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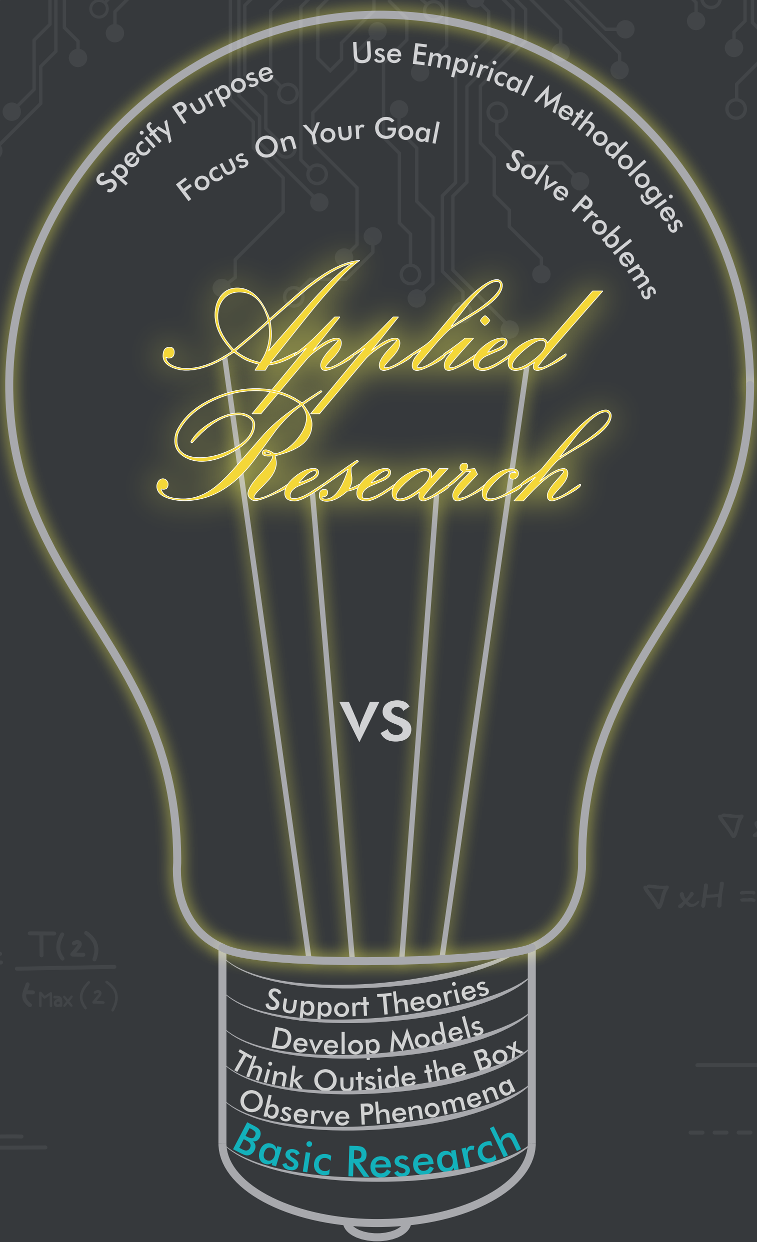
JUnQ

Do We Need Fundamental Research?



International Year of Light 2015

Interview with Prof Niemela from IYL Global Secretariat

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Editorial Note

Dear Reader,

When you read this issue of JUnQ, you might wonder why there is no article section. This is not - as one might think at first - due to a lack of submissions. Quite the contrary, we constantly receive articles, showing the need for a platform like JUnQ. The real difficulty lies in finding other scientists who are willing to put personal time and effort into reviewing these articles. Although this might be a general problem for many scientific journals, we do our best to ensure that it will not be a permanent one for JUnQ as the publishing of negative and null results still is supposed to be its key feature.

In our current issue, we have a look at a categorization of science not based on different scientific disciplines but on the very motivation behind scientific endeavors: fundamental science *versus* applied science. Correspondingly, this differentiation of the underlying motifs of science is already reflected in the cover, which has been designed by Robert Lindner for this issue.

To get an idea if the categories "fundamental *vs.* applied" are relevant for the classification of science especially in Germany, we have interviewed representatives of two of the big German research institutions - Prof. Maskos from the "Fraunhofer Society" and Christoph Herbort-von Loeper from the "Leibniz Association", both emphasizing the importance of transfer between fundamental research and applied science.

In his essay "Do we need Fundamental Research", Dr. Andreas Müller, astrophysicist at the "Technische Universität München" gives a complementary view on the topic in pointing out why classic fundamental science has been and still is relevant for modern societies, even if there is no obvious application in sight. Prof. Klaus Roth, whom we have interviewed regarding his upcoming JUnQ lecture series talk "How to Win a (Ig)-Nobel Prize" (more information can be found at the end of the journal), argues along the same lines when he states that "Basic research is *sine qua non* for any progress in the natural sciences, medicine, and all engineering disciplines".

2015 was the International Year of Light (IYL) - the second topic of this issue and consequently, the second theme illustrated in the cover. In an interview with Prof. Niemela, global coordinator in the IYL2015 secretariat, we take a look back at last year's IYL events. The interview is accompanied by two essays: In "A Brief History of Light", Susanne M. Hoffmann provides an overview about the history of using light and about its meaning for ancient cultures. Our new editorial board member Theresa Lückner writes about optogenetics - an exciting new principle of utilizing light-gated ion channels in neurobiology. At this point at the latest, with an example of how fundamental research in optogenetics may lead to new medical applications, we, in turn, can draw a connection to the first topic of this issue.

In addition to Theresa, we are lucky to count four new members to the JUnQ editorial board who I want to welcome on this occasion - Jennifer Heidrich, Tatjana Dänzer, Martin Nalbach and Kai Litzius.

Having said this, I hope you will enjoy this issue of JUnQ and that we can raise your interest to dig deeper into the featured topics.

—Philipp Heller

Fundamental *vs.* Applied Research – Interview with the Leibniz Association

The Leibniz Association was founded in 1995 after a fusion of institutions of the Western German association "Blaue Liste" and other research institutions of the former German Democratic Republic (GDR). It was named after the German polymath Gottfried Wilhelm Leibniz (1646 – 1716). The association is particularly known in the eastern parts of Germany, being the biggest research association there. Interestingly, the Leibniz Association even patronizes several museums and the most commonly known are the Senckenberg institution in Frankfurt a. M. and Deutsches Museum in Munich. We spoke with Christoph Herbort-von Loeper[1] who is deputy press officer of the Leibniz Association.

Leibniz-Gemeinschaft

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JUnQ: Could you briefly tell us about the tasks and vision of the Leibniz Association?

Leibniz: The Leibniz Association's vision is to find answers to the big questions of our modern society. To put it in a nutshell, we conduct research that benefits mankind. This includes all kinds of disciplines, be it medical research, life sciences, engineering, environmental research or social trends.

JUnQ: Could you please tell us a bit about the historic background of the Leibniz Association?

Leibniz: Before the association was named after the German polymath Gottfried Wilhelm Leibniz in 1997, many of the institutes were included in the parent organization "Blaue Liste" (engl. blue list). This in turn was a fusion of former Eastern and Western German Institutes in 1992. However, some of our institutes were founded up to 300 years ago, such as the Leibniz Institute for Astrophysics Potsdam.

JUnQ: What is the organizational structure of the Leibniz Association?

Leibniz: Our institutes and museums are organized autonomously and are fostered by the Leibniz Association. The association itself is headed by a president and four vice presidents forming the management board. Furthermore, our institutes are organized into five different sections which have their own spokespersons. Together with the management board, they form the presidium.

JUnQ: How many different Leibniz institutes are there currently in Germany and what is their main emphasis respectively?

Leibniz: Currently, the Leibniz Association consists of 88 autonomous institutes and museums organized in the five sections Humanities and Educational Research; Economics, Social Sciences, Spatial Research; Life Sciences; Mathematics, Natural Sciences, Engineering and Environmental Sciences. These sectional topics are a guide for the research conducted but there are no specific primary focuses to ensure that it covers the whole spectrum of the society's needs.

JUnQ: What is your main way of funding?

Leibniz: On the basis of article 91b of the German Constitution, we are funded by the German Bund and Länder (federation and the federal states), which contribute 50% respectively. This forms about 70% of our funds. The remaining 30% are contributed by third-party funds coming from economy or foundations.

JUnQ: The Leibniz Association promotes a lot of applied research. What are the reasons for that? Is fundamental research a topic at all?

Leibniz: The research in our institutes is conducted focusing on a specific topic. Which type of research then is necessary, may it be basic or applied, depends on the questions that are investigated in the first place. There are a few institutes promoting primarily basic research but the aspects of application and social need are included as well.

JUnQ: In this context, do you think that a differentiation between fundamental and applied research makes sense or isn't it rather becoming more and more difficult to clearly distinguish between the two?

Leibniz: We rather see it as a continuous process, applied research lives from the ideas of basic research and one cannot be clearly separated from the other anymore. The main focus is not the type of research but the questions we want to solve. One can rather term it application-oriented basic research which is oriented to our modern society's needs without specific scientific boundaries.

