EVONIK
POWER TO CREATE

ELEMENTS

Research. Knowledge. The future.

On the Trail of Nature

3/2018

Skin Cream

A basic recipe

Skin creams are basically composed of a combination of water and oil that provides the skin with moisture and regenerates its natural film of fat. An emulsifier is needed so that the two main ingredients can combine in the first place. The molecules of the emulsifier each have a hydrophilic part and a lipophilic part, which bind with the water and the oil respectively. Stabilizers such as xanthan gum ensure that the water and the oil remain inseparable over time. For a long shelf life, the cream also requires preserving agents such as specific alcohols that prevent microbial attack.

Emulsifier: An excipient that enables the formation of an emulsion of liquids that would normally be immiscible
Lipophilic: Having a strong affinity for fats
Hydrophilic: Having a strong affinity for water
Xanthan gum: A naturally occurring carbohydrate that is also used in the food industry

→ More about cosmetics starting on page 10

DEAR READERS,

What does your sun cream actually consist of? Why does your shampoo smell like coconuts? And do you know what makes your skin cream so smooth and white? More and more cosmetics customers are asking questions like these. They are no longer satisfied with the fact that their products are sweet-smelling and effective. They want to know exactly what ingredients they contain. And they know exactly which ingredients they don't want. This is creating huge challenges for the producers of these products—and also huge opportunities. That's because the demand for cosmetics that are as natural, sustainably produced, and healthy as possible is constantly growing. In Germany alone, sales of cosmetic products have doubled in the past decade from €600 million to €1.2 billion. As a supplier of specialty ingredients, Evonik is benefiting from this trend—and its researchers are sparing no effort to unlock the deepest secrets of our skin. For this issue, we visited these researchers at their labs from Marl to Berlin and from Hamburg to the Cosmetic Valley in France.

But research at Evonik also goes under the skin: Transporting medical active ingredients through the body and ensuring that they develop their maximum effectiveness exactly where they should is a very exacting science. Scientists have been working for 120 years to develop optimal chemical transport mechanisms for drugs. Nanotechnology is now opening up new opportunities. The researchers' dream sounds fantastic: They would like to use targeted processes to kill cancer cells early on with molecular precision.

This fall Evonik will have an important anniversary to celebrate: Creavis, our unit for strategic innovation, will be 20 years old. In an interview, Professor Stefan Buchholz, the Managing Director of Creavis, explained to us how new ideas originate at his unit and are developed into successful businesses. We also took this anniversary as an opportunity to ask Professor Wendelin Stark from the University of Zürich to share with us his views about the future of innovation. Stark, a researcher at the Institute for Chemical and Bioengineering, has a provocative and radical thesis: Upheavals such as those that have occurred in the music and media sectors could also turn the chemical industry, which has been so stable to date, upside down. The dinosaur companies are dying out, and the future belongs to agile startups and creative spinoffs! Are we now experiencing the beginning of the end?

Evonik's magazine ELEMENTS is published in German and English, in a print version and digitally on the Internet. If you would like to continue reading ELEMENTS, you can order a subscription free of charge at https://elements.evonik.com. I wish you pleasant and instructive reading, and I look forward to receiving your suggestions and comments at: elements@evonik.com

Matthias Ruch
Editor in Chief of ELEMENTS

COVER STORY: COSMETICS

PHARMACEUTICALS

INNOVATION

ELEMENTARY

PEOPLE AND VISIONS

In order to get things moving, we need people with good ideas. Because they already know today where we should be heading in the future

TEXT **NICOLAS GARZ**

1

JULIA DANCKWERTH is a 32-year-old designer who is helping to improve the quality of life for people with dementia. She has developed "spur," a system of tiny sensors that are attached inside pieces of clothing. Thanks to these digital helpers, people with dementia can be located at any time by relatives or caregivers by means of an app or a receiving device. In addition, the sensors automatically sound an alarm if the person falls down or has gotten lost. It's an innovation that relieves many fears and anxieties

"I Wanted to Exploit the Potential of Technology for a Good Cause"

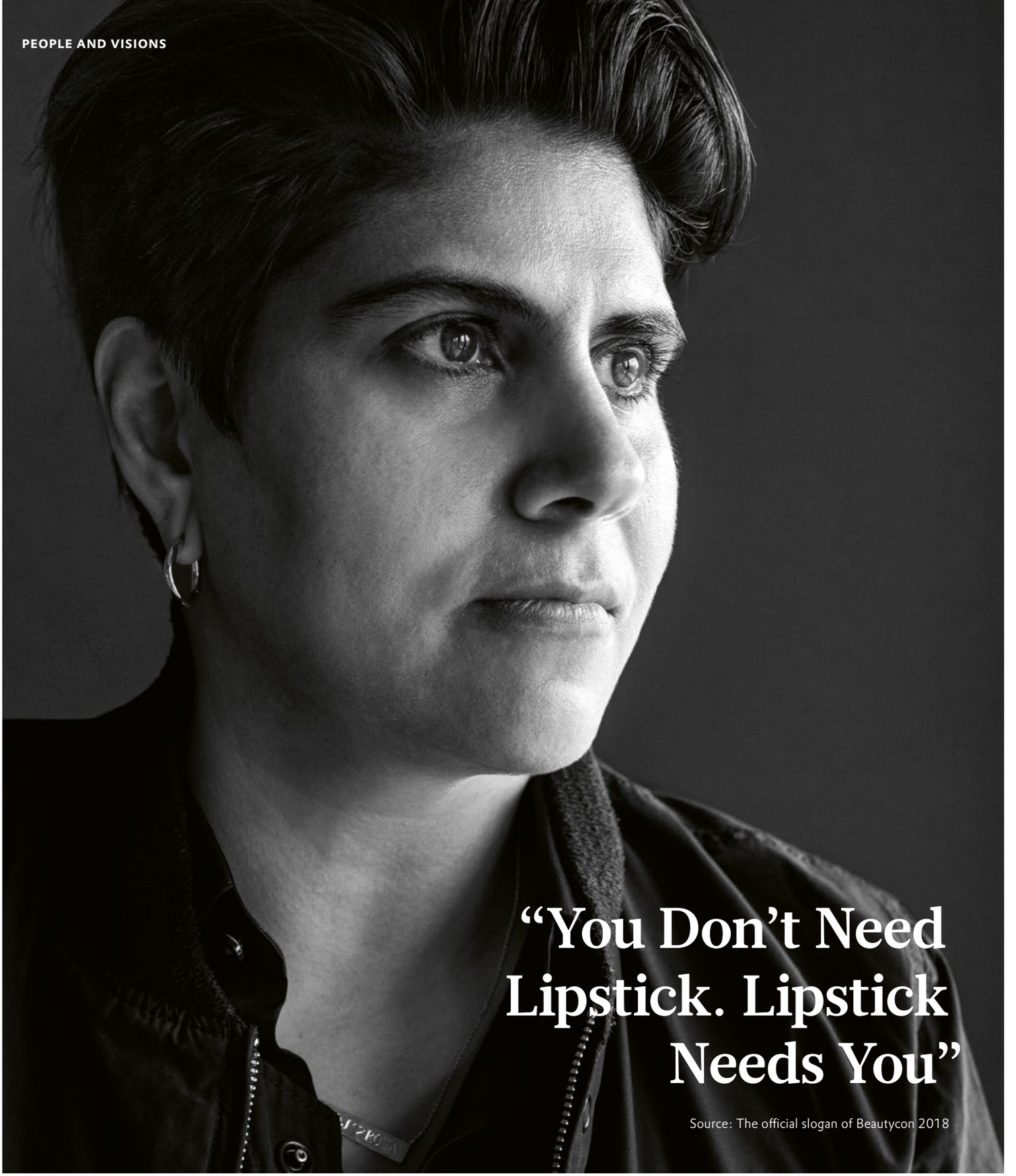
Source: Julia Danckwerth

“A Failure is Temporary. Giving Up Is Permanent”

Source: Kiran Mazumdar-Shaw on CNN.com

2

KIRAN MAZUMDAR-SHAW actually wanted to become a master brewer, but she couldn’t find a job. Instead, she founded her own company, Biocon India, in 1978, when she was 25 years old. It was located in her garage, with starting capital of US$250. In the decades since then, it has developed into India’s biggest biotechnology group—and Mazumdar-Shaw has become the country’s richest woman. The “Biotech Queen” is fighting the civilization diseases of our time. Her company is a pioneer in the development of drugs for treating cancer and diabetes. Mazumdar-Shaw, who is now 65, is also an advocate for poor people’s improved access to medicine. Looking back, it’s a stroke of luck that she had to swear off beer



“You Don’t Need Lipstick. Lipstick Needs You”

Source: The official slogan of Beautycon 2018

MOJ MAHDARA reinvented the US beauty trade fair Beautycon four years ago. When she took it over as its CEO, it was an exclusive event for YouTubers. Mahdara transformed it into a mass event and a platform for the latest trends. This year it attracted visitors with ads promoting the self-confident use of lipstick. “Out there is a new generation of talented young people who are completely redefining what we perceive as beautiful,” says Mahdara, an American with Iranian roots. Under her leadership, Beautycon is reversing relationships: Big companies used to launch beauty trends through their campaigns—but now they are tracing these trends to Mahdara’s trade fair

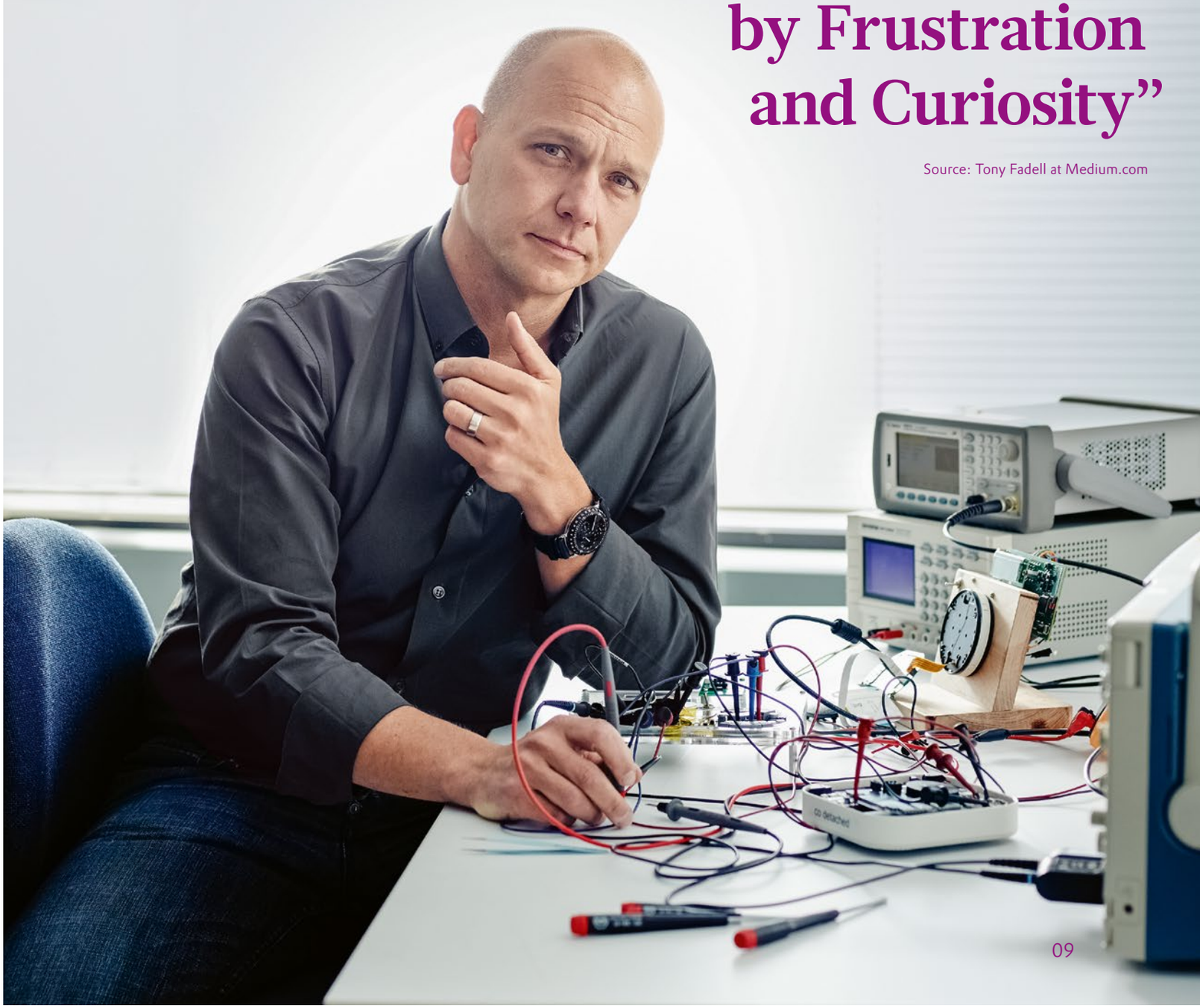
3

4

TONY FADELL is a Gyro Gearloose of the digital age. He's a US computer engineer who is known as the "father of the iPod" and was also one of the developers of the iPhone. After departing from Apple, he developed smart room thermostats at his own company, Nest, which he sold to Google a few years ago. Today Fadell, who is now 49, criticizes some of the spirits he has conjured up. He recently expressed his concern about smartphone addiction—a warning that may show he's still ahead of his time

"Inventions Are Spurred by Frustration and Curiosity"

Source: Tony Fadell at Medium.com



THE FUTURE OF COSMETICS

At Evonik Advanced Botanicals in Tours, ginseng seedlings are cultivated as suppliers of natural active ingredients

Tomorrow's Beauty Care

The cosmetics industry is once again reinventing itself. Its business is becoming more natural, more personal, and more digital. And this transformation is going deeper than ever before

TEXT **TOM RADEMACHER**

JAPAN is the biggest single market for cosmetics and body care products that remain on the skin or in the hair. Japanese consumers are especially discriminating and safety-conscious. Locally made products with high-tech active ingredients are especially popular.

It's a success story that began in a boiler room. In the early 1980s, Dr. Udo Straetmans, a chemist and enthusiastic inventor, was searching for ways to keep unwanted bacteria, fungi, and yeasts in check using natural substances. Accordingly, he was testing things that spoil and decay—as well as antidotes to these processes. He did this research in his basement, because the boiler room's cozy warmth was an ideal habitat for microbes. Ten years later, his initial attempts had become marketable products. Companies from the budding natural cosmetics sector flooded him with orders. Today, almost three decades later, the demand for Dr. Straetmans' alternative preserving agents is greater than ever. Natural cosmetics are currently a global megatrend. The worldwide market is expected to reach US$22 billion by 2024—thus doubling within eight years.

A CRITICAL LOOK AT THE INGREDIENTS

Dr. Jan Jänichen has often told the story of Dr. Straetmans. He's a nephew of the founder of Dr. Straetmans GmbH, and he and a fellow student joined the company in 2002. In 2005 the two of them became its Managing Directors. There's a family atmosphere at the company's small headquarters on the outskirts of Hamburg. Jänichen's sister-in-law is in charge of marketing, and the laboratory is headed by his former intern from the university. But the company has been operating globally for a long time, and nowadays the two Managing Directors travel frequently. Evonik acquired Dr. Straetmans GmbH last year. The new parent company—from Essen to Shanghai—is now adapting all of its key cosmetic formulations to preserving agents from Straetmans.

"Our customers don't just have definite ideas about what they need—they also know exactly which things they don't want," says Jänichen. And that list keeps getting longer. It includes parabens, aluminum, palm oil derivatives, and genetically modified plants. Critical consumers nowadays scrutinize the INCI lists on the backs of cosmetics bottles, tubes, and jars and even use

BRAZIL More rinse-off products—that is, products used in the shower or the bath—are sold here than in any other country. Long, well-groomed hair is an important component of ideal beauty. The average Brazilian woman showers more than once a day. A tropical climate and curly hair structures require special care products.

