one of a multitude of species of plant plankton that each year bind a good 50,000 million tonnes of carbon. (Photo: Wenche Eikrem/Jahn Throndsen, Biologisk institutt, UiO)

Human cognition may be both an individual and a social process. After all, we live in a world in which other people correct our thoughts the whole time, says Professor Pascal Engel.

Philosophy on its way back to Nature

Analytical philosophy is on its way "back to Nature" again after many philosophers in the 20th century turned up their noses at biology, psychology and sociology. The French philosopher Pascal Engel is perfectly happy with this development, and likes to take his point of departure in the fact that the human mind and mental functions are dependent on the fundamental physical processes.

"After all, there's nothing to be lost by saying that the mind is dependent on biology and physics. Obviously that's not the same thing as saying that biology and physics govern the mind completely. To take a parallel instance: it's pretty clear that sex can be described as a biological phenomenon. But that doesn't mean there's any reason to deny that there are also such things as romance and love," says Professor Engel.

Pascal Engel is Professor of the Philosophy of Logic, Language and Knowledge at the University of Paris IV Sorbonne, and is one of the participants in the CAS project *Towards a new understanding of the mental*. The project is headed by the Professors of Philosophy Bjørn Ramberg and Olav Gjelsvik from the University of Oslo, and takes its point of departure in the fact that the enormous progress in the natural sciences over the last few decades has led to our needing a new understanding of the relationship between body and mind.

Professor Engel is particularly concerned with the relationship between belief and knowledge, and is well known internationally for having gone new ways in his investigation of man's possibilities for freedom of belief as a mental state. "Is belief a question of will, and can we believe exactly what we want to? What must you do to transform belief into knowledge, and what must you subtract from knowledge to transform it into belief? These traditional problems in philosophy are renewed today in very interesting ways," says Pascal Engel.

At the CAS Professor Engel is first and foremost to dig more deeply into the relationship between the normative structures of human thought and the natural structures of the brain as well as society outside. "It's among other things interesting to look at human cognition both as an individual and as a social process. After all, we do live in a world in which other human beings correct our thoughts the whole time," says Professor Engel.

Biology sets the limits to the mind

But let us return to the relationship between human biology and the mind. "There ought not to be any doubt that the brain sets limits to the mind. What is called the Capgras Syndrome, which was described for the first time by the French psychiatrist Jean Marie Joseph Capgras early in the 20th century, is an extreme example of this relationship. It has in the course of time been well documented that patients with Capgras' Syndrome have damage to the prefrontal cortex, and this damage leads to a delusion which is typically that a close relative or friend has been replaced by an impostor, an exact double. These patients stick to this delusion even though they can recognise both appearance and behaviour," says Pascal Engel.

Capgras' Syndrome may be at the root of serious family tragedies, and there is for instance a famous case in which the patient killed his wife in the belief that she had been replaced by a Martian. This example shows that brain structures can influence human beings' mental states and cognition, but also that the brain structures do not explain everything. The subject here reacts by reinterpreting his own condition, and forges a "rational" belief: "This is an impostor".

A hierarchy without sharp distinctions

Professor Engel's approach to the relationship between belief and knowledge – an approach which is very influenced by one of the other participants in the Program, Professor Timothy Williamson – is that there is no clear distinction, but that it is instead a question of a hierarchy or continuum. "We often say that we *believe* something or other, but that we don't know. We can also think that we *know* something, so it's not a question of *believing*. But belief can also have knowledge as its objective. There are in general two ways of looking at this: the traditional and modest interpretation is that belief is the fundamental mental state, but that we will always seek for information that can tell us whether our belief is rational or irrational. The second interpretation is more ambitious and it is that it's knowledge that's important – for there are of course many things we *know*. We know among other things how to speak our own language, how to lift a cup of coffee without making a mess, and so on," Professor Engel explains.