JUnQ: Do you put special emphasis on technology transfer? How important are cooperations with industry (also with respect to funding)?

Leibniz: Transfer itself is an important aspect of the Leibniz Association. We make a lot of our new insight and databases available to open access since we perform research for the common good. This can also include technologies. In addition, we have cooperations with industry.

JUnQ: Do companies contact you as an external scientific consultant?

Leibniz: Yes, they do. However this is not our core activity. Whenever possible, we contribute to developing new technologies, especially in terms of innovation research and prospective technology. More commonly, we offer science-based policy advise.

JUnQ: Additionally, it appears as if a lot of your institutes are dedicated towards studying social trends. Is that avenue a fallout of an entrepreneurial mindset?

Leibniz: Some hot topics in modern society cannot be investigated exclusively by one scientific branch. For example, we have the research alliance "Science 2.0" dealing with knowledge in the digital age. We take up the development of our society and investigate them scientifically. Other examples are nanosafety, globalization or educational research.

JUnQ: In your opinion, what sets the Leibniz Association apart from other scientific societies like Max Planck, Fraunhofer or Helmholtz?

Leibniz: In contrast to MPG and Fraunhofer, we are focussing on specific topics, whereas MPG is known to be basic research oriented and Fraunhofer applied research oriented, respectively. In a way, we are located in between, just like the Helmholtz Association. Our institutes are legally and scientifically autonomous and our main aim is to provide knowledge to the benefit of our modern society. Besides research, we promote science transfer and offer scientific services and infrastructure, such as provision of data, equipment, collections and archives.

JUnQ: Thank you very much for the interview!

—Theresa Lückner

Do We Need Fundamental Research?

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Today, we find modern technologies everywhere in our daily life: computers, smart phones, navigation systems, wearables, high-tech medicine. Usually, they did not come by chance. These technologies are a result of fundamental research and breakthroughs and were developed by scientists, engineers and clever inventors.

What is Fundamental Research and Its Role?

By definition, fundamental research is not purposeful. A modern society invests several billion euros per year into research and development (R&D). This is not a luxury issue. We have to invest a significant amount of a country's gross domestic product (GDP) to develop new methods and technologies. These are essential for our economy, our prosperity and they are vital to face the challenges of a modern society. And there are quite a lot of challenges at the beginning of the 21st century: climate change, exhausting energy resources, terrorism, an over-aging society and, most recently, refugees coming to industrial countries for various reasons like war, terrorism or poverty. One example: Our knowledge about anthropogenic climate change is a result of modern science. About 800 scientists worked on the recent 5th assessment report of the Intergovernmental Panel on Climate Change (IPCC).[1] This report was only achieved by an international interdisciplinary collaboration of scientists who were financed by many countries with several billion euros over decades. The IPCC found evidence that mankind is responsible for global warming, mainly driven by the emission of carbon dioxide from our industries and traffic. This effect is seriously evolving as can be seen, e.g., from the following fact: Consider the (on average) ten hottest years since data archiving which started in 1880. Nine of these ten hottest years were after year 2000! Our modern society urgently has to find a solution for this climate change problem. The IPCC researchers are capable of forecasting our future using modern climate models. If we go on like we used to do, we will run into a significant mean temperature increase of about three degrees until year 2100 or even eight degrees in the worst-case scenario. Extreme weather events (violent storms, droughts) will appear more frequently. Coasts will be flooded due to increased sea levels. To prevent that from happening, we need new efficient CO_2-free technologies – now.

A Sidewalk through History

How did we end up like this? It is interesting to have a closer look on the evolution in the field of energy resources. History tells us how mankind discovered new resources, e.g. steam engines or electricity, and sooner or later was able to make use of them. New technologies come along with scientific discoveries. From our present perspective it is funny to remember that about 100 years ago there was a poor understanding of particle physics, for example. At that time, only two particles were known: the proton and the electron. Meanwhile, we now know more than 20 elementary particles (6 quarks, 6 leptons, the photon, 6 gluons, W^+, W^-, Z^0, and the Higgs particle)! And it turned out that the proton is not an elementary particle but consists of quarks. Furthermore, the notion "radioactivity" was coined in 1898 by Marie and Pierre Curie. The couple dedicated their life to fundamental research and they paid a high price because they did experiments with unknown and very dangerous chemical elements like Radium or Polonium. Thanks to their devotion for the unknown, we now know so much more about the nature of elementary particles and matter. This knowledge is vital to develop new technical devices and new experimental methods. Radioactivity was also used by Ernest Rutherford to investigate matter. He did scattering experiments with energetic particles (alpha particles) on gold foils and formulated a powerful atomic model. Later on, particle physicists built particle accelerators. They took electric and magnetic fields to accelerate and control electrically charged particles. By smashing them together they found new particles. This strategy is the same for the most powerful particle accelerator today, the Large Hadron Collider (LHC) at CERN. In summer 2012, it was proven that our knowledge of the microscopic world is still incomplete. The fundamental Higgs boson, a spin-0 particle, was found. The "Higgs" is responsible for the rest mass of all other fundamental particles. It seems that there is still a strong motivation to invest into fundamental research – not only in a discipline like particle physics.

A Modern Society Benefitting From Fundamental Research

The Higgs boson might be an example of something, which does not immediately affect applied sciences. It appears

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that in the next 20 or 30 years or so there will be no useful device, which is built on Higgs physics. Nevertheless this kind of fundamental research is extremely important because it is a puzzle piece in our understanding of the world. In a sense, Higgs physics is a cultural asset like classical music or contemporary literature.

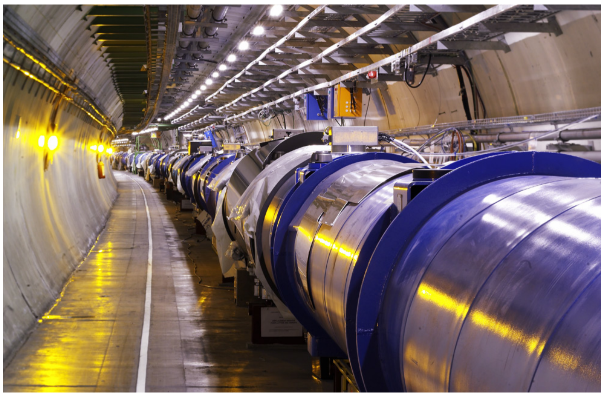

Figure 1: The Large Hadron Collider (LHC) at CERN is a multi-billion euros facility for several thousand scientists and engineers doing groundbreaking fundamental research. (Image credit: CERN)

Of course, you never know what can be the result of a long lasting scientific endeavor. Take the laser physics as another example. The acronym "laser" stands for light amplification by stimulated emission of radiation. The foundations of laser physics date back to 1917 when Albert Einstein contributed to the quantum nature of radiation. He found probability coefficients (nowadays called Einstein coefficients) which are important to our understanding of stimulated emission, a phenomenon which is a precondition to build a laser. Today, when we look around, we find lasers in everyday items like a DVD player or a laser pointer. Lasers are also important to manipulate matter on a microscopic scale. Here we see that the timescales for bringing fundamental research into daily life could be long, something like 100 years. The bottom-line is clear for everyone to see that we are benefitting from these investments into fundamental research – sooner or later. Accidental discoveries also play a crucial role in this context. Two examples: The cosmic microwave background (CMB) radiation was discovered in 1964 while radio astronomers were investigating the Milky Way. In 1928, the effect of Penicillin was discovered by chance as well in a hospital in London. Without fundamental research both would not have been possible. Both were breakthroughs: The CMB tells us about the birth of our universe in a hot "Big Bang"; Penicillin helps us to cure bacterial infections. There are also important secondary effects while doing fundamental research. Another benefit can be seen, e.g., at CERN: There are large international collaborations with several thousands of individuals cooperating peacefully for their research goal – no matter which origin, race or religion they may have.

A Modern Society Benefitting from Fundamental Research

Now that sufficient motivation has been established to invest into fundamental research, the remaining crucial questions are: How much should a modern country invest? What is the fraction of Germany's gross domestic product which is fed into R&D? And from a global perspective: Which nation invests most? The R&D investments of Germany amounted to 80.2 billion euros in 2013 which equals 2.85 % of Germany's GDP. The largest contribution came from the German economy (53.6 billion euros) because branches like automobile, computer, telecommunication, electronical, chemical and pharmaceutical industries invest quite a lot into R&D and significantly increased their investments in 2013. Compared to other European countries there were only three countries which invested more into R&D in 2012, namely Finland (3.55 % of GDP), Sweden (3.41 %) and Denmark (2.99 %).[2] The fraction in France amounted to 2.26 % and 1.77 % in the UK in 2012. The European average was 2.06 % in that year. In 2011 there were non-European countries which invested significantly more into R&D, e.g. Israel (4.38 %), South Korea (4.03 %) and Japan (3.39 %). The fraction for R&D in the U.S.A. was 2.77 % in 2011 – i.e. at a comparable level to Germany. The 3-percent-goal for Germany was achieved in 2012 with 2.98 %.[3] Let us compare the absolute numbers of R&D investments, e.g., national defense budgets. The German Government invests something like 30 billion euros here. Multiplying this by a factor of 20 we approximately get the US-American budget (nearly 600 billion USD).