"Our customers know exactly which things they don't want"

DR. JAN JÄNICHEN, MANAGING DIRECTOR DR. STRAETMANS

USA US consumers appreciate technological innovations—and large package sizes. The USA is one of the makeup markets with the highest levels of market penetration. Organic cosmetic products are becoming increasingly popular, with market researchers predicting annual growth rates of six percent until 2020.

special apps to find out whether their cosmetics contain undesirable ingredients. INCI stands for "International Nomenclature of Cosmetic Ingredients." This labeling of ingredients has been mandatory in the EU for over 20 years. "The cosmetics sector is much more transparent in this regard than the textile sector, for example," says Dr. Tammo Boinowitz, who heads the Personal Care business line at Evonik.

NEW CHALLENGES REGARDING SUSTAINABILITY

The Personal Care innovation center for cosmetics in Essen is the biggest of the seven cosmetics labs operated by this business line around the world. Here specialists develop and test new raw materials and active ingredients for the beauty sector in order to satisfy increasingly strict standards, organic certification requirements, and customer tastes. There is increasing demand for natural preserving agents, skin-like substances, and plant-based active ingredients.

The industry giant L'Oréal has introduced its own "Naturalness Index." "We use it to measure raw materials' naturalness and sustainability," explains Sylvie Fonteneau, who is responsible for monitoring which raw materials are authorized in-house at the company, which is the world's biggest cosmetics producer. "When I started working in this sector, performance was just about the only criterion," she adds. "Today we want to know exactly where the raw material comes from, how it was produced, and how it was processed." That's a tall order, especially for small suppliers. "We support our suppliers in this effort, but L'Oréal has set itself the goal of selling only products that have an environmental or social value by 2020. And as the sector's biggest buyer, we are of course pushing the raw materials market in this direction," she says.

Evonik has been producing ingredients for cosmetics and personal care products for over 90 years. Between the two World Wars, it was already providing the emulsifier TEGIN for Nivea Creme, and it still does so today. Over the years, Evonik's product range has grown—to begin with in the area of "functionals." These are raw materials that give lotions, shampoos, and other cosmetics their basic qualities. They emulsify, stabilize, conserve, cleanse, and provide the desired texture and the right skin sensation. Global cosmetics producers use "chassis formulations" for multiple products that they sell all over the world. Replacing a "chassis formulation" ingredient that has received a →

CHINA The affluent middle class prefers foreign labels and has little trust in Chinese products. Chinese customers buy their supplies of cosmetics when over seas and online. Temporary limits placed on travel because of political reasons therefore have immediate effects on the sales figures of local producers.

critical review with an alternative that fulfills the new demands for naturalness and sustainability is not an easy task—but it's worth doing. Evonik recently received an award at the cosmetics trade fair in-cosmetics Global for a new development in this segment: RHEANCE One, a cleansing substance for the skin and hair from the class of glycolipids. It's manufactured from sugar through a fermentation process and thus contains no tropical oils.

In addition to functionals, Evonik is increasingly producing active ingredients, called "actives" for short. "There's an especially big demand for natural and skin-related substances such as ceramides, peptides, amino acids, sphingolipids, and hyaluronic acid, which can have a direct influence on microbiological processes in the skin," says Boinowitz. Two years ago, Evonik acquired the French startup Alkion Biopharma SAS in order to expand its business with plant-based active ingredients. This subsidiary, which has been renamed Evonik Advanced Botanicals, cultivates plants that produce active ingredients in the form of herbal biomass under laboratory conditions. In this way it produces extracts in especially high concentrations and without seasonal fluctuations in terms of availability or active ingredient content (see the report starting on page 18).

BACTERIA FOR HEALTHY SKIN

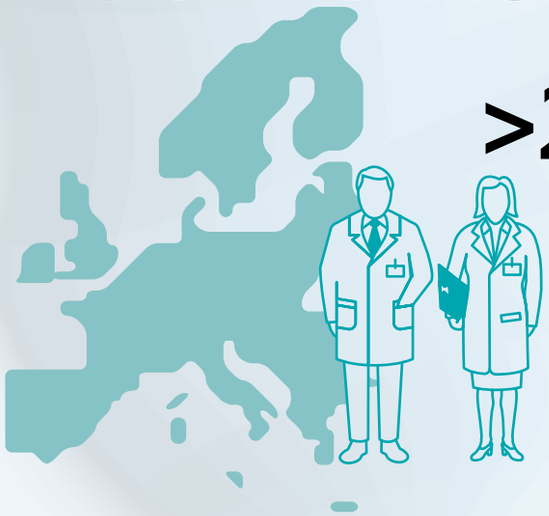
One new trend in the cosmetics industry is a focus on the skin's natural microbiome. "Right now we're learning how this interplay between good and bad bacteria on our skin influences the skin's health," Boinowitz explains. Evonik recently launched its first microbiotic skincare product, Skinolance, on the market. Established manufacturers such as Beiersdorf AG and the US pharmaceuticals and consumer goods company Johnson & Johnson are also keeping an eye on these new developments. Both of them have bought shares in S-Biomedics, a startup that was founded in Magdeburg, Germany in 2015 and has developed a product that combats acne by influencing the microbiome.

But the most important trend today has nothing to do with active ingredients or skin cells: Digitalization is causing far-reaching upheavals. "Things have changed more in the past three years than they did in the previous 50," concluded L'Oreal CEO Jean-Paul Agon in a recent interview published by the newspaper *Handelsblatt*. "Thanks to the Internet, small brands are popping up like mushrooms. In the digital world it's easier to create a small brand. As a result, there's a lot more variety in the sector today." In addition, there are online influencers who in some cases have millions of followers on Instagram or Twitter and set their own trends—and manufacturers have to react to these trends. "It's a big help if our suppliers can already pull the data about an active ingredient that is suddenly in demand, or even a finished formulation, out of their files," says Dr. Harald Büttner, Head of Technology Scouting at Beiersdorf. →

SWEDEN The Scandinavian countries spend the most for cosmetics per capita in comparison with other European countries. Swedes and other northern Europeans are willing to pay higher prices for top quality. Cosmetics manufacturers from Sweden, Denmark, and Finland are pioneers in the use of natural ingredients.

Unadorned Facts

In recent years the business operations of beauty and care product manufacturers have been largely impervious to crises. And the end of this period of growth is not yet in sight. The experts predict worldwide growth in sales, from more than €440 billion last year to approximately €670 billion by 2023



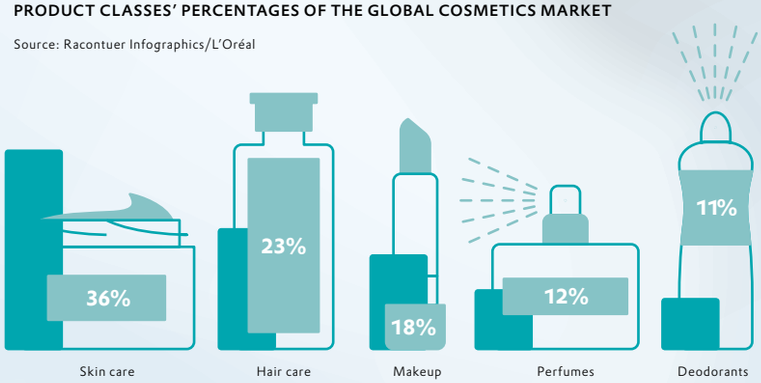
>27,900

NUMBER OF SCIENTISTS IN THE EUROPEAN COSMETICS SECTOR

Source: Cosmetics Europe

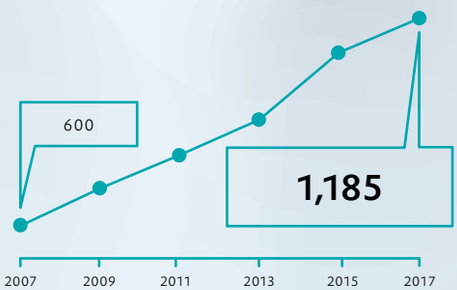
PRODUCT CLASSES' PERCENTAGES OF THE GLOBAL COSMETICS MARKET

Source: Racontuer Infographics/L'Oréal



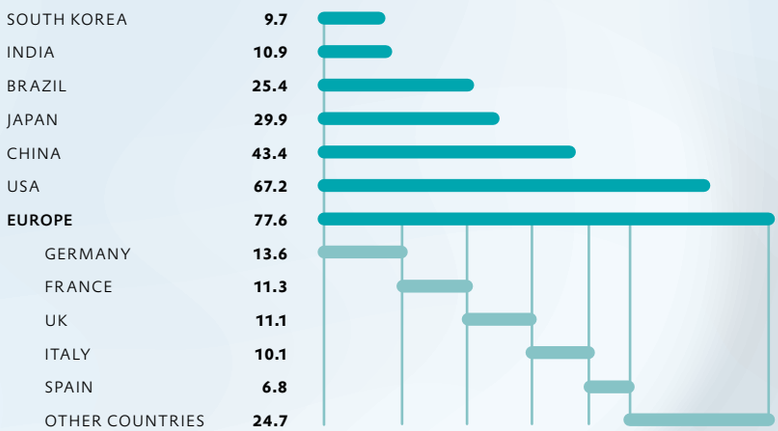
SALES OF NATURAL COSMETICS IN GERMANY (IN MILLIONS OF EURO)

Source: Statista



THE GLOBAL MARKET FOR COSMETIC PRODUCTS (SALES IN BILLION EUROS)

Source: Cosmetics Europe



2.35

BILLION EUROS ARE SPENT BY EUROPE'S COSMETICS SECTOR ON RESEARCH AND DEVELOPMENT (2017)

Source: Cosmetics Europe

WHAT CUSTOMERS LOOK FOR WHEN THEY BUY COSMETICS AND CARE PRODUCTS

Results of a survey of online shoppers in Germany, France, and the UK Source: A.T. Kearny

FRANCE is the second-largest cosmetics market in Europe, after Germany. It's the home of leading manufacturers of perfume and makeup. Frenchwomen use less than half as many makeup products per capita than British women, for example. However, anti-aging creams are especially popular in France.

IRAN is an important cosmetics market—as long as sanctions do not impede business operations. Women in Iran set great store by cosmetics, using extremely striking eye makeup—and prefer very high-quality care products.

The good news is that social media is boosting the cosmetics business. For example, about 1.5 billion tubes of lipstick were sold in 2017—an increase of 13.6 percent compared to the previous year. This was partly due to the fact that young consumers today want to be "selfie-ready" at all times and use makeup accordingly. Striking looks, with luscious lips and strong contours, are popular. A flood of makeup tutorials on YouTube shows how it's done.

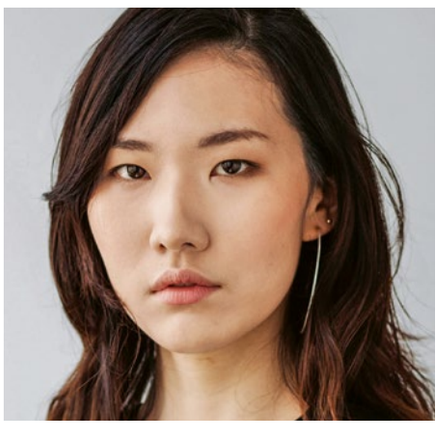
TRYING OUT MAKEUP PRODUCTS VIRTUALLY

In the digital world, services and data are growing in importance. L'Oreal recently bought Modiface, a Canadian tech startup that enables customers to use augmented-reality software to try out different makeup products virtually. The software runs as an app on smartphones, but can also be used for interactive mirrors in a customer's own bathroom or in a boutique. "We acquired Modiface because we are absolutely convinced that services represent the future of the beauty sector," said L'Oréal's Chief Digital Officer, Lubomira Rochet, to the business magazine *Forbes* concerning the acquisition.

Modern sensors are driving another trend: individualized care for every skin type and every lifestyle. At the beginning of 2018 L'Oreal launched a small UV sensor that can be glued onto a fingernail and wirelessly sends data to the wearer's smartphone. Evonik is literally going even deeper. It has invested in a startup called mySkin based in New Jersey, USA, which has developed the mobile terminal OKU. This is a handy cube that uses an optical sensor to analyze the user's skin in depth. A smart app uses this data to create individualized tips about care, nutrition, and lifestyle. On the basis of constantly updated user data, OKU contin-

"We are absolutely convinced that services represent the future of the beauty sector"

LUBOMIRA ROCHET, CHIEF DIGITAL OFFICER L'OREAL



KOREA is nowadays influencing global trends almost as strongly as France. "K-Beauty" has become an umbrella term for innovative products and elaborate beauty rituals from Korea. The Korean ideal of beauty is light-colored skin that resembles porcelain.

uously learns—and so does Evonik. "We're learning what works, and for whom it works," Boinowitz explains. "As a result, in the future we could also distribute test products to OKU customers and conduct large-scale studies of their effects. So far, even the biggest cosmetics producers have seldom been able to conduct such studies."

CARE PRODUCTS FROM THE FOOD PROCESSOR

Both digitalization and natural trends are being influenced by beauty product customers' desire for greater personal control. Customers want to know what's inside the products they buy. Minimalistic formulations with only between five and ten natural ingredients are popular, and there's a flourishing do-it-yourself scene in which the popular Thermomix food processor is used to create the user's own care products. The startup The Function of Beauty enables customers to concoct shampoos and conditioners according to their own preferences. The Experimental Perfume Club is an open-access perfume laboratory in London that can turn anyone into a fragrance designer.

"It's all about creating the equivalent of Nespresso for the perfume industry. We think this is a really hot trend," says L'Oreal CDO Rochet. In a few years, it may be a matter of course for cosmetics consumers to create their own care products at home at the push of a button—just like an espresso from an aluminum capsule. A skin sensor will provide them with the necessary data. L'Oreal, Beiersdorf, and similar companies will offer the microbiological know-how as a digital service. And Evonik will provide the sustainable natural raw materials. —

"We can't have all the ideas ourselves"

Dr. Harald Büttner, Head of Technology Scouting at Beiersdorf AG, depends on open innovation. That enables his company to build on its suppliers' know-how and learn from other sectors—such as the construction industry

Mr. Büttner, what was the last place where you looked for new ideas?
I've just come back from a congress and trade fair in Japan that focused on fermentative production processes and the related raw materials and products. The Japanese and the Koreans are traditionally strong in this area, and I'm convinced that it will become important for our sector.

How important is open innovation for Beiersdorf, and why?
We can't have all the ideas ourselves. It's extremely worthwhile to screen technologies from a very wide spectrum—including companies outside the cosmetics sector.

Can you give us an example?
Think about the problem of finding substitutes for aluminum in anti-perspirants. The main question is how we can block the sweat glands. It might be useful to examine how other sectors deal with fine pores and capillaries. For example, what are construction companies and paint producers doing in this area? Can we learn anything from them?

What are you looking for via your open innovation platform Trusted Network?
We are turning to our registered partners with very specific questions. These partners include universities and research institutes, as well as individuals and our suppliers. But Trusted Network is only one of the many channels we use.

Is this a new phenomenon in the sector?
Today almost all of our competitors are doing that in various ways. However, our sector as a whole has been slower on the uptake than other sectors. For a long time, it was dominated by a certain degree of secretiveness, because our know-how is extremely valuable and the entry barriers are relatively low.

What key factors are needed for open innovation to work?
You need absolutely trusting cooperation. We've had that kind of cooperation with Evonik for decades.