When it comes to the possibilities of free belief, Engel's interpretation is that belief is basically passive in the sense that it cannot be changed exclusively by means of the will. "But on a metacognitive level it's possible to think about your belief and to revise it in small steps, and there are laws of logic that govern how this can happen. In other words, you have an autonomy in the forming of belief," says the researcher.

"Forming a belief may be compared with baking a cake! You can't choose the ingredients completely freely, because most cakes must be made on the basis of different combinations of flour, sugar, eggs and different spices. But even though the ingredients are to a great extent given, you can bake many different cakes! In other words you don't form a belief exclusively through the passive collection of information, but instead through active investigation of how things actually relate to one another and what possibilities there really are."

Not a prophet in his own country

Professor Engel is not a typical French philosopher, but is instead happier in the company of British, American or Norwegian philosophers, for example. "True enough, French philosophy is famous, but I don't particularly care for the typically French notion of a philosophy that develops its own system of ideas without bothering very much about other sciences. Nor am I so very enthusiastic about the fact that the French philosophers place enormous weight on mastering the traditions and having a profound knowledge of the different historical trends through which the subject has passed. To take a parallel with chemistry: it's not necessary to know the theories that the father of modern chemistry, Antoine Lavoisier, developed in the 18th century if you want to understand modern chemistry!"

Nor does Pascal Engel like the notion of "The Great Philosopher", who sits in his ivory tower hatching great, and perhaps pretty incomprehensible, thoughts. "Modern philosophy consists very much in discussing and exchanging experiences with other philosophers. But the most important thing of all is that this work of ours, which is to dig far into cognitive processes to develop new knowledge about man, becomes pretty useless if we can't also communicate it to our students of philosophy and others who are interested. It's very important to be able to explain the concepts in a more or less comprehensible manner," Pascal Engel emphasises.

The Centre for Advanced Study

■ The Centre for Advanced Study at the Norwegian Academy of Science and Letters (NASL) is an independent foundation with a board appointed by the NASL, the Council for Universities and Colleges and the Research Council of Norway. The intention is that the academic activity at the CAS shall be recognised as achieving the highest international standard and thereby contributing to raising the level of basic research in Norway. The Centre's academic activity is of a long-term nature and it is to be permanent and academically independent vis-à-vis political and economic influences and the influence of research policy.

Outstanding researchers from Norway and abroad are invited for one-year stays to engage in research in the Centre's premises in the Academy's villa in Drammensveien in Oslo.

Each year the activity is organised in three research groups, each with from six to ten members. Each group is planned and organised within a common theme and headed by one or more outstanding researchers.

The groups are chosen from each of the following three areas:

- The Humanities
- Social Sciences/Law
- Natural Sciences/Medicine/ Mathematics

The Centre is exclusively a basic research institution where the participants have no other obligations than their own research. The Centre is administered by a permanent staff of four and was officially opened on 1 September 1992.