A Pleading for Fundamental Research

For a modern society it is absolutely crucial to continuously invest into R&D and fundamental research. It seems reasonable to fund R&D with 3 % of a nation's GDP. This has to be done over a variety of disciplines and from the industries as well as from the governments. The R&D achievements in the last 100 years clearly show that mankind enormously profits from these investments and that the findings, sooner or later, influence and facilitate our daily life. The time scales for these changes are rather long, decades or even one century. However, the impact of new technologies can be very high, see e.g. computers, the internet, or smartphones. Funding agencies should not have the narrow perspective to exclusively invest into industrial R&D, applied sciences, or industrial projects with a dedicated application-driven goal. History tells us that also the funds for fundamental research, which is not purposeful by definition has its return on investment and, of course, an understanding of our world in general represents a cultural asset.

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Fundamental *vs.* Applied Research – Interview with the Fraunhofer-Gesellschaft

The Fraunhofer-Gesellschaft is one of Germany's most important research associations with its main emphasis on applied research. It was founded in 1949 and it goes back to Joseph von Fraunhofer (1787 – 1826). He was famous for his way of accurate conduct of science combined with a sense for entrepreneurship, which is why he became the role model for the Fraunhofer-Gesellschaft. We have talked to Prof. Dr. Michael Maskos[1] and Beate Koch[2]. Prof. Dr. Michael Maskos is the director of Fraunhofer ICT – IMM in Mainz, which focuses among others on the synthesis and characterization of nanoparticles for different applications. Beate Koch is head of internal and external communications of the Fraunhofer-Gesellschaft.

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JUnQ: Could you briefly tell us about the tasks and vision of the Fraunhofer-Gesellschaft?

Fraunhofer: Research of practical utility lies at the heart of all activities pursued by the Fraunhofer-Gesellschaft. Founded in 1949 and based in Munich, the Fraunhofer-Gesellschaft is a non-profit research organization that undertakes applied research and development (R&D) in areas of the natural and engineering sciences that are of importance to Germany's economic competitiveness. It currently operates 67 Fraunhofer-Institutes and Research Institutions across Germany, whose mission is to develop innovative solutions of direct benefit to industry and society as a whole. Fraunhofer's research portfolio covers a broad spectrum of topical areas, which are also featured in the German government's latest High-Tech Strategy, including resource-efficient manufacturing, transportation and mobility, energy and housing, information and communication technologies (ICT), protection and security, as well as healthcare, nutrition and the environment.

JUnQ: Could you please tell us a little about the historic background of the Fraunhofer-Gesellschaft?

Fraunhofer: The Fraunhofer-Gesellschaft was founded in Munich on March 26 1949, as part of a program to reorganize and expand Germany's research infrastructure. The organization takes its name from Joseph von Fraunhofer (1787 – 1826), the successful Munich researcher, inventor and entrepreneur. In its early years, the main function of this non-profit organization was predominantly administrative: to raise funds through government bodies, donations and association members for distribution to research projects of relevance to industry. Initial activities primarily focused on industry in Bavaria. This being the early post-war period, there was particular need for research in the fields of mining, the iron and steel industry and mechanical engineering. These activities developed into a wide range of application-oriented research with a focus on key technologies of relevance to the future.

JUnQ: What is the organizational structure of the Fraunhofer-Gesellschaft?

Fraunhofer: Fraunhofer profits from a decentralized organizational model. Today, Fraunhofer means 67 institutes in Germany working in different fields yet under one legal framework and strong brand: Fraunhofer. This comes along with the close alignment of every Fraunhofer-Institute to one affiliated German university. This special relationship is reflected by the fact that every Institute's director at the same time holds a chair at the affiliated university institute.

JUnQ: How many different Fraunhofer-Institutes are there currently in Germany and what is their main emphasis respectively?

Fraunhofer: Currently there are 67 Fraunhofer-Institutes in Germany. Their fields of research center around:

- Health and Environment: In addition to medical care, two key factors that also affect people's health are nutrition and the environment. Current Fraunhofer research in the area of environmental and life sciences derives its key goals from these three factors.

- Security and Protection: The objective of safety researchers is to provide people and the environment with the best possible protection from threats. They adopt a long-term approach in order to gain control of all the different phases that occur in a disaster, focusing on early detection, prevention, direct protection and quickly overcoming the consequences of a disastrous event.

- Mobility and Transport: The mobility of goods and passengers has become an indispensable factor for industry and society, and continually poses new challenges for the scientific community: from vehicle development to traffic management, from new safety requirements to efficient transport logistics. Fraunhofer researchers are working on ways to make mobility safer, more efficient and more economical.

- Production and Supply of Services: A scarcity of raw materials, a shortage of qualified workers, competitive pressure – these are only a few of the challenges manufacturers face. Researchers are working on energy- and resource-efficient processes for tomorrow's manufacturing.

- Communication and Knowledge: Information and communication technology is an overlapping area that covers almost all other research fields and sectors, from medicine and the media industry through to the manufacturing sector. Digital technologies open up many new ways to communicate. Personalized, interactive and mobile learning methods help us to prepare for the work environment of the future.

- Energy and Resources: If we want heated homes, hot water for showers, and electricity to power our ovens, appliances and computers, we need energy. Until now it's been mainly oil, coal and gas that have driven the economy and supplied our home comforts. The problem is that, slowly but surely, these finite resources are running out. It is imperative that we use raw materials more efficiently – and that includes using energy more efficiently, finding reliable ways to store it and redoubling efforts to tap renewables.

The main emphasis of the individual institutes is indicated by their names. You can find a list here: http://www.fraunhofer.de/en/institutes-research-establishments.html

JUnQ: What is your main way of funding?

Fraunhofer: An important step for Fraunhofer towards being a decisive column in the German innovation system was the introduction of the so-called Fraunhofer model of financing - a performance-related system of financial management. The underlying model of allocating and distributing public funding to Fraunhofer and subsequently within Fraunhofer to specific research groups (institutes) is one of the success factors of Fraunhofer. About 70 percent of the Fraunhofer-Gesellschaft's contract research revenue is derived from contracts with industry and from publicly financed research projects. Around 30 percent of Fraunhofer's contract research budget is accounted for by base funding provided by the German Federal Ministry of Education and Research (BMBF) and the state governments in a ratio of 90:10 for the internal use of the organization at its own discretion. This enables the institutes to work ahead on solutions to problems that will not become acutely relevant to industry and society until five or ten years from now.

JUnQ: The Fraunhofer-Gesellschaft is known to promote primarily applied research. What are the reasons for that? Is fundamental research a topic at all?

Fraunhofer: With its clearly defined mission of application oriented research and its focus on key technologies of relevance to the future, Fraunhofer plays a prominent role in the German and European innovation process. Applied research has a knock-on effect that extends beyond the direct benefits perceived by the customer. Through their research and development work, the Fraunhofer-Institutes help to reinforce the competitive strength of the economy in their local region, and throughout Germany and Europe.

They do so by promoting innovation, strengthening the technological base, improving the acceptance of new technologies, and helping to train the urgently needed future generation of scientists and engineers. In addition, Fraunhofer-Gesellschaft carries out publicly funded precompetitive research. This forms the basis of the contract research projects conducted for customers.

JUnQ: In this context, do you think that a differentiation between fundamental and applied research makes sense or isn't it rather becoming more and more difficult to clearly distinguish between the two?

Fraunhofer: Although the two are interlinked on many levels, there is still an essential difference: Fundamental research provides answers to basic scientific questions bringing forward science itself. Applied science on the other hand provides solutions for practical problems; the research results are technologies that can be put into practical use.

JUnQ: Do you put special emphasis on technology transfer? How important are cooperations with industry (also with respect to funding)?

Fraunhofer: Fraunhofer's mission cannot be fulfilled by excellent research alone, but has to be complemented by the transfer of this research into real-life applications – in other words: innovations. Fraunhofer has various mechanisms for transferring knowledge to business and industry:

- Direct bilateral contract research: A Fraunhofer-Institute is contracted to perform work for a company and invoices that work accordingly. The results to be delivered and the price are fixed in a contract. Negotiations on the use of intellectual property rights are often a critical step because for Fraunhofer it is essential to be allowed to use generated knowledge for further applications without compromising the interests of the original client. Fraunhofer takes care not to depend on a few individual companies for large portions of its contract work, so as not to be exposed to financial risk if and when such customers discontinue the relationship.

- Spin-offs: Companies founded by former Fraunhofer staff. They often retain close ties to Fraunhofer because their business is normally based on patented Fraunhofer inventions. In some cases, Fraunhofer may take on the role of a minority shareholder of the spin-off company, on condition that its shares are sold by the latest after 8 years.

- Licenses: Some Fraunhofer technologies or intellectual properties are licensed to customers without any further contract research.