Don't you have any worries about suppliers gathering more and more know-how about your business operations?
No. After all, we benefit from the fact that suppliers come to us with market-ready ideas to which we can apply our own know-how. That's how differentiation and new product attributes are generated for our customers. And of course we have our world-renowned brand portfolio, with Nivea in the forefront. —

PROTECTING THE SKIN

New active ingredients in cosmetics protect the skin from increasing environmental pollution. They boost the body's own detoxification processes and bring the skin flora into balance

TEXT **BERND KALTWASSER**

Human skin is really a high-performance organ. It keeps our bodies from drying out and losing essential minerals. Despite the skin's minuscule thickness of only a few millimeters, if it is healthy it also reliably prevents dirt and microbes from penetrating the body. In the summer, the skin is often exposed to intense UV radiation, in addition to the environmental impacts to which it is subjected all year round. It is also subject to stressors such as particulates, diesel soot, and the acid rain that still falls in some regions of the world.

These external pressures are still growing. That's why it's becoming increasingly important to preserve the skin's ability to function by giving it targeted and effective care. "In recent years the cosmetics sector has expanded its focus and worked harder to develop new active ingredients," says Professor Jean Krutmann from the Leibniz Research Institute for Environmental Medicine in Düsseldorf. "The goal is to protect the skin and help it if it has been thrown out of balance by environmental impacts."

NEW APPROACHES TO PROTECTING SKIN CELLS

Krutmann is one of Germany's leading experts when it comes to deciphering the complex interactions between biological processes in the skin and external stress factors. He was one of the first re-

searchers to successfully demonstrate, through epidemiological and mechanistic studies, that there is a causal link between fine particulate pollution and skin aging. In order to understand these connections even better, Krutmann, a licensed physician, has been supervising large-scale national and international cohort studies since 2012. Some of these studies are working with volunteers from the Ruhr region of Germany, the heavily polluted Taizhou region of China, and New Delhi, India, the city with the dirtiest air in the world.

"By now we've been able to demonstrate that between 70 and 80 percent of all skin changes are due to external influences. Only between 20 and 30 percent are caused by inevitable genetically caused aging processes. The most important environmental factor driving the skin aging process is air pollution, next to natural ultraviolet radiation," Krutmann recently reported at the Evonik Meets Science conference. At this regularly held science forum, experts from Evonik discuss ideas with renowned German researchers concerning a variety of innovation-related themes. More than 250 participants gathered in Berlin for the most recent meeting, which was held in September.

In past years, Evonik has discovered a range of new approaches to protecting skin cells against premature skin aging due to environmental stress. "We offer a wide range of cosmetic active ingredients with scientifically proven effectiveness," says Peter Lersch, Head of Global Innovation Management Personal Care at Evonik's Nutrition & Care segment.

One important starting point is the external layer of the skin. Its structure, which is similar to that of a brick wall, consists of dead horn cells that use lipid bilayers with a complex structure as a binder to form a highly effective barrier. If this structure is destroyed, the skin dries out and becomes rougher and more cracked, thus becoming more vulnerable to penetration by harmful substances. "Skin-identical, synergistic sphingolipid mixtures can balance out defects in the membranes, strengthen the skin's defenses, improve its moisture levels, and thus bring the skin barrier back into balance quickly and lastingly," says Lersch. His business line already developed such products a few years ago.

Even if the skin is already irritated, cosmetic ingredients can help to provide effective relief. "We know that aryl hydrocarbon receptors inside the skin cells react to diesel soot," explains Krutmann. These AH receptors are basically present in an inactive form. But if they are activated by soot particles, for example, they drift into the nucleus of the cell, where they launch a program that can contribute to skin aging.

SKIN CARE COSMETICS BOOST THE BODY'S OWN DETOXIFICATION

Skin care cosmetics can counter this aging effect, either by neutralizing the metabolic pathways that have been activated by soot particles or by stimulating the body's own detoxification processes so that the environmental stress is reduced. Free radicals are highly reactive oxygen molecules. If they are present in large numbers, they cause damage to cells and tissue that the body cannot readily repair on its own. Natural scavengers of free radicals in the skin, such as thioredoxin, dock onto these oxygen molecules, making them less reactive and thus harmless. TEGO Turmerone is a natural substance that is extracted from turmeric. As a cosmetic ingredient, it activates the thioredoxin signal cascade and thus promotes the formation of the skin's own scavengers of free radicals.

> **"The skin's microbiome has a decisive influence on health"**
>
> JEAN KRUTMANN, LEIBNIZ RESEARCH INSTITUTE FOR ENVIRONMENTAL MEDICINE

SKIN MODELS FOR ACTIVE INGREDIENT RESEARCH

For quite a while now, dermatological research has focused increasingly on the natural colonies of microorganisms in the skin. "Today we know that a balanced composition of the skin's microbiome has a decisive influence on health and well-being," says Krutmann. Whereas healthy skin has a great variety of microorganisms, in pathological skin conditions the diversity of the microbiome often decreases. In order to reinforce the natural balance of the skin flora, the researchers at Evonik have developed a special microbiotic product called Skinolance. This cell-free extract of *Lactobacillus brevis* lactic acid bacteria stimulates the growth of other desirable bacteria called *Staphylococcus epidermidis*. This has a positive effect on the skin's barrier function, inhibits inflammation, and thus prevents the skin from becoming rough and drying out. These effects on the skin flora and the skin's appearance have been demonstrated by a clinical study.

Skinolance is thus the most recent example of Evonik researchers' intention to provide scientific proof of the effectiveness of the company's own cosmetic ingredients. "This is why we are also participating in the new Tissue Engineering Project House in Singapore," says Lersch. In the Project Houses of the strategic innovation unit Creavis, researchers work on innovation projects that are relevant to the company as a whole. The projects in Singapore will include the development of new skin models that will be used, for example, to screen new ingredients for cosmetics in order to assess the possible effects of potential active ingredients. "The influence of ethnic factors on the biological mechanisms of skin changes is another extremely interesting area that we also want to investigate in Singapore," says Lersch. So far there have been a number of interesting approaches, but on the whole we still understand far too little about possible differences. So this is exactly the right time for Evonik to tackle this theme together with partners doing scientific research.

GREEN FORCE

TEXT **JOHANNES GIESLER** PHOTOGRAPHY **JANN KLEE**

In Tours, France, Franck Michoux creates customized active ingredients for cosmetics by subjecting plants to brutal levels of stress. Time is of the essence: The first product must be launched on the market in November

Not a refuge for romantics: In an industrial zone on the outskirts of Tours, Franck Michoux and his team cultivate especially high-powered plants

Plants can't run away. They have to face their enemies and adapt their survival strategy as needed. If temperatures sink, some flowers flood their cells with a natural antifreeze agent. Other plants pump poison into their extremities when insects nibble on them or a fungus infests them. Evolution has equipped plants with these tools for successfully repelling attacks. Provoking the use of this arsenal and harnessing it for the benefit of human beings is the daily work of Franck Michoux, a 38-year-old entrepreneur with a doctorate in plant biology, and his team. "Plants are constantly under threat, whether it's from heat, cold, predators or parasites," he says. "For them it's a matter of life and death to produce a life-saving substance in the nick of time."

Some of these substances do more than just protect plants—they are also active ingredients in cosmetic products. Michoux and his colleagues have specialized in the production of these substances. His seven-person team cultivates plants that are unusually robust. To achieve this, they do not change the plants' genetic material. Instead, they alter the conditions under which the plants are cultivated.

Years of research have gone into this technology. The results of their work are very pure, highly concentrated, and natural active ingredients whose production requires significantly less water and less land. From the plants growing on one square meter in his lab, Michoux extracts the same amount of active ingredient as a conventional grower cultivating 400 square meters.

BETWEEN THE BEAUTY GIANTS IN "COSMETIC VALLEY"

Tours lies in the midst of the picturesque Loire Valley. It's a quiet university town that is surrounded by lush vineyards and is renowned for its churches and cloisters. Few tourists wander into the nondescript industrial zone north of the town limits, where Michoux and his team have established their research center. It's a massive two-story laboratory with a dozen parking spaces in front. On the right is a noisy air conditioner, on the left a sun-dried yellow lawn. This is not a refuge for romantics, but it's a mecca for the cosmetics industry. All of the giants in the beauty industry have production facilities in this region, which is popularly known as "Cosmetic Valley." So it's the perfect spot for Michoux. He founded his company, Alkion Biopharma, at a site near Paris in 2011. He had big plans, looked for a strong partner, and found Evonik. In 2016, after the company was acquired by Evonik, he moved it here.

Early this morning, the sun is already hot as Michoux opens the building's security doors. Today he's going to take us through operations at an accelerated pace: from the initial idea through years of research to the first market launch of an own product. "The next few weeks will be incredibly important. We've worked for years to reach this point," he says. The countdown has begun: In November the company will present its first own active ingredient, Neoplanta® Withania, in distant Bangkok. Its name is derived from the plant *Withania somnifera*, which is currently the center of attention at the lab. Practitioners of Ayurveda call it *ashwagandha*, and it's popularly known as Indian ginseng or winter cherry.

Michoux is standing in his laboratory and looking at metal racks full of rows of containers that represent the challenges to which he exposes his plants. There is an incubator with desert-like temperatures up to 40 °C. Next to it, green seedlings are being cooled off to 7 °C. An apparatus on the floor is swinging back and forth. Attached to it are six glass flasks in which a yellowish liquid sloshes around. The plants in the liquid are growing under the conditions created by rising water levels. In a corner, plastic tanks are standing under LED tubes that emit light of various wavelengths simulating different times of day, such as dusk or high noon. In between the few green plants languish others that are blackish brown. For them, the attacks mounted by Michoux's team were too brutal. Up to 40 different extreme conditions are being tested here simultaneously. Not all the seedlings survive.

"We change the light conditions, the pressure, the temperature, the composition of the nutrient medium, add chemicals or →

hormones, simulate attacks by fungi or insects, or do all of these things together. We really stress out the plants," says Michoux, who also likes to test his limits in his private life after work. For a long time he did triathlons, but his greatest sports achievement was his completion of an Ultra-Trail four years ago. It's an ultramarathon that runs for 60 hours over 170 kilometers at an altitude of 10,000 meters. "I'm always looking for solutions," he says. "That's why I can also adapt to every situation in extreme sports." Through his attacks, he forces his plants to protect themselves by producing the desired substance. "The variety of these substances is incredible," he enthuses. "We know of hundreds of thousands of chemicals that are produced by plants, but that's only the tip of the iceberg."

GENES PROVIDE THE BLUEPRINT

Many genes in a plant's genome only become active when danger looms. The rest of the time they are not read. But if a fungus infests the stem, an alarm is triggered. Receptor cells, which exist in every cell, identify the attacker. The plant's genes then deliver the blueprint for a fungicide. Finally, the plant uses this antifungal substance to combat the pest. The more varied the threats faced by the plant in its daily life, the greater is its defense potential.

At the beginning of the work with *Withania somnifera*, the herbal active substance was not the only focus of attention. Its marketing potential also seemed promising. "In order to effectively advertise the finished product, there has to be an exciting story behind it. 'Indian ginseng' sounds mystical and powerful," says Michoux. Another special feature of the work was Michoux's intention to extract the cosmetic active ingredients from ginseng roots.

The person responsible for the plants until their roots grow is Ruben Mallon, a 38-year-old botanist with a doctorate in plant biology. Two weeks ago he cleaned the ginseng seeds with ultrapure water and alcohol and put them in a plastic box. The nutrient medium in the box is a gelatinous liquid full of vitamins, sugar, hormones, and other secret ingredients. It contains everything the seeds need to live. "In this way we grow many young plants as fast as possible under ideal conditions," says Mallon.

Seedlings are now sprouting in the box. Mallon now selects tiny leaves from the seedlings and treats them so that they will grow roots. He's sitting in a glass cubicle behind a metal table. In front of him is a white honeycombed membrane wall from which filtered air is hissing in order to blow away unwanted particles. Mallon is wearing a hairnet, purple rubber gloves, and a white lab coat. When he speaks, the turns his head sideways so as not to contaminate the Petri dish in front of him. "We have to work in sterile conditions, because we're cultivating the roots in a special nutrient medium. Bacteria would enjoy growing there as well."

Mallon's fifteen years of experience in plant research help him decide which leaves will grow roots and which ones will wither. His scalpel slices through the tender green leaves, and he uses tweezers to place the tiny leaves in a Petri dish. After they start to sprout, they will be transferred from the Petri dish to glass vessels called bioreactors. There the roots will grow for two months in a dark cultivation room.

Patricia Corral will be watching over them. Now she presses the light switch and fills the cultivation room with green light. Along the walls are rows of bioreactors with condensation water running down their glass walls. From each bioreac-

The botanists let ginseng seeds sprout in plastic boxes with a nutrient medium under the best possible conditions (left) and then select the plants that are to form roots (top)

“The research I do here is much more creative than what I did at the university”

PATRICIA CORRAL, PLANT BIOLOGIST AT EVONIK ADVANCED BOTANICALS

tor’s cover emerges a plastic tube for regulating the pressure within. “Plants can’t perceive green light, so for them it’s always still dark here,” she says. Her sentences have a staccato rhythm. Just now she spoke to her colleagues in Spanish, then French, and now she’s speaking English. All the members of this team can communicate in several languages. Corral has a doctorate in plant biology from the University of Santiago de Compostela. She worked there for ten years as a research associate, collecting and protecting endangered plant species. She used to work with Ruben Mallon there, and he recruited her for Franck Michoux’s team. “The work I do now brings me a new challenge every day. The research I do here is much more creative than what I did at the university,” she says.

But she also needs a lot of patience. It took Corral and her team a whole year to find out the optimal conditions under which the tiny leaves of *Withania somnifera* would form roots. And it took them →

an additional year to find out how the roots could be forced to produce even more of the active ingredient. In the process, the ginseng plants were subjected to countless tests under various conditions and different kinds of stress. The process ended with a "final protocol." This is the definitive blueprint that shows the composition of the nutrient medium, the light, the temperature, and the maturation period. In short, it shows all the conditions under which *Withania somnifera* will produce the desired active ingredients. It's one of the well over 70 final protocols for various species that Corral has already worked with.

SUDDENLY, 80 PROSPECTIVE BUYERS

For Michoux, all of this began in London. While he was studying at Imperial College, he came up with the idea of extracting complex chemical substances from plants. He wanted to come up with herbal active ingredients with a very high degree of purity—active ingredients that did not yet exist on the market. However, this happened during the recession of 2008, and he couldn't find any investors. So he founded Alkion Biopharma on his own and continued doing his research right through the economic crisis.

He also did research with plant stem cells—the primordial cells that can develop into every other type of cell. Back then, only a handful of companies were conducting research in this area. The breakthrough came suddenly in Paris in 2012. Michoux had just presented a few of his research results at a conference—and he suddenly had 80 prospective buyers including L'Oréal, Chanel, Dior, and Clarins, the grandees of the cosmetics industry.

All of them were eager to benefit from plant stem cells. "Back then they were hoping that plant stem cells could work in the same way as human stem cells and thus rejuvenate human skin," Michoux recalls. They followed up their interest with lucrative orders. Michoux successfully entered a sector he had never considered before—through the back door, so to speak.

Only two years later, all of his orders were coming from cosmetics companies, and Michoux and his colleagues were concentrating on research and development. In order to ride the trend toward natural cosmetics, the producers were seeking the team's expertise. The cosmetics companies would come to Alkion with a plant, and Michoux's team would coax out its active ingredients or reduce its toxic substances. And everyone benefited. The young company, which is now called Evonik Advanced Botanicals (EAB), established itself and grew, while its customers received quick results thanks to its cutting-edge technology. These customized preparations, which are often provided exclusively to certain companies for years, are still EAB's core business.