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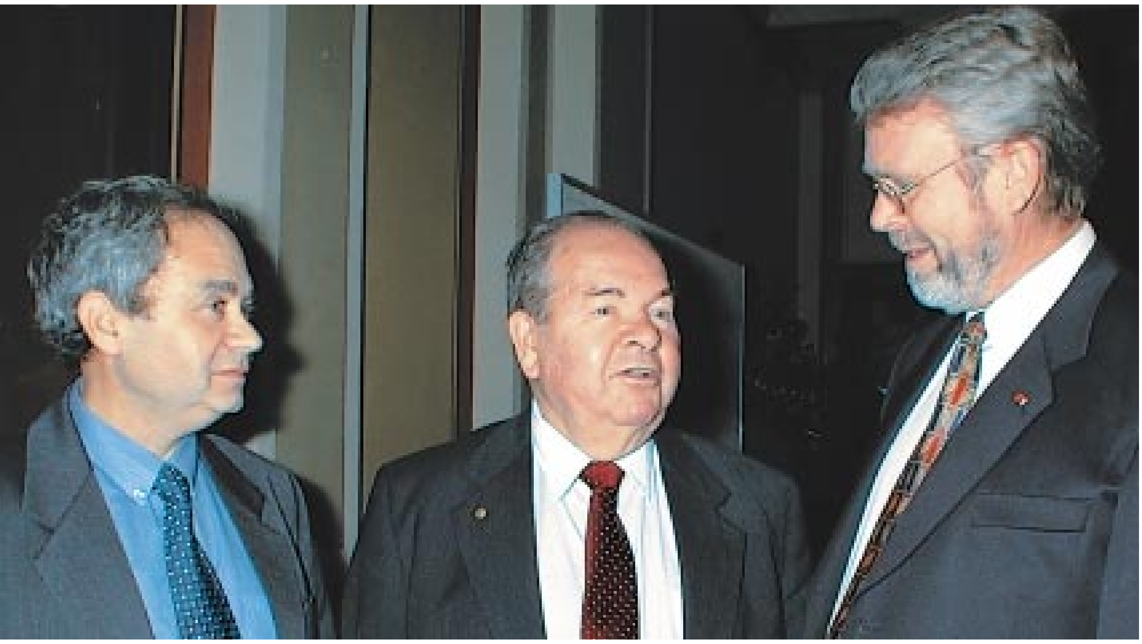
The dream of the Nobel Prize

Alexei Abrikosov had two dreams when he was between the ages of 10 and 12: he very much wanted to win a Nobel Prize, and he also wanted to become a member of the world's most famous academy of science, The Royal Society of London. "But those were simply a boy's dreams. I never dreamt that they would come true," says a modest Nobel Prize winner a good 60 years later.



From the left: Professor Yuri Galperin, Nobel Prize winner Alexei Abrikosov and CAS Director Willy Østreng at the annual CAS Christmas dinner.

Alexei Abrikosov, who was born in 1928, did in fact become a member of both the Royal Society and a number of other academies of science, and in 2003 he was awarded the Nobel Prize in Physics. But a long time was to pass between the discovery that was to bring him the Nobel Prize and the recognition that his discovery deserved.

Abrikosov was awarded the Nobel Prize for his discovery of what are called the type-II superconductors. Superconductivity is a physical phenomenon that makes some materials (such as metals, alloys and ceramic substances) able to conduct an electrical current without resistance. Abrikosov's superconductors have inter alia other magnetic properties and function at higher temperatures than other superconducting materials.

Unconventional thinking

"If you discover something that really breaks with conventional thinking, it's difficult to become recognised. But if you break with conventional thinking, the chances are also pretty high that you have made a real discovery!" said Abrikosov during a visit to Oslo in December 2003. Among his activities in Norway he attended the Christmas dinner at the Centre for Advanced Study, gave a guest lecture in the Department of Physics at the University of Oslo (UiO), and spent some days together with his colleague Yuri Galperin, Professor of Physics at the UiO. Incidentally the two met when Abrikosov was an opponent for Galperin's demanding Russian doctoral dissertation at the A.F. Ioffe Institute of Physics and Technology in St. Petersburg in 1980.

The young Abrikosov was practically an infant prodigy, and he took his doctorate in physics at the Institute of Physical Problems in Moscow as early as 1951 – at the age of 23. His doctoral dissertation actually described a new theory of thermal diffusion in plasma, but in the course of his work he came across phenomena that called for closer examination. The result was that he discovered the new type of superconductors only a year later. But the first publication was quite simply ignored by other researchers in Russia.

Internationally recognised

"My research first remained on the shelf for four years before I could go any further with it, because the results were contrary to the "accepted" views. Then a further ten years passed before people eventually started believing in what I had discovered," he relates.

Abrikosov is not in any way bitter about this delay, and has long since received all the recognition he could wish for. His research has been internationally recognised at any rate since 1975, when he was made an honorary doctor of the University of Lausanne. The type-II superconductors have also gained new relevance in our days, in step with the development of superconductors that function at ever higher temperatures.

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