- Transfer of skilled minds: Every year, several hundred scientists leave the Fraunhofer-Institutes in order to take up a position in industry. They are highly qualified and put to new use the know-how they gained at Fraunhofer.

- Strategic cooperation with companies on their own premises or at a Fraunhofer laboratory: For companies requiring long-term cooperation and ongoing support, Fraunhofer sometimes establishes small project groups on the company's premises where researchers from both parties work together. An alternative option for companies is to lease laboratory space on the premises of a Fraunhofer-Institute, where they can conduct their own R&D with the assistance of Fraunhofer researchers.

- Innovation clusters: Given the increasing complexity of innovations and the need to assemble teams composed of specialists in different fields, Fraunhofer has adopted the concept of "innovation clusters". Different companies representing all links in the value chain are brought together in order to develop common standards and system solutions (for example a group of 18 partners was formed to develop the "intelligent home"); Fraunhofer takes on the role of coordinator or prime contractor.

- Fraunhofer Academy: Fraunhofer organizes its activities in training and human resources development as a separate business unit. As part of lifelong learning, specialists and managers from business and industry can acquire additional skills at Fraunhofer. Knowledge from the research conducted by the various institutes is transferred directly to companies by seminars and complete courses provided in cooperation with major universities.

JUnQ: Do companies contact you as an external scientific consultant?

Fraunhofer: Companies rather contact Fraunhofer looking for expertise in R&D. One of many practical examples from Fraunhofer ICT-IMM is related to the expert's knowledge of nanoparticle technology: the internationally renowned research in nanoparticle synthesis and characterization is a typical door opener for industrial requests.

JUnQ: Additionally, it appears as if a lot of your institutes are dedicated towards studying social trends. Is that avenue a fallout of the entrepreneurial mindset of the Fraunhofer-Gesellschaft? Does this kind of monitoring help to prioritize, which research areas to focus on primarily?

Fraunhofer: Social trends are actually only a rather marginal subject of Fraunhofer research – but they do play an important role when doing research on solutions for real-life problems: Research in electro mobility, for instance, ties in with general developments in society's mobility, research in solutions for energy supply cannot be conducted without keeping in mind the society's energy needs, research in IT security will always have to consider society's use of IT.

JUnQ: In your opinion, what sets the Fraunhofer-Gesellschaft apart from other scientific societies like Max Planck or Helmholtz?

Fraunhofer: The Fraunhofer-Gesellschaft is the only research organization of these three specializing in applied sciences. Our research always results in technologies that provide solutions for practical problems. Fraunhofer's focus lies on the transfer of research results to the markets.

JUnQ: Thank you very much for this interview.

—Kristina Klinker

A Brief History of Light

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Thinking about light, we immediately realize three directions of human's dealing with it: first, the observation of light, second, the myth of and praying to light and third, the usage and rationalization of light in physics and technology. All three directions of our modern world have roots in very old history and accompany mankind from their early beginnings and in every culture. The emotional connection humans feel with celestial games of light and darkness as well as warmth and coolness during seasons and lunar phases caused early and perpetuating observations and consequently, the knowledge of calendar signs. Since calendars have always been used for religious purpose to date public holiday and so on, making calendars and observing the celestial rhythms have been a special duty of priests and the gods have been located in or above the sky. To summarize, we can conclude that light influences all directions of our life. The question of this article is how long back in history we can pursue the traces of human relations to light.

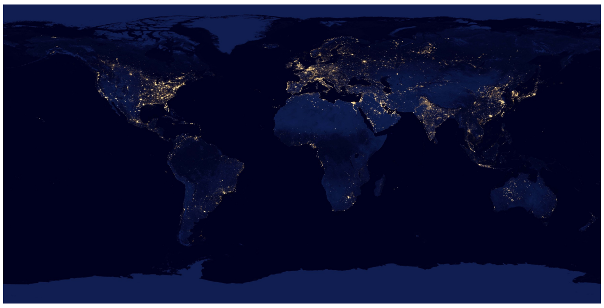

Figure 1: Today's culture illuminates the night. Satellites mapping the Earth's surface at night show clearly in which areas of this planets humans live in.[1]

Our modern civilization is able to live in brightness all the time and whenever we want to have artificial light (see fig.1). In this century, probably every average human being knows how to switch on the light in a room at night by only clicking on a button. In school, we have learned that the button closes an electric circuit and due to the voltage potential, a stream of electrons travels through the cables and induces a glowing of the matter in the light bulb (gas or a cable or whatever). So we have the impression of understanding how it works. But the real understanding of modern physics is much more complex: consider the atoms in the light bulb. Among other things they contain electrons on different energy levels and we can imagine that an electron falling from an upper level to a lower one emits the difference in energy as a photon – a particle of light – with a certain frequency (i.e., a certain color). Furthermore, the frequency (color) depends on the difference of energy between the levels where the electron jumps. At an even closer look, we have to consider the electrons as waves and not as particles. Therefore, they have an intrinsic wave energy. Again, we have to develop another model to explain the nocturnal illumination of our planet by human activities using the wave energy instead of energy levels...

Finally, we think we know a lot about our technical and natural environment but in fact, there are so many things, which are undiscovered, and even the few things we already happen to know have been developed over huge periods of time with regard to the existence of mankind. The knowledge that the color of light emitted by a light bulb depends on the energy the electron bridges goes back only to the previous century. The physics was written in the famous formula $E = h \cdot f$ published by Einstein in 1905 (Nobel Prize 1921). The description of light as electromagnetic waves is only forty years older. James Clarke Maxwell published the mathematical description of it in 1862. The understanding of white light as a composition of all colors of light is a bit more than another century older, when Newton experimented with glass prisms in a dark room during the 17^{th} century and later published his 'Opticks' in 1704.

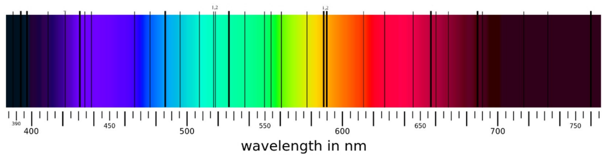

Figure 2: White light is a composition of all colors of light. In the 19th century, the physicist Wollaston and the optician and glas expert Fraunhofer independently discovered black lines in the artificial rainbow a prism makes from sunlight. Today we know that these are absorption lines indicating the chemical composition of the sun's atmosphere.[2]

Newton's experiments were the first steps toward an understanding of the physics of light. Before, there were only different considerations of geometrical optics; i.e., people considered bunches of light rays or beams of light like they are seen switching on a flashlight or an artificial lamp in the night. In foggy air, we can see light being emitted as a directed beam and so the idea of focussing the light of a fire rose up at least in antiquity. Of Archimedes, for instance, we know that he constructed instruments and military devices, sometimes using fire and light.

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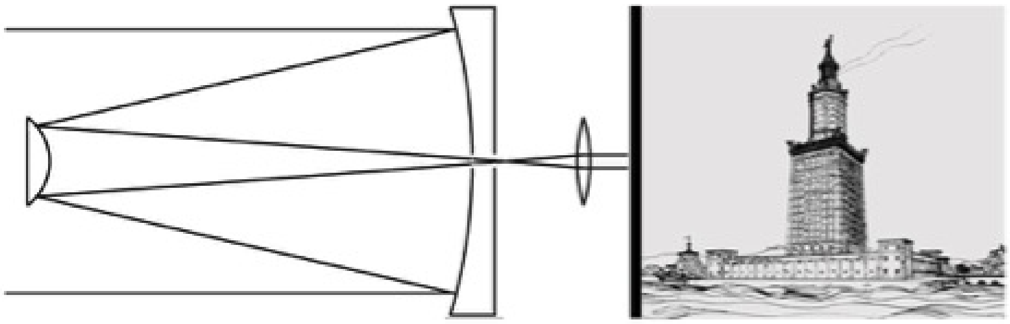

Figure 3: Since antiquity the technology of collecting and focussing light by concave mirrors has been known. The lighthouse of Alexandria was one example of an artificially directed beam of light.[3]

We also know that the olympic fire was kindled in the focus of a concave mirror and that also concave mirrors bunched up the light in light houses at least since hellenistic times: the lighthouse of Alexandria (3rd century BCE) was one of the seven wonders of the ancient world because of its enormous height. The history of using light for a technical purpose is, therefore, at least a few dozen centuries old.

Nevertheless, we know that people even before hellenistic times tried to invent myths to 'explain' how the light came into the world. Famous are the Bible's verses describing that God made a small light and a big light and divided the darkness from the bright daylight. Also well known is the Greek hero Prometheus who stole the fire from the gods and brought it to Earth for human usage. All these kinds of stories reflect the human consciousness of the importance of light for life on Earth. Not every culture projects the importance in the celestial body of the Sun (like the Egyptians did), but in some cases it is the fire or the light itself: notice for instance that in the Bible, God created the day-night pair way before he created the disks of Sun and Moon in the sky: 'And God said, "Let there be light", and there was light. God saw that the light was good, and he separated the light from the darkness. God called the light "day", and the darkness he called "night".' is the very first creation in sentence 3-5 to create the very first day. Sun, moon, and the stars appear only in sentence 14-16; they are created only on the fourth day to govern day and night and to make signs for his people. This means that also in the Jewish culture – inspired during the Babylonian exile, where chapter "*genesis*" of the Talmud and later of the Bible had probably been transferred to this form – the concept of light has been considered independently from the celestial bodies: it is not the sun which makes the day, but the daylight is naturally there, accompanying the solar disk in the sky. With regard to nature, this is not surprising since light in the sky is not only at the place of the sun's or moon's disk, but the whole hemisphere is illuminated.