However, Michoux has so far not had a catalogue of active ingredients derived from various plants that customers can freely choose from. That will soon change. For a young company, launching its own products on the market is a big step, and it's connected with considerable financial risks. Now EAB is taking this step with Neoplanta® Withania. "We entered the right market at the right time with the right technology. But we also had some luck," says Michoux, who has a realistic perspective on his own success story.

His company has been owned by Evonik since May 2016. With Evonik backing him up, Michoux could finally undertake the market launch of his company's own products, which are being sold to several producers.

A GREATLY EXPANDED PORTFOLIO

The hard work, the long waiting periods—all of it hones in on this moment: the harvest. The ginseng roots, which have been growing in the dark for two months, have developed into a damp nest with a total weight of 25.48 grams. That doesn't sound like much, but the roots have precisely followed the blueprint. They are full of the active ingredient.

And the result will never fluctuate, in contrast to conventionally cultivated plants, which suffer from hot summers, environmental pollution or contamination by chemical sprays. However, this high degree of reliability requires a big investment of energy. One day this energy may be provided by solar panels covering an area of 600 square meters.

After the harvest, the roots are freeze-dried and crushed to produce a very fine odorless brown powder. The powder is dissolved and distilled in glycerol until the result is highly concentrated. Michoux now uses a pipette to fill a testing flask with this concentrate. Next, he places the flask in a high-performance liquid chromatograph, or HPLC. This device identifies all of the active ingredients in a product and indicates their concentrations. The result rises and falls in a curve on the monitor, looking very much like an irregular heartbeat. The researchers have subjected more than 70 plant species to this procedure, and only two of them produced no results—the line of their HPLC "heartbeat" stayed flat. Today Michoux points to two spikes in the profile. They represent the desired active ingredients. When Neoplanta® Withania is admixed in face creams and shampoos later on, it will account for only one percent or even less of the total volume.

But *Withania somnifera* is only the beginning. In the years ahead, EAB plans to greatly expand its portfolio of own active ingredients with 14 other plant extracts. "In the past, our company was known in four countries," says Franck Michoux and pauses for a short, almost solemn, moment. "Today it's known in 100 countries."

"We entered the right market at the right time"

FRANK MICHOUX, HEAD OF
EVONIK ADVANCED BOTANICALS

Company founder Franck Michoux and his team have stringent criteria for the selection of plants (left). Tours in the Loire Valley, the "Cosmetic Valley" of France (bottom)

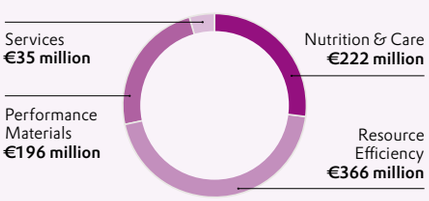
Fiscal 2018: A Brighter Outlook

A strong first half-year due to higher sales prices and growing volume sales

Evonik has upgraded its outlook for full-year 2018 and now expects its adjusted EBITDA to be between €2.60 and €2.65 billion. The company is also expecting to generate a noticeably higher free cash flow in fiscal 2018 than in the previous year. "The implementation of our strategic measures and a heightened cost awareness are being increasingly reflected in the development of our operative business and a considerably improved free cash flow," said CEO Christian Kullmann.

In the second quarter of 2018 Evonik increased its adjusted EBITDA to €742 million. All three segments increased their adjusted EBITDA as well as their EBITDA margin compared to the same quarter of 2017. In the second quarter, sales increased to €3.9 billion, largely due to increasing sales volumes and higher selling prices. The adjusted net income increased to €354 million, which corresponds to adjusted earnings per share of €0.76.

Adjusted EBITDA by segment



Evonik expands plant capacity for silica

Evonik is expanding its Rheinfelden location's capacity for the processing of fumed silica. The company is investing a sum in the low double-digit millions of euros in the expansion of a facility that processes hydrophilic silica into hydrophobic silica. The extension, which is scheduled to go into operation by the end of 2020, will increase the location's annual production capacity by 20 percent. This measure is part of Evonik's ongoing expansion of its specialty silica business in response to strong market demand. Johannes Ohmer, Member of the Board of Management of Evonik Resource Efficiency GmbH, commented, "Through the expansion in Rheinfelden we aim to support the growth of existing application areas that are very specialized and to open up more new and innovative business areas." Hydrophobic fumed silica, which is marketed under the AEROSIL® brand, is used in coating systems, adhesives, and sealants as well as thickeners and flow additives.

Joint venture with Wynca

AEROSIL® brand silica is also the focus of plans for a joint venture that has been agreed on by Evonik and the Chinese company Wynca. Evonik will hold 60 percent of the shares in the new company. The joint venture, Evonik Wynca (Zhenjiang) Silicon Material Co., Ltd., is planning to build a production facility for fumed silica in the Zhenjiang New Material Industry Park (Jiangsu province, China). It is investing an amount in the mid-double-digit millions of euros in the facility, which is scheduled to go into operation in 2021.

PEBA powder for 3D printing

Evonik is the first company in the world to develop a flexible plastic material based on PEBA (polyether block amide) for use in 3D printing. This new high-performance powder has high elasticity and stability and can be used in a variety of powder-based 3D printing technologies. 3D-printed components made of the new PEBA powder have high flexibility and very good chemical durability, as well as excellent long-term use durability across a wide range of temperatures from -40°C to 90°C. The powder is suitable for the manufacture of functional 3D high-tech plastic components—for prototypes as well as for series products.

Another listing in sustainability indices

Evonik has been included for the third time in a row in two renowned sustainability rankings: the Dow Jones Sustainability Indices DJSI Europe and DJSI World. The company received especially high ratings for its reporting on environmental and social issues and for its customer relationship management. Investors are increasingly basing their investment decisions not only on financial data but also on environmental and social criteria. They are guided by leading sustainability indices such as the DJSI, which invites 2,500 companies all over the world to participate in its annual evaluation process. Out of this pool, DJSI World lists the top ten percent of companies in their respective branches, while DJSI Europe lists the top 20 percent. The evaluation process is conducted by the Swiss rating agency RobecoSAM. Evonik is also very highly placed in the lists of other leading sustainability rating companies and indices, such as FTSE4Good, ISS-oekom, MSCI World ESG, and Sustainalytics.

A superfast capsule

Students at the Technical University of Munich (TUM) have won the Hyperloop Pod Competition. The objective of the competition, which was established by SpaceX founder Elon Musk, is to develop the proto-

type of a hyperloop. A hyperloop is a transportation system in which a capsule is shot through a tube at nearly the speed of sound. Musk's vision is to create a hyperloop system that will in the future connect major cities and transport people and goods. The team from TUM has now won the competition for the third time in a row. This time around, the students increased the speed of their capsule by almost 50 percent to 467 kilometers per hour. Evonik provided a crucial component made of ROHACELL® rigid foam. This material was used in the prototype's foam core, whose robust and lightweight properties stabilize the carbon structure and thus make higher speeds possible. Evonik and TUM are connected in a strategic partnership.

CALOSTAT® is honored

Dr. Bettina Gerharz-Kalte and Dr. Gabriele Gärtner from Evonik at the presentation ceremony of the German Innovation Award 2018

The high-performance insulation material CALOSTAT® (from Evonik) has received the German Innovation Award 2018 in the category "Building & Elements" from the German Design Council. The expert jury singled out the material's user-friendliness for special praise. This sustainable sheeting material presents no health hazards, is easy to handle, and can be fully recycled. The expert jury was also impressed by the wide spectrum of possible uses that the special properties of CALOSTAT® offer to architects, professional planners, and designers. This lightweight super-insulating material is up to 50 percent thinner than conventional insulation materials. It thus combines excellent thermal insulation performance with architectural aesthetics.

Technology cooperation with Siemens

As part of their technology partnership, Siemens and Evonik are developing an asset lifestyle data model. Their goal is to integrate this model into the Siemens software solution Comos. The data model was defined by Evonik on the basis of internationally valid norms. It covers the elements and structures that are relevant to facilities of the chemical industry over their entire life cycle, from product development through facility planning and operation to facility decommissioning. The two companies are developing this application for the software-based support of the entire engineering and operation process. The results of this collaboration will become a component of the Comos software portfolio.

Evonik plans its own GAA product

Evonik is planning to launch its own guanidinoacetic acid (GAA) product on the market to support the energy metabolism of fattened livestock. The company decided to take this step after the AlzChem Group AG gave notice that it would terminate its supplier contract as of the end of 2018. The GAA product CreAMINO® is manufactured by AlzChem and sold by Evonik. Its delivery to Evonik's customers is guaranteed at least until the end of 2018. AlzChem's termination of its supplier contract opens up options for Evonik to further develop applications of GAA for animal nutrition all over the world and to meet customers' needs with its own GAA product. Guanidinoacetic acid is a starting material that is used by the organism to form creatine and as a source of arginine. Among other things, creatine helps to supply the muscle cells of vertebrate animals with energy.

Strategic partnership

Evonik and the technology company The Linde Group have signed an exclusive cooperation contract regarding the use of membranes for natural gas processing. The two companies will jointly carry out research in the area of membrane technology, with Evonik focusing on membranes and polymers and the Linde Engineering Division serving as a system integrator for complete membrane systems. The jointly manufactured product will be sold by Linde as the high-performance "HISELECT™ powered by Evonik" membrane system. HISELECT™ membranes are opening up innovative new methods of gas separation, especially in combination with other well-established processes. Through this step Evonik is reinforcing its position as the world's leading company for gas separation technology and as a supplier of complete gas separation packages.

An outstanding archive

Evonik's Corporate Archive has been honored as the "Business Archive of 2018" by the Association of German Business Archivists (VdW). The archive received this award for its exhibition "VerSIErt" about women in the chemical industry. The jury explained its decision by pointing out that through this exhibition Evonik's Corporate Archive has made an important contribution to current public discussions and has not hesitated to present a self-critical perspective. The jury also emphasized Evonik's many cooperative projects with external institutions that made the exhibition accessible outside the company. Evonik's Corporate Archive is celebrating its 70th anniversary this year. The archive's two locations, in Marl and Hanau, store more than 8,500 meters of material that documents approximately 170 years of the company's and the chemical industry's history.

US Jayhawk location sold

Evonik is taking the next step in its systematic concentration on specialty chemicals by selling its US Jayhawk facility in Galena, Kansas. This facility manufactures precursor products for agrochemicals that are not part of the company's defined growth business areas. The operations at Jayhawk are part of the Agrochemicals & Polymer Additives business line of the Performance Materials segment. Funds advised by the international investment company Permira are buying the company and its facility, which has approximately 120 employees, as part of a share deal. "We're looking forward to successfully advancing Jayhawk's business operations," said Sebastian Hoffmann, a Principal and a member of the Industrials team at Permira. The purchase price is in the high double-digit millions of dollars. The transaction still needs to be authorized by the cartel authorities in several countries.

The current political consensus is that Germany should quickly phase out coal-fired power generation. How this process could succeed without causing economic upheavals is not yet clear. Ideological demands won't help us move forward

by Christian Kullmann

Christian Kullmann
has been a member of the Executive Board of Evonik Industries AG since 2014. He became the Chairman of the Executive Board in May 2017

The vision behind Germany's energy transition sounds superb. We will renounce nuclear power, coal, and natural gas and instead generate our electricity from the sun and the wind. These are free, clean resources that will be endlessly available forever. We will make ourselves completely independent of imports, significantly reduce our emissions, and simultaneously develop pioneering new technologies that we can sell all over the world.

Of course this wonderful vision makes it worthwhile to continue investing in research and development in the area of alternative power generation. We want to one day actually build systems that can not only generate but also store electricity in ways that are clean, reliable, and economical. And if our engineers, technicians, physicists, and chemists can't do it, who can? At that point, conventional power plants would be unnecessary. The researchers at Evonik are also working hard to make this prospect a reality. For example, with our products we are enabling the construction of ultramodern high-yield wind turbines. As the CEO of a company whose future crucially depends on its innovative power, I have confidence in this research. But at the same time, I know from experience that achieving the impossible doesn't happen overnight. And performing miracles takes a little bit longer.

In order to bring Germany's energy transition to a successful conclusion, the two things we need most of all are time and money. As far as time is concerned, the people who are mainly responsible for it are the politicians who are legislating ambitious timetables in Berlin, Paris, and Marrakesh in order to steadily increase the proportion of renewable energy and decrease CO_2 emissions. The goal of the Paris Convention, to limit global warming to a maximum of 2 °C compared to the temperature of the preindustrial era, has been defined. And Evonik is giving it its full support. However, if we want to take these plans seriously, we need a broad international consensus, because this global challenge can certainly not be solved by solo initiatives of individual nations.

As for the second requirement, money, we are the responsible partners—private electricity consumers and companies large and small. In other words, all of us. Through the German Renewable Energy Sources Act, we are subsidizing the construction of more and more new wind turbines and rooftop solar panels with over €20 billion, year after year. That's a huge amount of money. By comparison, the amount spent on subsidizing Germany's hard coal mining industry, which has at times been vehemently criticized, seems quite modest.

If we were in fact on the brink of genuinely being able to generate and store clean, reliable, and economical power from renewable sources, these gigantic subsidies paid out over decades would be justified as worthwhile investments. However, the reality is quite different. So far, we have not been able to safeguard a baseload supply of

power from wind and solar systems in Germany. On the contrary, this summer conventional power stations covered well 63 percent of our electricity needs. And the main providers of this energy were coal-fired power plants, whose contribution to safeguarding the power supply continued to grow, in spite of the increasing construction of "green" power stations.

For industrial companies, this reliable power supply is a key advantage of Germany as a business location. Energy-intensive companies such as Evonik can operate production facilities only in places where there are virtually no power failures. This circumstance, which is a key factor of our country's prosperity, seems to be neglected at times in the broad-based discussion of how to phase out coal mining and save the world's climate. Against this background, the composition of the German government's "Coal Commission" raises a number of questions. How many representatives of energy-intensive industries are among the over 30 members of this important commission? It's striking that the only one is Michael Vassiliadis, the Chairman of the IG BCE labor union. There's no doubt that he's a good representative of the interests of the employees. But the commission's work would benefit if the energy-intensive industry were also directly represented at the negotiation table.

So far, no binding date has been set for the end of Germany's coal-fired power plants. We've been hearing that it's no longer a question of whether but rather of when. Meanwhile, the question of how still remains open today.

What will eventually replace coal-fired power generation? How can Germany stay attractive in the tough competition with the up-and-coming industrial locations in Asia and the Americas? And how can we successfully encourage other industrial countries to join us as we move toward a huge energy transition—instead of forging ahead on our own? To answer these questions, we need to create a master plan for the energy policy of Europe as a whole, instead of only symbolically haggling over dates.

Given the current state of technology, if nuclear and coal-fired power are phased out as a matter of policy, power stations fired with natural gas will be the only substitute that can safeguard our power supply. Natural-gas power plants also emit CO_2, but in much smaller amounts than coal-fired power plants. They can also be ramped up and down faster—and thus are more easily harmonized with the volatile generation of energy by solar and wind systems. However, this raises the question of supply reliability to a whole new level: that of the amounts of fuel they will need.

Germany has no natural gas deposits worth mentioning, and suppliers in Europe such as Norway, the Netherlands, and the UK can by no means cover Germany's requirements. As a result, our natural gas-fired power plants will be primarily dependent on natural gas from Russia. It's a good thing that the USA's producers of natural gas are now also rushing into the European market.

"So far, we have not been able to safeguard a baseload supply of power from wind and solar systems in Germany"

"For industrial companies, this reliable power supply is a key advantage of Germany as a business location"

That's creating competition between the suppliers and, from a European viewpoint, preventing overly one-sided dependencies.