Additionally, light in general can be generated not only by the sun but also by an oil lamp or by an open fire. That is why, even in mythological thinking it is easy to consider light as one entity and the disks of the sun and the moon as another two entities like 'clusters of light' or illuminated celestial disks – in fact the Bible does not explain the concept behind them.

Nevertheless, astronomical observations of the 'lights in the sky' are documented since ancient times. We know about continuous observations of the stars from historical sources in ancient Greece, ancient China and ancient Babylonia – probably also practiced in other cultures which did not conserve written protocols. The Babylonians' believe in gods communicating with humans by giving signs on earth and in the sky led to the wish of systematic observations: If the gods expressed their intents by signs, predicting the signs led to a better understanding of the intentions and wishes of the gods. Therefore, earth and sky were observed in order to conclude, which signs appeared together and which were followed by each other. During the first millennium BCE, there was a huge project of writing scientific diaries of all those observations, regularly noting the water level of the Euphrates river as well as positions of celestial lights and prices of common trading goods. This awakening of systematic observation and deriving patterns (rhythms, dependencies, cause-effect-pairs etc.) is the root of all sciences: it is one of the crucial conditions that the light of science can shine into our culture; i.e. that causal connections can be discovered and falsified between observed phenomena, world views rise and fall, and technologies can be developed to improve our daily life.

As far as we know, Babylonian astronomers observed the path of the moon by occultations of stars and wrote it down canonically at least in the later half of the second millennium BCE. Since they also found out that the path of the sun was roughly similar but inclined, they also observed helical risings and settings of the small lights (stars) of the morning sky to indirectly determine the path of the sun among the stars. The result of those observations was the zodiacal circle, which was divided into twelve equidistant zodiacal signs in the later half of the first millennium BCE. This equally divided circle was taken over by Greek astronomers to make first coordinate systems: one of the basic concepts of modern mathematics. Therefore, the observation of the lights in the sky and the wish to predict their appearances caused a new light on abstract thinking.

Figure 4: A reconstruction of the circular enclosure near Goseck, Germany. Researchers think that the gates in the palisade circles mark the directions of the solstices for an observer at the center.[4]

However, we assume that the observations of sun and moon date back to many millennia earlier. The enormous significance of the sun in Egyptian culture is preserved in religious texts and funeral rituals since the third millennium BCE and from the same era observations and predictions of the celestial light-and-shadow games are known in China. Famous is the story of the two Chinese astronomers, He and Xi who were beheaded because they failed to predict the solar eclipse in 2137 BCE. Additionally, there are some hints that even the circular enclosures in central Europe from neolithic times (ca. 4500 BCE) have had some use for observing the turning points of the sun; i.e., the solstices, where the duration of daylight begins to increase (winter) or decrease (summer).

Even today, we celebrate the two points of the shortest and the longest night of the year – interestingly in both cases with fire. The midsummer night is celebrated with big open fires in the countryside, where people meet and sit together. Around winter solstice, the Christian and Jewish cultures celebrate "festivals of light", i.e. Hanukkah in the middle of December (25. Kislew) and Christmas, the birth of the "light of the world" on December 25th. To conclude, we can say that – since many millennia – humans observe light, adore light, pray to light. We analyze light, try to describe the rhythms and nature of light, try to understand light and for roughly one hundred years, we make models of light, compare it with rays, waves, particles and so on. But what is light? To be honest we do not know exactly.

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[3] Drawing Prof. Hirsch, 1909.

[4] Drawing Rainer Zenz, based on plans from the Institute for Prehistoric Archaeology, Martin-Luther-Universität Halle-Wittenberg.

International Year of Light 2015 – Interview with IYL Global Secretariat Global Coordinator Prof. Niemela

The International Year of Light and Light-Based Technologies (IYL2015) was a global event in 2015 to increase the public interest and knowledge regarding optical technologies and research. Prof. Joe Niemela[1] is the Global Coordinator from the IYL Secretariat and was responsible for the coordination of all activities.

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JUnQ: In 2013, the UN proclaimed 2015 as the International Year of Light (IYL2015). What were the reasons for this decision?

Niemela: The UN realized the potential for increasing the quality of life in both developing and developed countries through advances in light technologies, and considering the general consensus that this would be recognized as the "century of photonics", made the correct decision that raising awareness of the potential of light technology was both timely and important.

JUnQ: What were the main goals of the IYL2015? If you now look back on 2015, have the goals been achieved?

Niemela: The main goals were, in fact, to raise awareness of the potential of light-based sciences in addressing societal challenges in a number of areas including energy, lighting, climate change, etc., and to promote at the same time education, women's empowerment in science, and sustainable development. Another goal was to bridge science and society. Looking back on 2015, most of these goals were achieved to an extent that we feel is convincing and impressive. Through our network of national committees we ran several thousand events, organized contests, went to schools to talk with students, and more. The key role that art and philosophy, light design and architecture played in the International Year brought a natural connection between scientific and non-scientific members of communities around the globe.

JUnQ: Who was/is responsible for organization and promotion of IYL2015 events?

Niemela: Most of the organization and promotion of the IYL2015 events happened from the bottom up, namely from the national and regional committees. Global themes were also organized and promoted by the IYL Steering Committee, including founding partners and UNESCO, but really, the emphasis was on empowering local nodes to work within their own communities. This was invaluable in building the bridges between science and society on a local level where it matters most. The Secretariat at the ICTP in Trieste took care of the organizational tasks associated with running the Year at all the global level and coordinating actions taking place regionally around the world.

JUnQ: Browsing through your site, it seems you went all out to make it a global celebration of light. Did you find it difficult to disseminate the importance of this message, say in nations from Africa or some other parts of the world where science is still catching up?

Niemela: Certainly, in parts of the world where resources are scarce, it is more difficult to achieve the numbers and level of activities we see in economically advanced countries. While the underlying technologies are universal, specific focus and implementation is often a matter of local needs. For instance in Sweden the concern in illumination might be with smart, tunable and integrated lighting systems in schools and offices, while in the poorest villages in Africa, typically off the electricity grid, the same concern may be with replacing kerosene lamps with modern and energy efficient solid state lighting powered by small affordable solar collectors in individual homes. Both depend on the advances in LEDs that led to the 2014 Nobel Prize in Physics.

JUnQ: Have any of the multitudes of events in your calendar led to some new and exciting developments? Between society and research/academia or some sustainable collaboration, as regards light-driven technologies, between developing nations and industry?

Niemela: The events that have been held this year have brought people together that normally do not mix, for instance between scientists doing fundamental research and Vatican scholars in 'Fiat Lux' held at the Ateneo Pontificio in Rome this year. Or with panel discussions in Lund, Sweden, that brought scientists doing basic research and lighting engineers together with politicians, this has helped motivate a pilot project in smart lighting in one of the local schools. Photonics21, held in Brussels, is a natural meeting place between politicians, industry and academia. Other large conferences, like SPIE's Photonics West in the US help to form bridges between research and development in industry and in academia. In fact, even though the IYL2015 started out primarily among academics, many of the special talks connecting light sciences and development have been invitations extended by large industrial events.

JUnQ: For planning the events, did you distinguish between fundamental and applied science?

Niemela: Most events have some mix of fundamental and applied science but with a particular emphasis on one or the other. The nice thing about the International Year was that we could bring diverse groups together often. There were many artistic events, and one of the nice surprises this year was the wonderful interaction between scientists and South African light artist Marcus Neustetter at the ICTP/IYL2015 event at Fort Hare University (alma mater of Nelson Mandela) in the Eastern Cape in September. There was a real communication that occurred between people speaking very different 'languages'.

JUnQ: What types of events did take place and which were the most successful ones? Is it easier to reach your audience with a topic from the field of fundamental or from applied science?

Niemela: It is difficult to say which events were the most successful – in terms of audience numbers there is no question that applied science events reached the largest crowds, but this is not the only measure of success. For instance, teacher training programs like the Active Learning in Optics and Photonics (ALOP) workshops reach only 30 teachers at a time but the multiplier effect can be huge as they teach their students who teach others and so on. Then there are events in which science and society come closer together. One measure of success was simply that we could measure it in so many diverse ways this year.

JUnQ: Public participation always factors into a successful event. How have you ensured that the events cater to the general populace as well? Also how has been the public perception to all the activities planned by IYL2015?

Niemela: This has been a good year in terms of public involvement – from photo contests, art displays, illumination of buildings, science café style events, public lectures at science museums, etc. We have given particular emphasis to public engagement. We have striven from the beginning to "talk to people we normally do not talk to", in other words to bring the fascination of light and light-based technologies to non-scientists.

JUnQ: Why is communication of science to the general public so important?

Niemela: It is extremely important for us to communicate science to the general public and to politicians for that matter. The problem is that scientists are in general not very good at it. There is no real difference between science and society even though we may talk about building bridges between them. Science is part of society and the bridges are in our own minds, to help us develop a broader vision about how we fit together and are all working together to shape the human condition. When we speak about societal challenges like energy and climate change, science alone cannot solve them. Poets and philosophers also play an indispensable role, as do people from all walks of life, because any solutions we come up should act to improve the quality of life and science by itself is neutral on that matter – the same technology that can destroy civilization can also save it. Besides this, we have become a society of specialists and there is no doubt that being able to translate into words the excitement of new discoveries– both to our fellow colleagues in other areas of science but also to non-scientists– brings a sense of joy and community.

JUnQ: If you look to the future: Are there any items on the agenda that will continue in 2016? Are there already plans for a next IYL or something similar?

Niemela: There are a number of activities that will continue as legacy actions. One of those concerns the "training of trainers" in the optical sciences in the least developed countries. We also will keep the effort up in finding ways to promote the migration of academics to industry and especially the reverse process, which is unfortunately exceedingly difficult in many industrialized countries. Given the broad applicability of light, and the fact that we are entering into a so-called "century of photonics", there is no doubt that we will see more international years where light technologies play a key role.

JUnQ: Thank you very much for the interview!

—Jennifer Heidrich

Light in Biology: From Fundamental Life-Giver to Brain-Modulator

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Photosynthesis: The Fundament of Life on Earth

When relating light to biology, the first thing that pops into one's mind is photosynthesis. The sunlight shines onto the leaves, photons excite the light-sensitive molecule chlorophyll and with the use of several cascades, nature produces carbohydrates and oxygen out of carbon dioxide and water. The usage of light is the fundament of eukaryotic life on earth and there is only little life that can exist without it. Even life in the deep sea relies on organic sediments produced by photosynthesis in upper sea levels.[1] The oxygen produced by photosynthesis is used in aerobic metabolic pathways and the produced carbohydrates make up the basis of the food chain with animals on the top of it.

The Visual System – Sensing Light

Animals do not only benefit from the supply of nutrients and oxygen, but also have several light-sensitive systems. The most obvious one is the visual system. In vertebrates, the photons affect the protein opsin which is coupled to the molecule retinal located in the photoreceptors of the retina. Subsequent events generate signals to the brain relaying information about color, contrast, object movement and shapes.[2] Vision is considered to be the most dominant sense in humans and without light, sighted people would surely miss seeing the beauty of a sunset, the colorful Times Square or the face of our loved ones.

Light Influencing Wakefulness and Mood

In addition to the photoreceptors, there are light-sensitive cells in the retina containing melanopsin whose activity does not yield information relevant for vision. These cells send signals to brain nuclei, such as the suprachiasmatic nuclei, to maintain the circadian rhythm. On this basis, the release of e.g. the hormone melatonin and the neuropeptide orexin is synchronized.[3] Both substances influence wakefulness in humans. Humans frequently experience the importance of the balance provided by the circadian rhythm upon disharmonizing it while on long-distance flights, commonly known as jet lag.[4] However, not only the circadian rhythm relies on the regular presence and absence of light. A specific form of depression is predominantly found in northern countries that characteristically have long and dark winters or even polar nights. Seasonal depression is expressed in wintry bad mood and negative habit changes. So we should not wonder why we are less happy during winter and there even is a tendency that the suicide rate increases in the winter months, especially in Scandinavian countries.[5]

Applying Light to the Brain

All the above-mentioned systems demonstrate that light is fundamentally important for life on Earth and especially for humans. Our visual system and our brain are naturally influenced by photons and their absence makes our life colorless, sleepy and sad. However, this is not the end of the story. Late developments in neuroscience demonstrate that what we know about the fundamental mechanisms of how light is used in biology can be applied to further study the function of the brain by shining light on it.

It has been known before that there are certain algal proteins that are light-sensitive but do not contribute to photosynthesis. Primarily, these are light-gated ion channels that enable the organism to orient and to move towards light by creating photocurrents (i.e. electrical currents induced by photons).[6] In the beginning of the 21st century, the structure of these channels was artificially modified and reconstructed in order to integrate them into other organisms. In the brain, they were firstly used in flies and the roundworm *Caenorhabditis elegans*. They were genetically expressed in dopaminergic cells and light was shone onto these animals. As a result, their behavior changed in response to light stimulation, just as if someone had switched the light on in this brain region.[7,8] Not long after, the first successful experiments in mammals were reported.[9] Specific brain cells were transduced with light-gated ion-channels and their stimulation induced activity in the region's neurons. So, how does this magic work?

The most frequently used light-gated ion-channel is channelrhodopsin. Just like in the photoreceptors of the eye, the light-sensitive molecule is retinal and it is coupled to a 7-transmembrane protein. Without light of a channel-

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typical wavelength, the channel is closed but once it is stimulated, the channel opens for cations.[10] In neurons, the most relevant ones are sodium, potassium and calcium ions and protons. Once a cation channel is opened, the sodium-influx into and the potassium-efflux out of the cell results in electrical currents. These currents are signals that are passed on to other neurons. Once channelrhodopsin is integrated into neurons, the experimenter can decide when and where these processes occur.

Beforehand, it has been possible to arbitrarily manipulate neurons using electrical currents. The novelty using the light technique is, that it can be specified which cells are supposed to respond to stimulation. Using electrodes, all cells in the vicinity could basically respond to an electrical stimulus.[11] However, if only specific cells are equipped with a light-sensitive cation channel, selective stimulation can be achieved. So how is specificity in cells determined? In genetics! Every cell type has its very own cluster of expressed genes. The developments of modern genetics allow using cell-type-specific genetic promotors to express genes that have been smuggled into the cell. Hence, the channelrhodopsin lying on a DNA plasmid contains a special code that can only be read in cells that have the encryption key. Because the light technique uses optics and genetics, it was termed optogenetics.

In the past years, this method has been used to study the function of specific cell populations in the brain and the neurotransmitter systems. Furthermore, it is possible that optogenetics can be applied to recover vision[12] or to treat neurological diseases such as Parkinson's disease[13] and epilepsy.[14] However, to accomplish clinical application, some open questions need to be answered. For example, more research has to be conducted on the method itself and light delivery. All in all, the importance of light for our life in general and for our well-being in particular is very prominent. Light is fundamentally necessary. More and more applications arise that make use of light, such as optogenetics. Still, we might not yet be at the tip of the iceberg when it comes to exploring the full potential that light has to offer in biology.

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How to Win an (Ig)-Nobel Prize – Interview with Prof. Klaus Roth

Klaus Roth[1] is an emeritus professor at the Freie Universiät Berlin. He studied chemistry at the Freie Universiät Berlin from 1964 – 1969 and completed his dissertation at the same university in 1973. After a post-doctoral stay at the Institute for Medical Research in Mill Hill, London from 1979 – 1980, he completed his habilitation at the Freie Universiät Berlin in 1981. Between 1986 – 1988, he held a position as visiting professor at the University of California in San Francisco, after which he returned to his home university as extraordinary professor and became full professor in 2000. During his research career, he dealt with many aspects of NMR spectroscopy and also popular science such as the chemistry behind licorice sweets, balloons, and *la fée verte*. Furthermore, he is interested in the Ig Nobel Prize, a scientific award similar to the "regular" Nobel Prize but somewhat more peculiar. In this interview, he gives an insight into this alternative award.

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JUnQ: Can you give us a brief history of the Nobel Prize?

Roth: The Swedish chemist and inventor Alfred Nobel established the awards in his last will. Each year a prize is given in the categories Physics, Chemistry, Physiology or Medicine, Literature, and Peace, to those "who, during the preceding year, have conferred the greatest benefit to mankind." The first Nobel prizes were awarded in 1901 to Röntgen in Physics, van't Hoff in Chemistry, and von Behring in Physiology or Medicine. The Nobel Prize is the most prestigious award available and is the secret dream of every scientist. By the way, it is also a lot of money, around one million Euros.

JUnQ: What is the Ig Noble Prize?

Roth: The Ig Nobel Prizes honor achievements that make people laugh and then think. The prizes are intended to honor a scientist's curiosity and to celebrate unusual and sometimes weird studies. In late September, in a gala ceremony in Harvard's Sanders Theatre, the new winners step forward to accept their prizes in front of more than 1000 excited spectators. Although the prizes come with no cash and the winners have to cover their travel expenses on their own, the prizes are physically handed out by bemused genuine Nobel Laureates.[1]

JUnQ: How did the Ig Noble Prize evolve?

Roth: The Ig Nobel Prize was created by people who also founded the Journal of Irreproducible Results. When the Journal's publisher decided to abandon the magazine, the staff decided to continue their work. Unable to use the old name, they started a new publication: Annals of Improbable Research. The editor and spiritus rector is Marc Abrahams and, since 1991, he and his team have been organizing the annual Ig Nobel Prize ceremony.