But our enthusiasm for this new possible source of supply should not lead us to block off our connections with the East. Germany and the rest of Europe urgently need the second Nord Stream pipeline through the Baltic Sea. Without it, natural gas would soon become scarce if we one day really do take the last German coal-fired power station off line. And let's not forget that Russia has been our reliable partner as an energy supplier for decades, undisturbed by any political conflicts, even across the system boundaries of the Cold War. There's no reason why that should not continue in the future.

In conclusion, the phasing-out of coal and the transition to renewable energy sources and natural gas can succeed in our country without major economic upheavals only if we move forward with sound judgment and without ideological inputs. What will happen to the coal market at that point? Well, it will continue to flourish without us. At the moment, no less than 1,500 new coal-fired power stations are under construction all over the world. This fact is common knowledge in Europe. But it seems to be having no effect on the urgency of Germany's phaseout of coal.

GETTING SAFELY TO THE DESTINATION

Liposomes transport active pharmaceutical ingredients to the target cells, while ensuring that the cargo does not break down prematurely during its journey through the body. Their use opens up new therapeutic pathways for the treatment of cancer as well as genetic and other diseases.

TEXT **NIELS BOEING**

Biologists continue to dig deeper and deeper into the composition and functionality of cells to better understand their enormously complex biochemical machinery. Through this process of scientific discovery, they decipher the importance of more and more genes in cell metabolism and discover new pathways. Pharmaceutical companies hope to use this new knowledge to develop new therapies against cancer, hereditary diseases, and other serious illnesses. In the process, they are increasingly turning to ribonucleic acids (RNAs for short) with the goal of knocking out specific genes or promoting the formation of essential proteins.

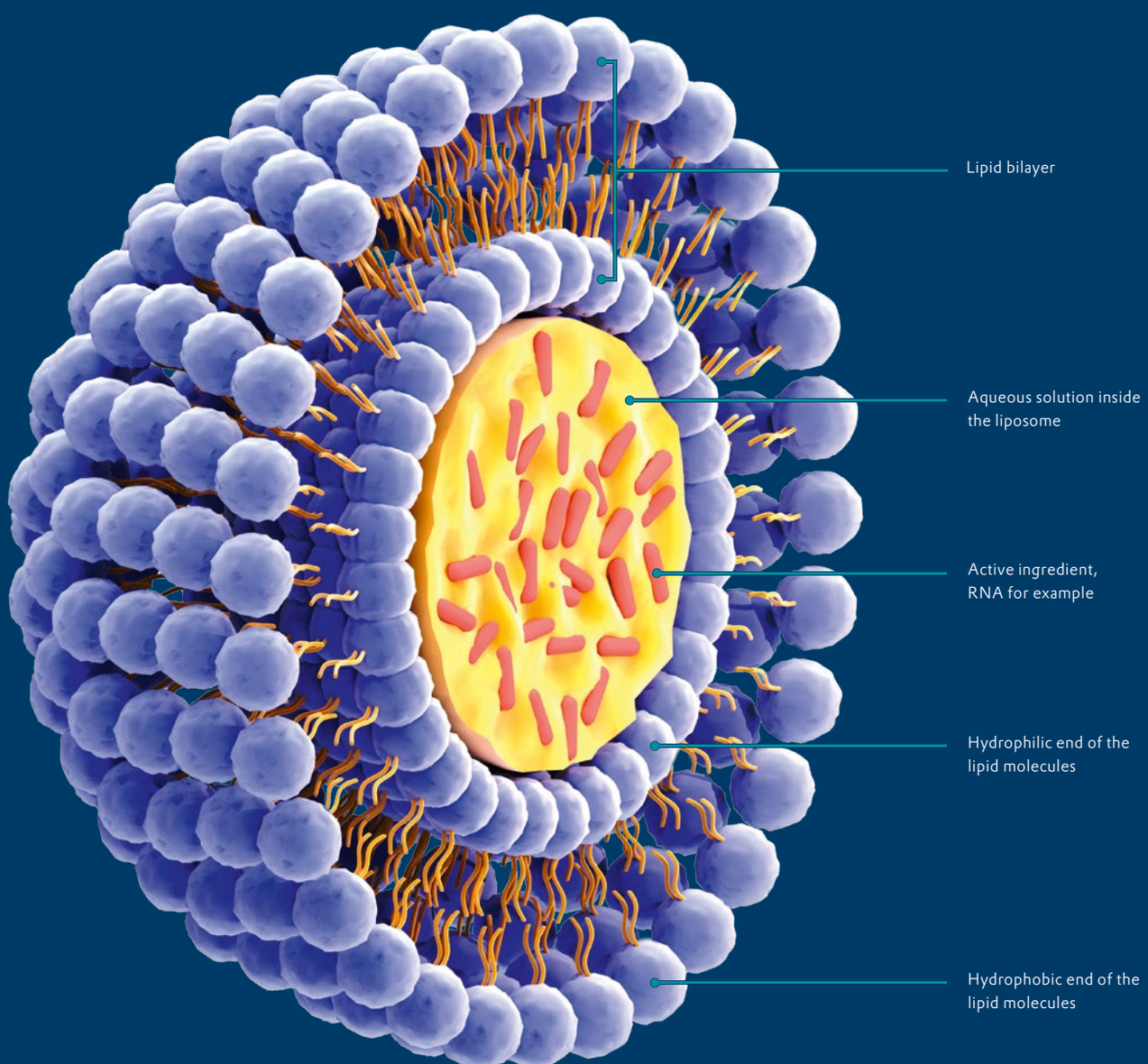
For this to work, the RNA molecules must make their way directly to the targeted cells of the affected tissue. "RNA strands are unstable," says Andrea Engel, who is responsible for drug delivery technologies in the Innovation Management unit of the Health Care business line at Evonik. If they were injected directly into the bloodstream, they would be broken down rapidly by the immune system. So there is a need for transport mechanisms that can convey their pharmaceutical package directly into the interior of the cells.

Liposomes provide one of the most important mechanisms to achieve this outcome. They are tiny spherical structures with outer membranes composed of a bilayer of membrane-forming molecules such as phospholipids or fatty acids, and they can be loaded with RNA. Unlike tablets or capsules, however, liposomes cannot be administered via the digestive tract. There, the RNA-charged liposomes would simply be broken down. Instead, they have to be administered by a parenteral route such as via intravenous injection directly into the bloodstream.

A COMEBACK THANKS TO NEW THERAPIES

Liposomes have actually been known for a long time. The British physician Alec Douglas Bangham discovered them in 1964. The first approvals for liposomal formulations of active ingredients for use as medications were issued almost three decades ago. Ambisome, the first remedy to contain an active ingredient against fungal infections that was formulated using liposomes, was launched on the market in 1990. This was followed in 1995 by Doxil, a preparation using liposomes charged with an active ingredient against Kaposi's sarcoma, a type of cancer that forms in the lining of blood and lymph vessels. Doxil was the first cancer medication of this type, and further indications followed. →

A liposome is created when a double layer of lipids arranges itself into a ball due to molecular interactions. Water-soluble active ingredients can be stored inside the liposome, which can then transport them to their destination



The cosmetics industry was increasing its use of these formulations in parallel. While liposomes developed into a standard technology in that area after 2000, their applications for medical use were less visible. However, this has now begun to change.

"Liposomes are making a comeback, because they are so well-suited to new therapeutic applications with strands of RNA or DNA," says Stefan Randl, who is responsible for Innovation Management at Evonik's Health Care business line. "The liposomes can be manufactured in an extremely flexible and customized way, and can thus be applied for a wide range of active ingredient formulations."

With liposome-based RNA therapies helping to create new segments in the pharmaceutical market for advanced drug delivery, Evonik acquired Transferra Nanosciences, a leading contract development and manufacturing company for liposomal active ingredient formulations, in 2016. This Canadian company, which is based in Vancouver and is now called Evonik Vancouver Laboratories, has also developed a technology that enables liposomes to be produced with extreme precision in a narrow, well-defined range of sizes.

FASCINATING PROPERTIES

One option for the production of liposomal active ingredient formulations involves a special extrusion process. First of all, an ethanolic solution of lipids, which are molecules that also occur naturally as the building blocks of cell membranes, are mixed with an aqueous phase in which the active pharmaceutical ingredient is present. During the mixing, tiny structures arise in which the lipids create a bilayer. Lipids are long molecules that have one hydrophilic (water-attracting) end and one hydrophobic (with little affinity to water) end. In aqueous systems, they line up parallel to one another and form a ball filled with water. The membrane that forms the outer shell of the liposome is a lipid bilayer, which is a double layer of lipids that is similar to the membrane surrounding a cell. This is one reason why researchers were fascinated by the discovery of liposomes. During the production of the formulation, medically active ingredients that are not soluble in water accumulate preferentially in the lipid bilayer, while water-soluble ingredients accumulate in the interior of the sphere.

The lipid structures with their active ingredient loading are then forced through a membrane with pores of a specific diameter in the range of one hundred nanometers, i.e. one hundred times smaller than the diameter of many of the cells that comprise human tissue. The liposomes form when they pass through the membrane. As a result, the original dispersion of liposomes becomes more homogeneous and the size distribution grows narrower. After the extrusion processes, the liposomes produced are all of similar size—around the same diameter as the pores in the membrane.

"The advantage of this process is that it can easily be scaled to clinical and commercial production," says Randl. A broad range of batch sizes, from a few milliliters to hundreds of liters, can be produced using the extrusion process at Evonik Vancouver Laboratories. To illustrate, a batch of 100 liters can theoretically provide up to 10,000 ten-milliliter doses, which is the standard dose of the medication Doxil. Thanks to the use of membranes with different pore sizes, the process can produce liposomes with diameters ranging from 50 to 200 nanometers.

> **"Liposomes are making a comeback"**
>
> STEFAN RANDL, INNOVATION MANAGEMENT
> EVONIK HEALTH CARE

CAMOUFLAGE AGAINST THE BODY'S DEFENSES

RNA strands are copies of individual genes (refer to the information box). Similar to the punched cards that were used with early computers to store data, the sequence of their nucleobases is evident in the interior of the cell. They can determine which amino acids are linked together, and which proteins (which essentially control the cell's metabolism) are formed.

In cancer cells, the genome has mutated so that the individual genes are permanently issuing instructions to the cell that it is to divide, and thus grow a tumor. Likewise, in hereditary diseases genes with defects are no longer transcribed, resulting in metabolic or other disorders. Because RNA strands carry the instructions

for these processes, scientists recognize that RNA interference technologies may provide solutions and enable causal treatment of the disease. If RNA strands with nucleobase sequences that are complementary to those of the cell's own RNA are introduced, the cellular RNA is inhibited. These RNA strands, which are known as siRNA (small interfering RNA), can suppress the action of the genes transcribed by the RNA.

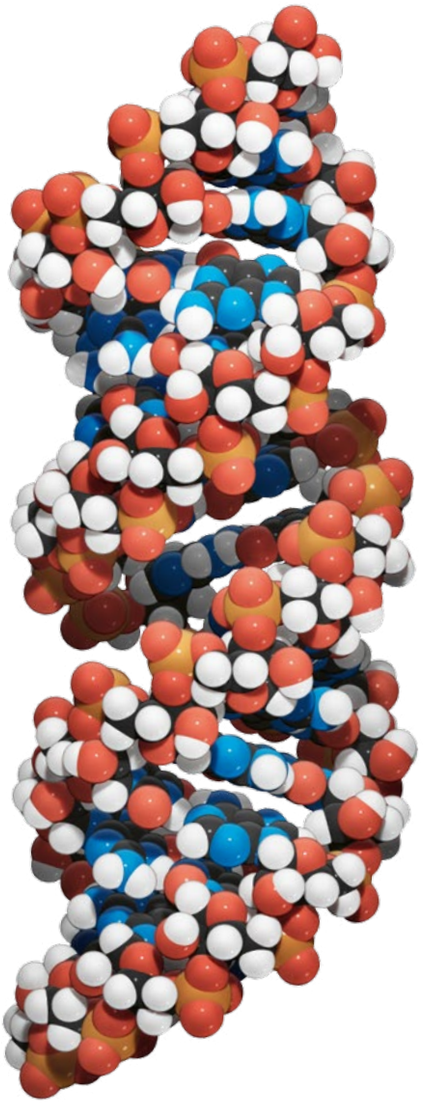
Liposomes can be used to transport siRNA into the cells. The liposomes provide the siRNA with a kind of protective coating that enables them to be transported without being noticed by the body's immune system. The liposomes can reach their target cells because the blood vessels in tumor tissue are not properly lined up, as in other tissue, but have gaps. The liposomes can thus diffuse out of the bloodstream into the pathological tissue and make their way further into the cells.

Various pharmaceutical companies have developed siRNA that can destroy carcinogenic liver cells or reduce the uncontrolled cellular division of tumor cells. "Some RNA liposome preparations are already in phase III clinical studies," says Engel. It is therefore likely that therapies of this type will become part of the range available for treating patients in the coming years. The first liposomal RNA medication was recently approved by the US pharmaceuticals authority. Onpattro® will in the future be used for the treatment of familial amyloid polyneuropathy, a hereditary disease which leads to symptoms including signs of paralysis and muscle loss in the extremities. With the active ingredient molecule inhibiting the abnormal production of the protein that is responsible for the syndrome, the therapy promises to substantially improve the quality of life for affected patients.

A MARKET WITH PROSPECTS FOR GROWTH

Similarly to the RNA process, liposomes can also be used to transport genes, which are strands of DNA, into a cell. That makes lipid vesicles of interest to those seeking to create new types of gene therapy. Randl therefore expects to see considerable growth in the market for RNA and DNA therapies over the coming decade.

However, the first generation of RNA and DNA therapies has not yet been fully exploited within this market segment. Many research institutes around the world are working on a further improvement that is known as active drug targeting. Here, transport systems, such as liposomes, are augmented by the addition of other molecules which bind to receptors on, for example, tumor cells. The objective is to prevent liposomes from getting lost on the way through the bloodstream, and to deliver them in complete form to the target tissue. In the future, the use of such precise drug targeting in precision medicine will open up new treatment options that are far beyond what is possible today.



Messenger RNA is a long, twisted molecule that copies part of the DNA and thus transports the genetic information required for protein synthesis

Nucleic acids

Nucleic acids such as DNA and RNA are molecules that are essentially composed of nucleobases. In DNA, these are adenine (A), thymine (T), cytosine (C), and guanine (G), and are arranged in the pairs A-T and C-G. This gives rise to the typical double helix of DNA, a twisted ladder with A-T or G-C base pairs as the rungs. RNA contains uracil (U) in place of the thymine in DNA. The sequence of the nucleobases in the DNA encodes the gene. Each set of three base pairs in the gene codes for a specific amino acid that is added to the protein being synthesized in the ribosomes. Messenger RNA is a single-strand copy of the sequence of the DNA, with uracil standing in for the thymine. This copying process is called transcription. The RNA transfers the information in the sequence of base pairs from the gene to the ribosome. In addition to the important messenger RNA, the cell also contains other RNA strands with other functions such as ribosomal RNA or transfer RNA.

TRANSPORT WITHOUT SIDE EFFECTS

Researchers have been working for 120 years to provide drugs with good chemical packaging so that they can reach their targets in the human body. In the past, the active ingredients were protected by a layer of sugar in dragées. Today nanotechnology is opening up entirely new opportunities

TEXT **NIELS BOEING** ILLUSTRATION **MAX NERTINGER**

Packaging counts. This basic principle applies not only to perfumes and filled chocolates in elegant flasks or decorative boxes but also to medical active ingredients if they are to optimally develop their healing effects inside the human body. For example, the active pharmaceutical ingredient in a tablet must be bound and safely packed in such a way that it can penetrate all of the body's physiological barriers against foreign substances. That's the only way it can reach the diseased organ and precisely deliver its desired effect. The art of finding the right packaging or formulation for drugs is professionally known as galenics, after a renowned physician of antiquity, Galen of Pergamon.

Whereas the science of curative substances, which originally came from plant parts such as leaves and roots, developed over the whole course of human history, pharmaceutical research in the area of formulations is less than 120 years old. During this time, chemists and apothecaries have repeatedly found new ways to deliver active ingredients to their targets.

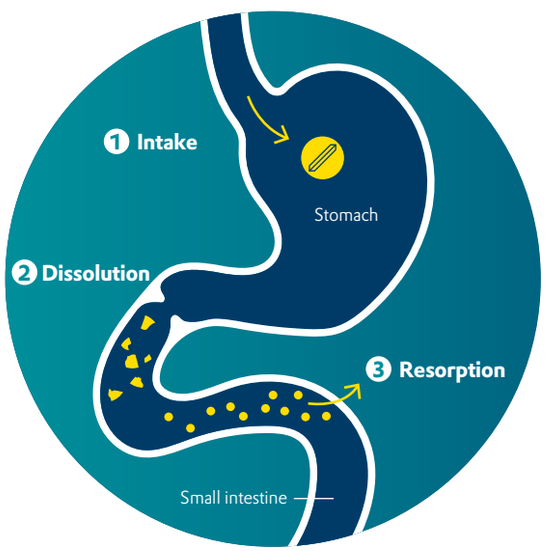
PAINKILLERS UPSET THE STOMACH

As long as this knowledge was missing, drugs were prescribed fairly nonspecifically. As a result, on their journey through the body they often lost much of their effectiveness and in many cases caused unwanted side effects. Some 2,400 years ago, the ancient Greek physician Hippocrates advised pregnant women to chew willow bark in order to mitigate their labor pains before giving birth.

He didn't know that the cause of the analgesic effect was the salicylic acid salts contained in the bark. Nor did he know about the side effects of these salts. Even in 1874, when salicylic acid was first produced on an industrial scale, it was a double-edged sword for the patients who used it. Their original symptoms disappeared—but the patients then complained of stomachaches.

Jakob Hoffmann, a merchant in Ludwigsburg, was not satisfied with this outcome. He challenged his son Felix, an up-and-coming chemist, to find out the cause of the problem. At the time, Felix was working in the scientific laboratory of the pharmaceutical company Farbenfabriken vorm. Friedr. Bayer & Co. in Wuppertal-Elberfeld. He went to work immediately. The experiment in which he reacted salicylic acid with acetic acid finally yielded the desired result: acetylsalicylic acid. Hoffmann produced this substance synthetically for the first time on August 10, 1897. Under the brand name Aspirin, acetylsalicylic acid became one of the best-known medications of the modern era. Aspirin was initially sold in bags in powder form, but in 1900 Bayer launched this active ingredient on the market in the form of tablets containing 500 mg of acetylsalicylic acid.

Orally administered active ingredients were initially simply pressed into tablets, but the producers soon realized that the tablets would be more durable and effective if they had a protective coating. Apothecaries would traditionally coat the tablets with a thick coating of sugar. These dragées often also contained pigments such as titanium dioxide that would block the ultraviolet radiation of sunlight. As a result, the active ingredients would not disintegrate into undesirable decomposition products, even if they were stored for a long period of time.



RESORPTION AFTER ORAL ADMINISTRATION

Orally administered medications pass via the stomach to the small intestine. Thin coatings protect them from the acidic gastric juices, so that they reach the small intestine before they dissolve and pass through the intestinal tissue into the bloodstream.

PLASTIC COATINGS FOR MEDICATIONS

On a drug's journey through the body, the gastrointestinal tract is the first major barrier. From here, the active ingredient must find its way into the bloodstream so that it can be transported into the diseased tissue. "Resorption" is the term used by pharmacists for the passage of the active pharmaceutical ingredient through the cells of the intestinal wall. But before the substance reaches the small intestine, it must first pass through the very acidic environment within the stomach. It can do this successfully if it is covered with a film of polymethacrylate. A layer that is only 50 micrometers thick is sufficient to resist the gastric fluids.

The chemist Otto Röhm Jr. was the first one to recognize the pharmaceutical significance of this plastic. Röhm's father is still well-known as the inventor of Plexiglas. He applied for a trademark for it in 1933. Two decades later, his son launched pharmaceutical film coatings under the brand name EUDRAGIT on the market. Incidentally, the company he worked for is now part of Evonik. EUDRAGIT has a crucial advantage over traditional sugar coatings: Whereas sugar coatings can double the weight of a tablet, a film coating of EUDRAGIT only increases the weight by about three percent.

Ever since then, this material has developed into a versatile technology platform. Today it can be used to combine the different attributes of medications by means of a modular system. For example, active ingredients can be precisely released in a certain section of the small intestine. This is made possible by the fact that the polymethacrylates used for this purpose do not dissolve in acidic environments, but rather in the neutral environment of the intestine.

More on page 38 →

How Medications Enter the Body

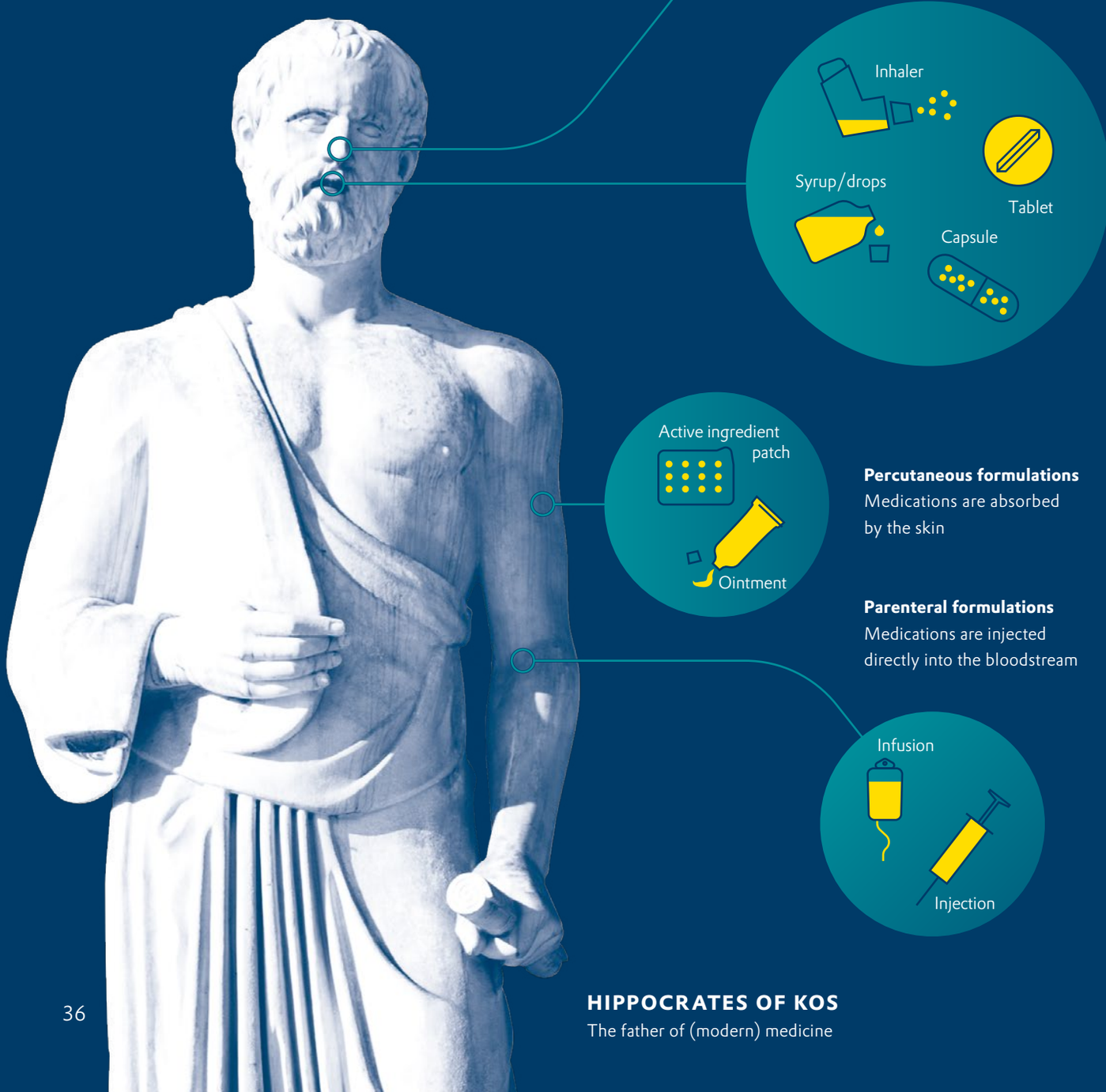
In the past 200 years, pharmacology and medicine have considerably expanded the methods by which medical active ingredients can be transported into the body. All four methods were basically already known in antiquity

Intranasal formulations
Medications are administered via the nose and the respiratory tract

Oral formulations
Medications are transferred via the mouth to the gastrointestinal tract

Percutaneous formulations
Medications are absorbed by the skin

Parenteral formulations
Medications are injected directly into the bloodstream



HIPPOCRATES OF KOS
The father of (modern) medicine

Thanks to increasing knowledge about the biochemistry of the body, formulations of active ingredients have become high-tech processes.

Active ingredient Excipient Coating

1870s
Capsule

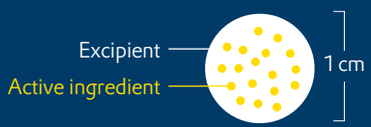
Two-piece telescoping capsules enable better administration of unpleasant-tasting active ingredients in powder form.

1930s
Dragée—A tablet with a sugar coating

Dragées have a thick sugar coating to protect them against light and moisture, which is modeled on those used by confectioners.

1850s
Tablet

Early tablets were pressed from a mixture of the active ingredient, fillers such as starch, and binders such as gelatin.

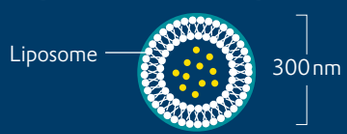


1950s
Modern tablet

Thanks to extremely thin polymer coatings, tablets can work after a time delay or only when they reach specific parts of the intestine.

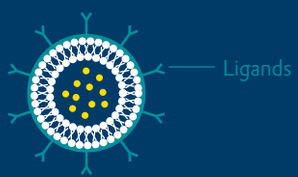
1990s
Passive drug delivery—Liposomes

The lipid bilayer, sometimes enhanced with a layer of polyethylene glycol, protects the active ingredient until it reaches its target tissue.



The future
Active drug delivery—Liposomes

Formulations such as liposomes will use special ligand molecules to dock precisely onto receptors on tumor cells.



2000s
Passive drug delivery—Metal particles

Sugar-coated particles of gold or iron oxide are physically excited to cause cell death in tumor tissue.

Size comparison:

Liposome
Diameter ~ 300 nm

Tablet
Diameter 7 mm

The pH of an aqueous medium indicates how acidic it is. In an empty stomach with high acidity, the pH value is between 1 and 2. By contrast, in the small intestine the pH value is initially 5.5 and gradually increases to as much as 7. If the solubility of the polymethacrylate film is set at a pH value of 7, the active ingredient is not released until the passage between the small and large intestines. This is medically useful in cases such as the local treatment of inflammatory intestinal diseases.

OPTIMAL TIMING FOR HEART PATIENTS

Polymethacrylates also have another important use, in addition to the guaranteed targeted release of active ingredients at the right location. With their help, poorly water-soluble active ingredients can be made more easily available in the body. The molecules of the active ingredient are individually embedded in a matrix made of polymethacrylates—quite like the way they would be embedded between water molecules in an aqueous solution. That's why this is called "solid-solution" drug delivery. The molecules of the active ingredient are gradually released into the aqueous environment of the small intestine. If these molecules were to be quickly released in large amounts, they would form crystals and so be unable to pass through the intestinal wall—thus delivering no medicinal effect.

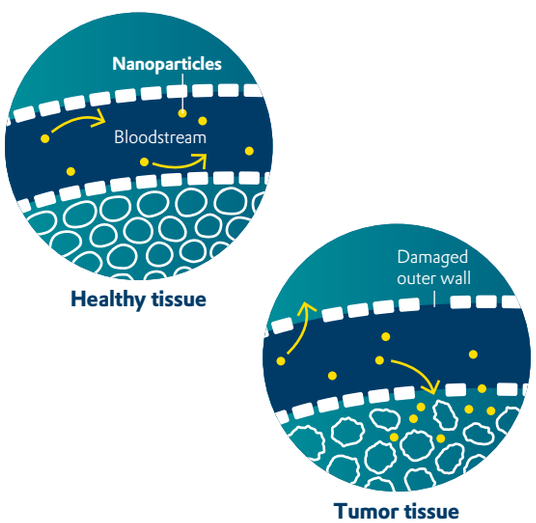
If active ingredients need to be released with a long delay, polymethacrylates can also be used to create formulations with pulsed release. These ensure that the active ingredient is released after a predefined period of time. They can be used to treat diseases that are especially dangerous in the early morning hours. For example, in cases of coronary heart disease the risk of a heart attack is greatest in the early morning. The patient can take a medication with pulsed release in the evening before going to bed. The film coating dissolves only between six and eight hours later, so that the blood level of the active ingredient increases exactly when the risk of a heart attack is greatest—and this happens unnoticeably, while the patient is sleeping.

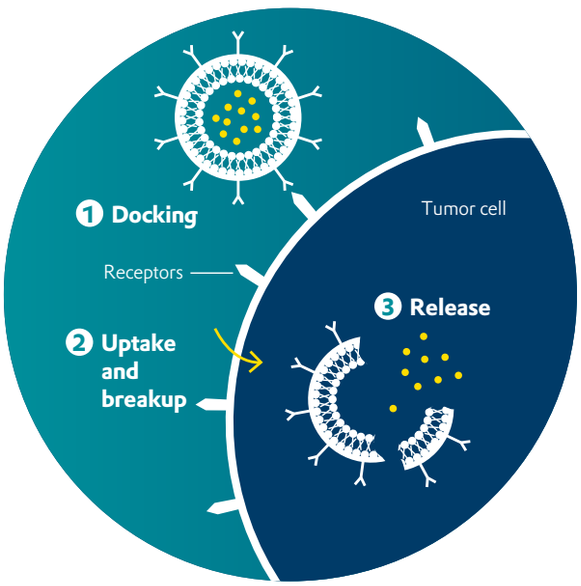
But tablets and capsules are not always the best choice. In some therapies, it's more effective to bypass the intestines altogether and inject the medication directly into the bloodstream. Alternatively, the active ingredient can be released into the body over a longer period of time from a depot that is located under the skin, for example. In these cases, parenteral drug formulations are used. A polymer such as polylactic acid or polyglycolic acid serves as the embedding matrix and breaks down over time within the body. The speed of this decomposition process can be precisely controlled. Meanwhile, the active pharmaceutical ingredient is released over a period of weeks or even months. This kind of delivery is used for implants against prostate cancer.

In the struggle against cancer cells, nanomedicine has an even broader vision: It aims to fight cancer with minimally invasive, personalized therapies. With the help of tiny particles, researchers are aiming to specifically deactivate cancer cells with molecular precision. That's because in spite of all the refinements of new cancer medications, it's still possible for the released active ingredients to attack healthy tissue as well. The resulting side effects can make ingestion of the drugs a form of torture for the patient.

PASSIVE DRUG DELIVERY

In cancer tissue (below) the blood vessels are porous, unlike those in healthy tissue (above). The active ingredient carrier can pass through the openings and into the tumor tissue. This is known as the enhanced permeability and retention or EPR effect.





ACTIVE DRUG DELIVERY

Special molecules known as ligands on the outside of the active ingredient carrier dock onto receptors on the tumor cell. The active ingredient carrier passes through transport channels in the cell membrane into the cell interior, where it releases the active ingredient.