JUnQ: The selection of laureates for the "regular" Nobel Prize is somewhat mysterious. By whom and how are the Ig Nobel Prize laureates elected?

Roth: In contrast to the original Nobel Prize, nominations for the Ig prize can be made by anyone and even self-nominations are possible. Marc Abrahams and his team get about 9000 nominations per year. The new winners in 10 disciplines are then selected by a Board of Governors. The Board is composed of scientists (including several Ig Nobel Prize winners and several Nobel Prize winners), science writers, and other individuals of greater or lesser eminence.

JUnQ: In which journals has Ig Nobel Prize-honored research been published?

Roth: In all kinds of journals, from the most obscure to first class. For instance, the most recent winners of the Ig Nobel prize in chemistry published their awarded results in the prestigious European Journal of Chemical Biology, Synthetic Biology & Bionanotechnology (CHEMBIOCHEM). In a paper "Shear-Stress-Mediated Refolding of Proteins from Aggregates and Inclusion Bodies",[2] the researchers reported a method to refold boiled hen egg white lysozyme by applying shear stress in thin fluid films. Miraculously, the Board misinterpreted the study as a method to "partially un-boil an egg." Anyway, Greg Weiss's group attended the ceremony.

JUnQ: Are Ig Nobel laureates proud of their prize?

Roth: The best answer to this question is: it depends. The Anglo-Saxon sense of humor is not for everybody. Most winners have shown up and given a presentation speech. But in some cases, I think nobody really expected that winners would come. One example would be Yuri Struchkov, the director of the Institute of Organoelemental Compounds in Moscow. He was the winner of the 1992 Ig Nobel Prize in literature, for publishing 948 scientific papers between 1981 and 1990, averaging two papers per week over a decade. You would not expect that he would attend the ceremony. But again, proud winners do and they have a good time.

JUnQ: Does the Ig Nobel Prize ridicule science?

Roth: Not at all. I mean, scientists are normal humans and many of us have a good sense of humor. To make people laugh is not a sin. Good scientific work can be odd or funny, bad science, too. Let me give you an example. In 2013 a Japanese group won the Ig Nobel Prize in Chemistry for answering the question, why we cry when cutting fresh onions. This is fun but also good science. The Board of Governors never comment as to which prize-winning achievement might be deemed "good" or "bad" or "important" or "trivial". In that particular case, the science was excellent and the whole Japanese group attended the ceremony and brought with them a lot of onions.[3]

JUnQ: What is the procedure of the award show? Does the audience really throw paper planes at the laureate during the ceremony?

Roth: Oh yes! The audience throws paper planes throughout the whole event onto the stage. And the paper planes are thrown back from the stage by real Nobel laureates. During the prize ceremony Ig Nobel laureates are given only 60 seconds to explain what they did and why they did it. In addition, each year, some of the world's top thinkers are invited to give a so-called 24/7 lecture. The speaker has to explain his or her topic twice: First, a complete, technical description in 24 seconds and then, a clear summary that anyone can understand in 7 words. You should try this out with your own research.

JUnQ: The Ig Nobel Prize has been awarded since 1991. Why is the prize almost unknown in Europe?

Roth: It is not unknown in Europe. In 2016, there will be again an Ig Nobel Eurotour with Marc Abrahams and several Ig Nobel prize winners and they will have shows in Denmark, Sweden, and the UK. As I said before, it's all based on a special Anglo-Saxon humor. I mean not everybody, for instance, in Germany likes Monthy Python's "Life of Brian" with all those vulgar jokes and wicked, low down, and bitter humor.

JUnQ: Would you be proud to be nominated or even elected for the Ig Nobel Prize? Have you ever thought about doing research in that direction?

Roth: Yes, of course, and I would be very proud to receive such an honor. But my life is filled with many other things and time flies. But I must admit that I have a wonderful project in mind, which would fulfill all expectations of the Ig Nobel Prize, but I am keeping it a secret.

JUnQ: The list of Ig Nobel laureates[1] and of most modern Nobel Prize laureates[2] appears to have orientated in the applied sciences. This is in contrast to the Nobel Prizes 100 years ago, which focused on fundamental research. Can you give an explanation for that?

Roth: As far as I remember, Alfred Nobel declared in his last will that the prize should go to the person that made the most important 'discovery' or 'invention' within physics and to the person who made the most important chemical discovery or improvement. To be honest, I have difficulties to differentiate between scientific discovery, invention, or improvement. Look, the "discovery" or "invention" of Magnetic Resonance Imaging (MRI) was mainly developed by Paul Lauterbur, a chemist, and Peter Mansfield, a physicist. Both got the 2004 Nobel Prize in Physiology and Medicine! When they did their experiments, they had no clue that someday hundreds of millions of people would profit from this powerful diagnostic tool. Of course, neither Higg's prediction nor the recent experimental detection of the Higgs Particle has changed our daily life. But it is an intellectual step forward in our understanding of the world in which we live. Isn't that also a benefit to mankind?

JUnQ: How great is the importance of fundamental research today? Is there a limit of fundamentals in natural science?

Roth: Basic research is the *sine qua non* for any progress in the natural sciences, medicine, and all engineering disciplines. There are endless fundamentals. Only our limited fantasy defines the limits of our horizons.

JUnQ: Does basic science appear less important in order to solve social and technical problems like, e.g., energy saving or overpopulation?

Roth: No, no! It is true that we cannot solve social prob-

[1] 1991, Robert Klark Graham (biology): development of a seed bank just for Nobelists and Olympic athletes. 1991, Alan Kligerman (medicine): development of anti-gas liquids (Beano®) against flatulence. 2015, Bruno Grossi, Omar Larach, Mauricio Canals, Rodrigo A. Vasquez, and Jose Iriarte-Diaz (biology): chicken walk like dinosaurs if there is a heavy stick attached to their bottom.

[2] 1901, Jacobus Henricus van't Hoff (chemistry): discovery of the laws for chemical dynamics and osmotic pressure. 2014, Eric Bertig, Stefan Hell, William Moerner (chemistry): development of the STED microscope. 1901, Wilhelm Conrad Röntgen (physics): discovery of X-rays. 2014, Isamu Akasaki, Hiroshi Amano, Shuji Nakamura (physics): invention of blue-light emitting diodes for energy efficient light sources.

lems alone with technology. But again, technology based on fundamental research is an absolute requirement for solving social problems. Technology delivers the necessary tools. The Nobel Prize in Physics 2014 was given to three Japanese scientists, I. Akasaki, H. Amano, and S. Nakamura, who developed, in a mixture of fundamental and applied research, the blue LEDs based on the difficult-to-handle semiconductor gallium nitride. We see the corresponding products already in our supermarkets and can use them for saving energy. Overpopulation is a very complex subject. But natural sciences have already developed some tools, like contraceptive pills and other methods of birth control. These tools are neither perfect nor can they solve this problem alone. Religious, social, and ethical obstacles must be overcome. But this requires an agreement of many societies in various and very different cultural environments. Again, science cannot solve all our problems, but we cannot solve any problem without it.

JUnQ: Thank you very much for the interview!

—Tatjana Dänzer and Andreas Neidlinger

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Questions of the Week

The Journal of Unsolved Questions presents a "Question of the Week" on its homepage every week. Set up and formulated by the members of the editorial board, or guest writers, the main purpose of the "Question of the Week" consists in intriguing the reader by presenting topics of ongoing research. "Questions of the Week" published so far cover a wide variety of scientific fields, but share the feature to be of certain interest to several disciplines.
In the following, we present selected "Questions of the Week" from the last six months.

Can Contrails Really Influence the Climate?

by Soham Roy

Mainz sports an unusually busy sky given its close proximity to Frankfurt International Airport. And quite often, maybe even every few minutes during the day, one just has to look up and see airplanes zipping across. In their wake, these vehicles leave behind long and wispy trails. Trails, not unlike those, of boats against the turquoise of the ocean. But if one patiently keeps on watching, he/she will be able to make out these trails combining to form cirrus clouds.

These trails are the ejected exhaust crystallizing under a supercooled condition and forming ice. In other words, they are very aptly named as condensation trails or contrails for short. Subsequently, these clouds then act as a blanket and trap the heat radiating from the surface... an impromptu greenhouse effect...and just like a greenhouse they prevent the sun's rays from reaching the surface also.

Contrails: Benign or not?

A 1999 report by the IPCC revealed an inconvenient truth – a 15 percent increase in global warming within the next 5 decades from aircraft carbon emissions [1]. Several international think-tanks including NASA over the last fifteen years have tried to promote zero-emission flights but results have not been commercially viable for long-haul flights yet. Still it remains one of the big challenges going forward [2]. So one must really take stock and think about where are we flying to.

Fortunately, not all is lost just yet. Researchers, after meticulously combing through 20 years of flight data over the busy North Atlantic flight route, have shown from calculations that even a small detour for long haul flights of around 100 km can lead to something quite unexpected[3]. Their predictions indicate it would not only reduce the formation of serpentine mile long contrails which would trap more heat but also at no added cost to the environment compared to CO_2 emissions from the jets themselves.
So yes, we may have 10 year old statistics stating the obvious misuse of our carbon footprint[4] but hey, those ethereal formations may yet have a silver lining.