This situation is set to change by means of "drug targeting," a process in which the drug is concentrated in a targeted manner exclusively in the diseased tissue, where it penetrates the cell membranes. In passive drug targeting, the tiny particles are injected directly into the tumor tissue. Alternatively, the enhanced permeability and retention, or EPR, effect is used: Because the blood vessels in tumors are not developed to the fully functional stage, particles loaded with the active ingredient can reach the tumor from the bloodstream through these gaps. The extent of this effect depends greatly on the nature of the tumor and on the formulation of the active ingredient.

Such transport systems of active ingredients made of lipids have already been used successfully since the 1990s. In the near future they are expected to also make RNA therapies possible (see the article on p. 30). The first liposomal RNA medication was recently approved by the FDA. Onpattro® will in the future be used for the treatment of familial amyloid polyneuropathy, a hereditary disease that leads to symptoms including signs of paralysis and muscle wasting in the extremities. The therapy promises to substantially improve the patients' quality of life in the future.

The particles for "passive drug targeting" consist of lipids, polymers or proteins. Some formulations also contain substances such as iron oxide or gold, which differ from traditional liposomes and other organic particles in that they do not transport any active ingredients. Instead, they themselves become active ingredients within the cell. The best-known example of this therapy is hyperthermia, in which the particles are injected into the diseased tissue and there energized through electromagnetic radiation from infrared light or through magnetic fields. This drastically heats up the cancer cells and thus kills them. A number of preparations that use this process have received official approval in recent years and are already being used in the first clinics.

"Active drug targeting" is even more ambitious: The carriers of the active ingredient are coated with special molecules that are supposed to dock onto receptors on the cells of the diseased tissue. Unlike passive drug targeting, these transport systems are provided with a targeting mechanism that enables their controlled uptake by special cells. In this case, success depends on whether the researchers can find the right molecules with the desired attributes. So far, the research results have admittedly been modest. In the past decade, 40,000 studies of this topic have been published, but almost none of the approaches they describe have so far been put into routine medical use.

DESTROYING TUMORS ON TARGET

In recent years, the progress made in the diagnostics of diseases has also made it possible to develop personalized therapies. This approach aims to use the perfect drug for treating each individual patient on the basis of his or her genetic, molecular, and cellular characteristics. That will make treatment better, safer, and more effective.

In any case, our understanding of the interactions between active ingredient carriers and cells is constantly improving. As a result, researchers are holding fast to their grand vision: that in the struggle against cancer, one day they will actually be able to offer medications that can use active drug targeting to eliminate even a tiny tumor right on target without any side effects before the tumor grows into a life-threatening case of cancer.

A fascinating multiethnic country and an innovative technology location: India unites tradition and progress to an extent that few other countries can match

Evonik's predecessor companies established footholds in India over 40 years ago. Since then, the company has continually increased its operations there. It's an investment with a promising future

TEXT **NICOLAS GARZ**

About 1.3 billion people live on the Indian subcontinent. More than 100 languages are spoken in this gigantic country. At times, communication can be challenging. Therefore, English serves as the universal business language. India is home to a wide spectrum of ethnic groups and religions. That's why the coexistence of various cultures is an everyday experience. India's diversity is what makes it so fascinating—and at the same time it's one of its biggest challenges.

The taste of diversity: Indian cuisine is characterized by an abundance of spices and condiments. It's also sumptuous, because it uses oil and butter lavishly. To make sure the vegetable oil used for cooking can be kept for long periods, it is hydrogenated during production. The necessary catalysts are produced by Evonik Catalysts India in the city of Dombivli in western India.

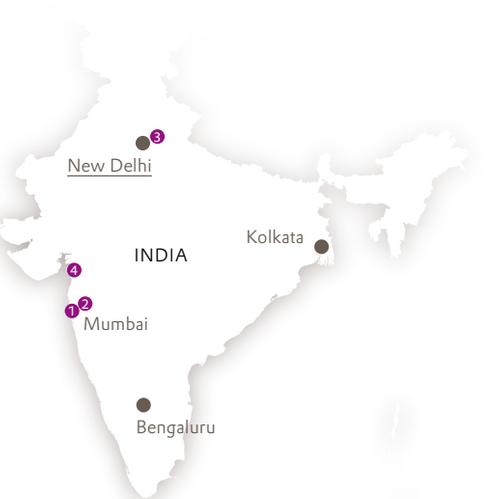
Technology creates opportunities: A flourishing IT industry has been developing in India since the 1970s. Today numerous companies and startups are driving the digitalization of the country forward. A key element of this process is the creation of a fiber-optic network with cables that operate reliably. Evonik produces raw materials for manufacturing optical fibers that are extensively used in India.

Visitors to India are more than likely to encounter freely roaming cows and bulls. Cattle enjoy a very special status in this country. Hindus worship them as holy. At the same time, cattle are important farm animals. India is the world's biggest milk producer, and consequently its need for nutritious animal feed is huge. As a major producer of amino acids for feed additives, Evonik is helping to meet this need. In addition, it's improving the gut health of Indian chickens with its probiotic GutCare® PY1.

A godly vision: Images of the Hindu divinity Lord Ganesha are produced in all sizes and carefully painted for the god's annual festival. At its production facility in the city of Jhagadia, Evonik produces silica that is used in such paints.

FOCUSING ON EXPANDING LOCAL FOOTPRINT

Evonik has three production facilities in India. In Dombivli the company produces hydrogenation catalysts for oils and fats, precious metal catalysts, and active metal catalysts. At its facilities in Gajraula and Jhagadia it produces silica. Evonik India has its headquarters in Mumbai. In addition, Evonik operates two research centers and numerous sales offices throughout the country.



Major Evonik locations
1 Mumbai
2 Dombivli
3 Gajraula
4 Jhagadia

At

7

locations in India, Evonik has

656

employees.

Startups and Spinoffs—Are Major Companies Going Extinct?

Thanks to their sophisticated and capital-intensive production processes, the established major chemical companies still seem to be protected from attackers using disruptive business models. But innovative young competitors could soon put them in jeopardy as well

Prof. Wendelin Stark
is the Professor of Functional Materials Engineering at the Institute for Chemical and Bioengineering of ETH Zürich. He studied chemistry at the ETH and has a Ph.D. in mechanical and process engineering

TEXT **WENDELIN STARK**
ILLUSTRATION **HENRIK ABRAHAMS**

The view from the executive floors of big international companies frequently offers great perspectives. However, it can also generate a sense of unease. That's because sitting somewhere far below are those people—the super-innovative and fully digitalized young teams of dynamic, highly motivated employees who would lay down their lives for their companies.

Some of these teams are hidden away in nondescript small-business premises, while others seek the companionship of like-minded people in collective coworking spaces. The dream of the young entrepreneurs who are our new heroes contrasts with the feeling of being subjugated by strict rules laid down by corporate headquarters and the demands of shareholders, regulators, and activist groups. And this dream persists, even though most startups' real achievements are often minuscule and don't justify the corporate value and expectations we generally associate with them.

The power of this new development can be seen on the stock market, where bold newcomers are pushing well-known companies out of the stock indices. It's also evident in the competition for talented young people, with new companies being acclaimed as popular employers and enticing qualified employees away from time-honored industrial groups.

In the chemical industry, we've been largely unaffected by major upheavals so far. In our sector, we still haven't had an Elon Musk directly attacking well-established companies. Nor can we expect existential shocks like those that have turned the media and the music industry upside down. So can we lean back, relax, and watch the turbulence in other sectors from a safe distance?

Why has the chemical industry so far remained unaffected by the upheavals caused by disruptive business models? In my opinion, there are four main reasons:

1. The chemical industry is profitable and extremely capital-intensive. In the entertainment, news, and music industries, there are low entry thresholds for digital business models with disruptive potential. That's because the initial investments are often relatively affordable, and as production quantities increase the marginal costs of the production and digital marketing of texts, videos, and songs approach zero. By contrast, the scale-up costs are high in the chemical industry, and every increase of production requires additional capital.
2. Regulation, security, and liability: The chemical industry is strictly regulated, its products must go through complex authorization processes, and its supply chains require extensive guarantees. These obstacles also make it hard for newcomers to start up companies in this sector.
3. Long years of training and specialization: The high degree of specialization of skilled workers in the chemical industry results in the mutual dependency of employees and employers.
4. Patent protection: Patent protection of a company's own products for 20 years is a central strategic tool. In the pharmaceutical industry, patent durations are in fact one of the most important valuation metrics for determining a company's corporate value and capacity for action.

The barriers discussed above are obstacles as long as capital-intensive business models offer advantages. But the low-interest policy that was introduced after the financial crisis of 2008 has made it much easier to enter a capital-intensive line of business. The seemingly stable pillars of the chemical sector thus turn out to be weak points, because they encourage companies to be sluggish and offer attractive fields of action to agile new market participants.

As a result of digitalization, manufacturers of electronic hardware long ago forfeited the dominant position they used to occupy. The development of operating systems was the basis of software suppliers' advancement. Today the operators of social networks are defining the business. It's not possible to draw a simple analogy with the chemical industry, but I believe it's worthwhile to think about whether similar upheavals could also happen here.

The corporate structure of our sector today is defined by a few big companies, gigantic production facilities with a high degree of specialization, and access to sources of raw materials such as oil and gas deposits and mines. The transition to cyclical raw material use and recycling processes, as well as the use of locally sourced energy and raw material components, are creating an entirely new business environment. As a result, the size and cost advantages of large facilities are disappearing. The key drivers of this development include the consumers' increasing desire for more transparent production and supply chains, so that a product's journey can be traced more accurately. In parallel, producers' and suppliers' technical capacity to create this transparency is also growing.

Until today, the strategic considerations of the chemical industry have been dominated by familiar chemical processes and product attributes. However, the decline of prices for computing and communication services is leading to increasingly affordable programs for modeling. There has been a similar decline in the prices for the analysis and synthesis of nucleic acids, and an enormous increase of the capacity of biological methods. This is opening up a multitude of new opportunities for synthetic biology. The convergence of these two developments could lead to a situation where even complex chemical products will be produced decentrally in the future. Large production facilities with long transport routes may be replaced by small decentralized units that produce specific products as needed, using local starting products. The only thing to be transported would be the information that defines the production processes. And the costs of this transportation would be practically zero. That would create a cost structure like the one that already exists in the world of the Internet and IT technology.

Chemical products will always remain important ingredients. But if the chemical industry continues to encounter new developments as passively as it has done so far, it runs the risk of losing its significance as an industry and retreating into the role of a supplier and provider of service functions. This development will be likely if other industrial sectors continue to push their way into the chemical industry's traditional areas of business, and if the chemical industry is no longer presented in social contexts and education as an independent discipline but rather as a contributing concept that has only subordinate importance.

If that happens, chemical companies would also become less attractive employers on the labor market. Young professionals now have a multitude of opportunities to shape their future. They can choose to become employees in a large company or to take a bold step and start their own business. The obstacles to entrepreneurship are much lower than they were 20 years ago, and access to capital is easier—for example, through crowdfunding or as a spinoff from a university. The most innovative and motivated young talents are more strongly attracted to entrepreneurship than are university graduates with rather average degrees. As a result, major companies are facing the challenge of either developing attractive job offers or having to recruit employees from a shallower pool of talent. Innovative approaches for major companies might include enabling greater participation for their employees—in other words, enabling employees to more quickly become shareholders of the company they work for.

The transformation of the world of the 20th century—which was characterized by major companies, massive marketing expenditure, and long-term investment planning—into a new world that is still undefined in many areas is both challenging and exciting. This new world is one in which critical customers have considerable influence on the structure of supply chains, with network-based opinion-making and low capital costs. All of the attempts made by major companies—including companies in the established chemical industry—to maintain the status quo as long as possible are not a promising way to deal with this fundamental transformation. Instead, what we need is much more openness to new ideas and the courage to entrust entrepreneurially minded young managers with greater responsibility for shaping this future.

"RESEARCH REQUIRES FREEDOM"

Creavis, Evonik's innovation unit, is turning 20. Its success depends on balancing its closeness to the company against its distance from it, explains Managing Director Stefan Buchholz

TEXT **MATTHIAS LAMBRECHT** PHOTOGRAPHY **BASTIAN WERNER**

Prof. Dr. Stefan Buchholz
has headed the strategic innovation unit Evonik Creavis GmbH since October 2012. After studying chemistry in Marburg and earning a doctorate at the Max Planck Institute for Polymer Research in Mainz, he started his professional career in 1993 as a research associate at the former Degussa company in Frankfurt. From 2008 on, he was in charge of the Innovation Management unit of the Advanced Intermediates Business Unit at Evonik. He has been an honorary professor at the University of Stuttgart since 2011.

Creavis has existed for 20 years as an independent strategic innovation unit. During this time, many other companies have followed Evonik's example and created comparable structures. Why is it so difficult to forge ahead with innovations inside big industrial groups?

Large companies' responsibility to produce results in their business operations inevitably leads them to focus on shorter-term objectives. By creating a strategic innovation unit, Evonik's Executive Board created a counterweight to this tendency. However, at Creavis we are not in a fundamentally different situation, because our resources are also limited. But we have a different perspective: We define "short-term" as "over a period of five years," whereas in the operational business it would mean "over a period of one to three years." But in spite of our independence, we don't do everything alone. Instead, we cooperate closely with the operating units—the business lines—especially the Project Houses.

1998 Creavis is founded as the innovation unit of Hüls AG. Merger of Degussa AG and Hüls AG to form Degussa-Hüls AG.

In which areas do you have to work closely with the company, and where do you need distance in order to create optimal conditions for innovation?

That's the central question! We need both. We need distance so that we're not under daily pressure to generate profits. That's why we compare Creavis with a greenhouse, where new ideas can sprout and where they have time to mature into new products or business models before being handed over to the operating units. But we also need a close connection with the company so that we can coordinate strategies for ultimately making the commercialization of these products and business models successful. Our job is to identify new themes and accumulate expertise so that we can develop products and open up new markets. When we get to the marketing stage, the responsible business unit at Evonik takes over. If the marketing stage is to succeed, it has to be clear in advance that there is interest in the new product.

Is it possible for the strategic approach to be too narrow, so that it's an obstacle to creative thinking and unpredictable innovations?

We focus on seven innovation fields, six of which correspond to the innovation growth fields of the company. We have agreed with the company on very clear rules of procedure. And we cooperate closely with the heads of the operating units when we identify potential innovations in the individual growth fields. But not everything we work on has to fall within one of Evonik's growth fields. In this regard, we take liberties—and after all, that's exactly what we're supposed to do.

When you're selecting projects, how closely do you cooperate with the company?

Of course we don't operate in a vacuum. But research requires freedom. The Steering Committee, which meets twice a year under the leadership of Harald Schwager, the Deputy Chairman of the Executive Board, provides the framework. This committee decides about matters such as the innovation fields that we recommend. However, when it's a question of launching a new project within an innovation field, that's an internal decision made by Creavis.

What happens when ideas have a disruptive potential that could threaten the work that has been done so far by important business units at Evonik?

In the area of product development, it often happens that a new product replaces an existing one. That can cause resistance. Especially in these cases, it's an advantage to have a separate unit such as Creavis, where projects can be pursued until they reach a certain degree of maturity. And if these projects reveal the superiority of the new technology, it's also easier to get the operating unit enthusiastic about it—for example, if we consider certain biotechnological processes that can replace conventional chemical processes. →

2000 First Project House for developing nanomaterials in Hanau.

2001 Entry into biotechnology through the launch of a Project House of the same name.

2003 The technological basis for the production of pharmaceutical amino acids via biotechnological processes is created at the Proferm Project House.

"For a researcher, it's normal to have some things that don't work out as expected"

How are new ideas generated at Creavis?

It's very hard to generate really good ideas. Of course I could assign my employees the task of inventing a beaming device like the one used in the Star Trek TV series. There would certainly be a need for it, and a market too. But we don't have the technological know-how to make this idea a reality. In the past, researchers would often think up technological innovations without clearly knowing how they could be developed into salable products. Innovation takes place only at the point where two factors come together: an approach to a solution and a demand resulting in a market. That's what we focus on here. Hierarchies don't play a very big role at Creavis. We encourage all of our employees to develop their own ideas. But proposals can basically come from anywhere: from our employees, from the Executive Board or from our customers. Our Portfolio Development unit then has the task of assessing these proposals. That also enables us to react quickly to new ideas that are brought to us from outside the company. That's a key factor for making sure that open innovation—that is, innovation in close cooperative networks with partners who contribute complementary expertise—works in practice. Keeping such networks operational is an important part of our strategic mission.

In the Project Houses at Creavis, experts from various units at Evonik work on a topic for a period of three to four years. How did this model come about?

This concept dates back to the Degussa company. Back then, the idea was to work cooperatively on topics that were relevant to several operating units and had a long-term outlook. However, in the beginning there were no direct connections with the operating units. That's why it was decided to bring employees from these units together with Creavis for a period of three to four years in a Project House so that they could work together very closely for a limited period of time. This model brings together experience and know-how from various units within the Project Houses. Initially an important objective was to exploit the synergies between the various business units. Today the focus is more on developing expertise—for example, in the

Medical Devices Project House. One of the projects we conducted there developed biodegradable materials for implants that are used to replace bones. There were already some points of contact with other parts of the company, but there weren't any real activities. We built up a new research team and the entire infrastructure, invested several million euros in apparatus and lab equipment, and worked on concrete projects. In the end, we transferred the entire Project House to the Health Care business line as a competence center.

What criteria do you use to decide which ideas you want to pursue?

We have an "open innovation" approach, and within this framework we check with increasing detail whether the assumptions that underlie each project are actually correct. Does the technical approach to a solution fulfill the criteria that have been set for it? Is the solution really as sustainable as we presume it is? In the beginning, openness and flexibility are important. The further the project progresses, the more concrete are the questions we ask. All of the aspects that are relevant to a project's success should already be thought of in the earliest phases possible. The managers at Creavis support the project managers by acting as consultants and helping them to realize their projects. But it can also happen that after a few months or even years the manager, together with the team, comes to the conclusion that the project should be discontinued because its further development would no longer be justified in economic terms.

Clever heads: Outstanding researchers from the history of the Evonik companies greet visitors in the foyer at Creavis

What factors are needed in order to create and sustain an open innovation culture?

I believe that the chemical industry as a whole is quite open. There has always been close communication between companies and universities. Basic research has generated lots of momentum for the industry. But there has been a fundamental transformation in the past two or three decades. Research is reaching its limits. In the past, pioneering discoveries such as polyethylene formed the basis for establishing entire industrial segments. Today innovation is much more strongly driven by the application. As a result, in the area of development we need a much better understanding of applications, and that means we have no other choice than using the open innovation approach. Let's take 3D printing as an example. We want our materials to work for a variety of technologies, so we have to collaborate closely with the manufacturers of 3D printers. In addition to cooperation with our customers, interaction with startups is also gaining in importance. But we have to keep in mind that many innovations coming from universities are more likely to end up in startups than in major companies.

Why is that?

That's a good question, and there's no simple answer for it. One important aspect is the fact that it has become harder to access the know-how of universities. That's because the universities themselves are utilizing their patents. In many cases, they prefer to support a doctoral candidate who wants to open his or her own business through a spinoff, rather than backing a major industrial company. But we also have to be realistic and admit that there are lots of interesting ideas that might justify founding a new company but are not relevant for a major industrial group. When we enter new territory, we have to be on the lookout for bigger potential than most startups are interested in. →

2005–2006 Development of the Science to Business Center in the Marl Chemical Park on the basis of open innovation together with cooperation partners from the science and business communities.

In the innovation unit, which is headed by Stefan Buchholz, hierarchies don't play a very big role. Every colleague is encouraged to contribute his or her own ideas

2007 Integration of Degussa AG into Evonik Industries AG.

2011 The Light and Electronics Project House is launched in Taiwan. It's the first Project House outside Germany.

When is open innovation equally fruitful for the company and for its external partners?

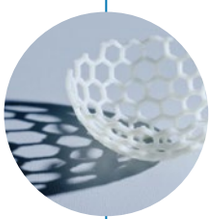
The biggest opportunities for us are in the areas where the knowledge is complementary. That's why we're interested not only in chemical startups but also, and perhaps even more, in young IT companies whose technologies can be combined with our products. This can generate benefits for both sides. Besides, we also work with other big companies, such as our major customers, with whom we jointly develop products.

Many big companies are making an effort to establish an ecosystem of innovative startups. How are you proceeding in this area?

We're keeping a close eye on this development, and we're involved in professional networks so that we can work together with partners in areas where it makes sense to do so. We closely coordinate these activities with Evonik's corporate venture arm, which maintains connections in the venture capital scene and invests in startups.

2014 The launch of Creavis 3.0, which has three new units: Portfolio Development, Sustainable Businesses, and Science & Technology. The harmonized innovation process I2P³ takes into account the ecological and social consequences of potential projects at an early stage.

2016 Entry into 3D printing through the establishment of the Direct Manufacturing innovation field.



2018 The temporary Medical Devices Project House is transformed into a permanent competence center. The recently launched Tissue Engineering Project House is intensifying Evonik's research in the area of regenerative medicine.

Independent development units have been created within many companies in recent years. What experiences have you gathered as a pioneer that the newcomers still have ahead of them?

We've learned that it's important to maintain the right balance between closeness to, and distance from, the company—and to have great operational freedom as well as a high level of strategic coordination. We're doing that much better now than we did in the beginning. Many companies from other sectors have come to us in order to learn from our experiences, because digitalization is forcing them to reorient themselves to an unprecedented extent, and because they don't possess the innovation culture that we've always had in the chemical industry.

Is the success of Creavis measurable?

Through Creavis, the company is investing in long-term innovation. And it wants to receive something in exchange for its investment. That's why for the past five years we have sat down together with the business line that is profiting from one of our innovations and used the discounted cash flow method to determine the value of each newly developed product. The business lines are very critical in this regard. At the end of the year, the value of all the transferred projects has to be commensurate with Creavis' expenditures. That's the benchmark for our success.

If you're trying to forge ahead with innovations and take bold new steps, do you experience failures as well as successes?

For a researcher, it's normal to have some things that don't work out as expected. I've spent years working in laboratories myself. About 99 percent of the trials don't deliver the result that was hoped for. That's normal. Researchers traditionally don't talk about a failure—instead, they think about the next trial. The wonderful thing about this approach is that in the end you've got a lasting success—and the many bitter setbacks you had on the way there are quickly forgotten.

If you look back at Creavis' first 20 years, what were your biggest successes?

Creavis' biggest success might be the fact that today we have a corporate growth field called Membranes. The second big success story is the area of biotechnology, which we have expanded through our development work. And the most recent example of a successful product launch is REHANCE ONE, a natural ingredient for cosmetics that recently received an award at a major professional trade fair. The foundation stone for this development was laid at Creavis. The crucial ingredients of successes like these are the combination of various kinds of expertise at Creavis, our willingness to take risks, and our long-term orientation.

SMART FABRICS

Pants that serve as sports trainers and jackets that detect poisons: Future-oriented researchers at Creavis are developing the textiles of tomorrow

TEXT **EVA MORSBACH AND BJÖRN THEIS**

Clothing is one of mankind's earliest innovations. Some researchers believe that humans were making clothing as early as the Middle Paleolithic period—approximately 200,000 years ago. The main function of this clothing was to protect the wearer from cold, sunlight, moisture, and injuries. For at least the past 5,000 years, clothing has had an additional significant function—one that was demonstrated by the discovery of the Tarkhan Dress. This elaborately knife-pleated linen garment is the world's oldest surviving woven garment. It testified to the wealth of Egypt's First Dynasty and signified its wearer's high social status. Clothing had become fashion.

Thanks to nanotechnology and the miniaturization of computers, today we are on the brink of the next evolutionary leap in the historical development of textiles. In the years ahead, pants, jackets, and coats will be performing entirely new and complex functions. In the vision of researchers, clothing will no longer consist of passive textiles. Instead, it will be the active performer of various tasks.

One important basis for these innovations was created when synthetic textile fibers were developed in the first half of the twentieth century. Before that time, clothing consisted of natural fibers such as linen, wool, and silk. In 1935, the DuPont company started selling the first synthetic fiber, which was made of polyamide. Nylon stockings, which were launched on the market on May 15, 1940—"N-Day"—immediately became a bestseller. On that day alone, five million pairs were sold in the USA. During the war years, synthetic fibers were needed for military equipment such as parachutes, tents, and ropes. As a result, nylon manufacturers promptly restricted their production of nylon stockings. They were sorely missed—in fact, surveys of American women showed that nylons were missed even more than the men who had gone to war.

Synthetic fibers opened up opportunities to provide clothing with new functions. For example, nylon stockings can be made so thin and elastic that they cling to the legs without becoming uncomfortably hot. Today's bulletproof vests are quite comfortable to wear, because they are made of lightweight synthetic fibers that are woven together into stiff and firm textiles that bullets cannot penetrate.

In the near future, clothing may watch over the vital functions of newborns, and protective work suits could monitor the well-being of workers. Sensors in romper suits could protect babies from sudden crib death while they sleep. Workers doing hazardous jobs could be warned by their clothing if the concentrations of toxic gases in their surroundings exceed the limit values.

Other types of fibers could make it unnecessary to change clothes when the temperature changes, because they will be able to switch between warming and cooling their wearers. The volume of the fibers would change according to whether the wearer is sweating or shivering. Sportswear could take over a number of trainer functions by vibrating at the points where the wearer's posture is not correct. In order to do that, fibers with a sensor function would have to register the wearer's posture and compare it with a database in which the ideal postures were described.

In order to integrate all of these functions into clothing comfortably, it must be possible to process the functional material into fibers without it losing its ability to gather information and share data. This requirement presents a number of problems, because the material's functional properties must be retained even though the material is manufactured in the form of very long fibers with tiny diameters. At the same time, the material must be flexible enough to be woven into a textile and robust enough to survive the spin cycles of washing machines.

The challenges posed by these requirements have not been solved so far. Evonik is playing an active role in the development of smart fabrics. After all, the company has gained expertise through its development of various polymers, and Evonik Fibres GmbH has had years of experience spinning polymer fibers. Evonik's Corporate Foresight team, which is part of the Strategic Innovation unit at Creavis, is conducting research on the future applications of intelligent clothing. And who knows? One day shirts and blouses might be smart enough to iron themselves.

This interactive dress developed by the Canadian fashion designer Ying Gao interacts with its environment: It reacts to an observer by moving around and glowing in the dark

6 12,011
C
Carbon

“We’ve Created a Molecule That Will Make It into the Textbooks”

PROTOCOL **NADINE NÖSLER**
PHOTOGRAPHY **JONAS HOLTHAUS**

Moritz Malischewski had to make a decision after graduating from high school in 2007. Should he study chemistry or music? He decided on chemistry. However, in his leisure time he still loves to play the piano and the organ

Carbon atoms can form exactly four bonds. At least that’s what the chemistry books tell us. This is a law that is carved in stone—supposedly. I say that because we’ve found an exception to the rule. My doctoral thesis supervisor, Professor Konrad Seppelt, and I have isolated a molecule in which a carbon atom is surrounded by no less than six bond partners. It’s called the hexamethylbenzene dication. This may sound very theoretical to a layperson, but for real scientists a discovery like this one is almost like the Holy Grail. Why? Because it expands our knowledge about the world and helps us understand it a bit better. That’s what basic research is all about. Because this special molecule is very unstable, it will never find any applications. Nonetheless, it enlarges our understanding of the chemical bonding behavior of the element carbon. I’m a specialist in inorganic chemistry, so it was a coincidence that I happened to investigate the bonds between carbon atoms. While I was doing the research for my doctorate, I came across a paper written by a Dutch chemist in 1973, in which he postulated the existence of such a molecular structure but was unable to prove that it actually exists. I was curious to see whether we could create it with the technology we have today, so I started experimenting. After many failed attempts, I wondered at times whether I would ever produce any results. Nonetheless, I persisted. I was determined to make my work pay off. I finally did find the proof, and that evening I left the laboratory grinning from ear to ear. Moments like these are what a researcher lives for. The fact that we succeeded demonstrates yet again that for every rule there’s at least one exception. You just have to find it!

On the desktop, the tablet or the smartphone—Elements is naturally also available online:

elements.evonik.com

Masthead

PUBLISHER Evonik Industries AG | Christian Schmid | Rellinghauser Straße 1–11 | 45128 Essen, Germany | **CONSULTING AND CONCEPT** Manfred Bissinger | **EDITORS IN CHIEF** Dr. Karin Aßmann, Matthias Ruch (responsible for editorial content) | **EDITORIAL TEAM** Chris Höfner (Head), Matthias Lambrecht (Text Editor), Jörg Wagner | **MANAGING EDITOR** Inga Borg | **AUTHORS** Niels Boeing, Nicolas Garz, Johannes Giesler, Bernd Kaltwaßer, Christian Kullmann, Matthias Lambrecht, Deborah Lippmann, Eva Morsbach, Nadine Nösler, Tom Rademacher, Wendelin Stark, Björn Theis | **PICTURE EDITING** Nadine Yun | **AGENCY, LAYOUT, AND EDITORIAL ADDRESS** BISSINGER[+] GmbH Medien und Kommunikation | An der Alster 1 | 20099 Hamburg | info@bissingerplus.de | **TRANSLATION** TransForm GmbH, Cologne | **PRINTING** Neef+Stumme premium printing Wittingen | **PICTURE CREDITS** Cover illustration: Tobias Wüstefeld/Die Illustratoren | p. 3 Kirsten Neumann | pp. 4–5 Jann Klee, iStockphoto, Bernd Thissen, Getty Images/Image Source | pp. 6–9 Marco Damaschek, Biocon, Sharon Sue, Bryce Duffy/Corbis via Getty Images | p. 10 Jann Klee | pp. 12–14 Getty Images | p. 15 illustration: BISSINGER[+] | pp. 16–17 Franklin Thompson/Gallery Stock, Getty Images, W2 photograpy/stocksy.com | p. 18 Ivan Genasi/Blaublut-Edition.com | pp. 20–25 Jann Klee | pp. 26–27 WARR Hyperloop Team, CALOSTAT/ German Design Council, The Linde Group | p. 28 Andreas Pohlmann/Evonik | p. 31 Science Photo Library/Alfred Pasieka | p. 33 Science Photo Library/Carlos Clarivan | pp. 34–39 illustrations: Max Nertinger, photography: yoeml/Shutterstock | pp. 42–49 Getty Images (4), imageBroker/Stefan Auth | p. 52 illustration: Henrik Abrahams | pp. 50–55 Bastian Werner (3), Evonik/Christian Schlüter, Karsten Bootmann, Stefan Wildhirt | p. 56 Dominique Lafond | p. 58 Jonas Holthaus | p. 59 creativemarket.com

Doubt is the father of invention,

as the polymath Galileo Galilei is reported to have said 380 years ago. Constructive doubt and critical questioning are the activities that make innovations possible. And that's why at Evonik we're always asking the crucial question "What can I improve—and how?"

This issue of ELEMENTS reports on researchers who have answered this question in various ways. They work in areas ranging from cosmetic active ingredients that combat stress to the battle of nanotechnology against cancer cells. These are stories about people who are changing the world through their ideas, because they never stop doubting the status quo.