Read more:

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Can We Control the Weather?

by Nicola Reusch

White Christmas, open air events without rain or in agriculture – the weather is important in many aspects of our daily life. From time to time, we would like to change it. But can we specifically influence it? If we aim to control weather, we first have to understand the correlation between different weather phenomena. But, actually, weather forecasts only indicate a probability about how the weather will most likely be on the next day. These forecasts are based upon numerical simulations, because weather phenomena are the result of nonlinear dynamics. They cannot be described by analytic solutions, but rather have to be described by means of chaos theory.[1] The most prominent example is the so called "butterfly effect": A small change in the initial conditions (e.g. the flapping of a butterfly's wings) leads to a big difference in the outcome. In this case, the result is not a compulsory consequence – not to be mixed up with the snowball effect! But if forecasts are already difficult, can we succeed in controlling the weather? For example, lightning rods are a tool to influence the weather. It also seems possible that silver iodide can be used for cloud seeding and, therefore, to induce rain or suppress hail. But scientific evidence is still missing.[2,3] Several ideas to prevent hurricanes have been gathered in a documentary in 2007.[4] They include the removal of electrical charge by means of lasers or the cooling of the surface of the ocean with liquid nitrogen to deprive the heat energy of an oncoming hurricane. In spite of several interesting applications, we are far away from controlling the weather. Mostly, we neither understand the complete outcome of such interventions, nor can we calculate them quantitatively. The future will show whether we can specifically influence the weather some day with all its chaotic effects.

Read more:

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What Is the Origin of Homochirality?

by Nicola Reusch

Among the building blocks of life there are molecules that behave like mirror images to one another. They are called enantiomers, which means that the atoms are connected in the same way, but in three dimensions they have another arrangement – just as the right hand differs from the left hand. To distinguish between two of such so-called chiral molecules we add L- or D- to their names. Though many properties of two enantiomers are similar, in biological systems they can show a rather different behavior. One example is the odor of carvone: one enantiomer smells like spearmint while the other one smells like caraway.[1] Furthermore, in nature we almost only find L-amino acids whilst sugars appear in their D-form – a phenomenon we call homochirality.[2]

Despite intensive research on this topic, we still do not know why nature chose to favor the corresponding configuration. There are several hypotheses on the origin of homochirality. Some state that it is a result of necessity, others explain it on a "by chance"-basis. In each case, an initially small excess of one enantiomer could have been amplified until only the D- or the L-form dominated.

One possibility is that asymmetric photochemistry led to an enantiomer enrichment in space that meteorites could have brought down to earth. Currently, the Rosetta mission investigates the question on enantiomer excesses on comets.[2] In some cases also the crystallization conditions can lead to a symmetry breaking. Furthermore, there is a really small energy difference due to parity violation (calculated to be on the order of 10^{-12} – 10^{-15} J/mol) between two enantiomers and by now we cannot exclude that this also could be the origin of homochirality.[2,3]

Either way, to understand where homochirality stems from would also improve our knowledge of the origin of life itself.

Read more:

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Does Your Sleeping Posture Help to Prevent Alzheimer's Disease?

by Kristina Klinker

When you sleep, the brain subconsciously processes a lot of information gathered during the day. This is often reflected in the fact that we dream. But besides processing an overflow of information, the accumulation of cellular waste products in our brain is happening during sleep. A mis-accumulation of these metabolic by-products plays an important role in the development of neurodegenerative diseases. For example, the accumulation and aggregation of β-amyloid proteins is hypothesized to be one major cause for Alzheimer's disease. Generally, the body has developed its ways to eliminate toxic metabolic by-products from the system. In other parts of the body than the brain, our lymphatic system is responsible for waste removal. Since it would be fatal if any compound were able to freely diffuse between the brain and the rest of the body, the blood-brain-barrier prevents the unhindered exchange very effectively. As a consequence, it is plausible that there must be a separate "garbage truck" exclusively for the brain. This system has been identified by a group of researchers in 2013 and called the glymphatic pathway.[1] In very simple terms, regulated by an expansion and contraction of the brain's extracellular space during sleep, solutes between the incoming fluid, called the cerebrospinal fluid and the interstitial lymphatic fluid in our brain are exchanged. In this way, metabolic waste is drained from the brain. Interestingly, the same group of researchers found in a follow-up study in rats that body posture during sleep exhibits an effect on the clearance rate of metabolic waste.[2] Using different techniques including dynamic-contrast-enhanced magnetic resonance imaging (MRI) and fluorescence spectroscopy, the researchers concluded that waste removal was more efficient in the lateral position (laying on the side) compared to the prone (laying on the stomach) or supine position (laying on the back). These findings combined may first of all explain, why sleep is essential for our survival. Second, even if there may be no simple explanation why one body posture during sleep improves the glymphatic transport compared to others, this research certainly goes in the right direction concerning fully understanding the molecular causes for neurodegenerative diseases and, thus, maybe finding a way to prevent Alzheimer's disease.

Read more:

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Do Germ Line Stem Cells Exist or is the Number of Eggs in Women Limited?

by Felix Spenkuch

Almost one year ago Facebook and Apple announced that they will cover the cost of egg freezing for their female employees.[1] Egg freezing is seen as a way to improve the success of a potential future in-vitro fertilization (IVF) procedure by using an egg that is years, even decades, younger than the mother. However, this approach is based on a not yet solid assumption: That a woman's eggs are produced during fetal development and, as direct consequence, gain in age (and loose in fertility) with the woman that carries them.[2,3] The age of first-time parents is rising in our time, which entails growth of the IVF industry that seeks to ensure fertility of women who are rather at the end of their reproductive age.[4] What if IVF could be circumvented by letting the body generate new eggs? This process would require appropriate stem cells that are able to divide. Whether such cells exist is still a matter of debate. In 2005 the group of Jonathan L. Tilly identified bone marrow transplantation as source for stem cells that restore fertility in sterilized mice.[5] The same group claimed to have identified actively dividing germ cells in the ovaries of reproductive age women, that were capable to develop into eggs.[6] The hoped-for natural substitute of IVF seemed found at last, but was soon challenged by Zhang et al., who could disprove the existence of dividing stem cell precursors in mice.[7] In fact another paper confirmed that mouse oogenesis originates from cells that are already formed at birth.[8] Thus the debate remains open, with some scientists claiming that "absence of evidence is not evidence of absence".[9] Current evidence arguing for or against non-renewable ovary stores in mammals is reviewed in.[10]

Read more:

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How Deep Can One Dig?

by Andreas Neidlinger

I am sure you all spent some time at the beach when you were a kid. And I am also sure that your started digging holes in the sand when you were there. Or maybe you did something like that in your backyard. Anyhow, have you ever wondered how deep you would be able to dig? If you maybe could dig through the whole world? And if yes, why hasn't anyone done this, yet? Russian scientists tried this out for real between 1970 and 1994. They dug a hole, the Kola Superdeep Borehole, which got 12.2 km deep in the end.[1] Only being about one third of the thickness of the earth's mantle, this is even deeper than the deepest point on earth, the Mariana Trench southeast of Japan, which is "only" 11.0 km deep. So why did they stop, when they already bested the Mariana Trench? Well, it just became too hot. The temperature in these depths is around 180 °C and this was obviously too much for the drilling equipment. So they just sealed up the hole and left it. Is the story over here? No! Just recently the so called 2012 MoHole to the

Mantle Project was started. It supposedly costs about one billion dollars. They adventurous plan: starting to dig at the bottom of the Mariana Trench, so the mantle to dig through would be thinner already in the beginning.[2] There weren't any news after 2012. So, if the project was stopped, I cannot tell, but maybe the diggers just need to collect some courage (and more money).

Read more:

[1] http://www.iflscience.com/environment/deepest-hole-world (last access on 23.08.2015)

[2] http://science.howstuffworks.com/environmental/earth/geophysics/dig-hole-to-earths-mantle.htm (last access on 23.08.2015)

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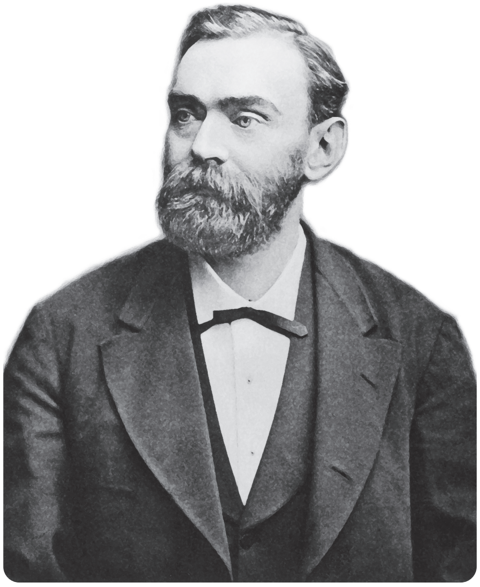

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