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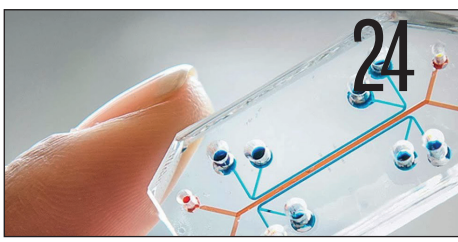
# CONTENTS

## FEATURES





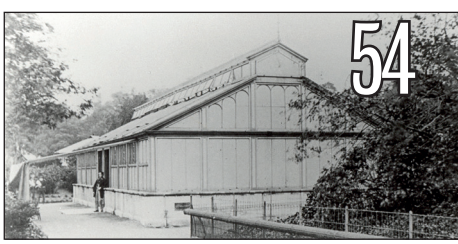

## GENERAL





## REGULARS



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wattnow

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2019 Q4 - 13 496

We are at the end of May, day 65 of lockdown, with June promising a bit more. Since March, many of us have become adept at working from home, attending daily meetings online and keeping the fires going all the while learning and experiencing the 'new normal'.

This issue of the **watt**now features Biomedical Engineering, and our first article, written by Professors Tania and Johan Hanekom from the University of Pretoria, is "The quest for person-specific computational models for custom interventions in Cochlear Implants". Read this on page 18.

Our second feature article discusses the organ-on-a-chip (OOAC) - one of top 10 emerging technologies and refers to a physiological organ biomimetic system built on a microfluidic chip. Find this fascinating article on page 24.

Dudley Basson entertains us with yet another of his in-depth historical article on Thomas Young (1773-1829), a polymath whose astonishing breadth of knowledge and expertise led to his becoming known as 'The man who knew everything.' Find his article on page 42.

On page 48, Dudley also gives us a "Timeline of Genius and Innovation", and he depicts this timeline on pages 50 & 51. It makes for a fascinating read.

Watch out the **watt**now ST-Talk: Biomedical Webinar, which will take place 13:00 CAT, 23 June 2020. Our presenters will be Professors Tania & Johan Hanekom, who will be discussing their research on Cochlear Implants.

This online version of **watt**now is interactive. So, on the contents page, click on the page number of the article you are interested in, you will be taken directly to the page. When you are done, select the endnote ( wn ) which will return you to the contents page.

Here's the May issue,
enjoy the read, take care and stay safe!

Minx

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**SY GOURRAH**
**2020 SAIEE PRESIDENT**

COVID-19 has turned our worlds upside down regardless of where in the world we are. It has drastically impacted our everyday situations as well as our health. In these uncertain times, when we have fears concerning our jobs, finances, health and survival, it is essential to stay positive and safe.

# What is happening?

Never in the history of the SAIEE have we had an 'e-AGM' followed the next week by the first-ever e-Presidential address. This goes to show our resilience and how quickly we can evolve when necessary. Since then all of SAIEE's meetings and many events have been scheduled as webinars, with record attendances. We have all been propelled a new world in ways we could never have imagined, for example working from home, social distancing and time restrictions.

SAIEE is using this opportunity to build on our existing digital platform of online ST-Talks, webinars to include committee, chapter and section meetings as well as online courses in the future. So far, 2020 can be described as a trailblazer. We all have had to navigate and innovate our way through the upheaval and survive the lockdown.

During this period, I call upon you to engage with industry specialists and leaders in the different committees, chapters and sections to learn and contribute to the body of knowledge in the electrical engineering arena. To date, we have networking platforms for numerous sections and their respective chapters, such as Renewable Energy, Battery Electric Storage, High Voltage Engineering Smart Grids, Asset Management, Robotics, Cyber Security, Computing, Biomedical, Smart Metering etc. On the cards are the launching of the following sections (and chapters): Transportation (Railway Signalling, Electrification, EV) and Building Services (Lighting, Smart Buildings, Security & Access, Building Energy efficiency etc.). We require passionate people who would be interested in becoming actively involved in the SAIEE. I urge you to participate in giving back to the Engineering society.

In these difficult times, let us band together to lead through this crisis and come out of COVID-19 stronger. For further information on centres, student chapters, committees, sections, chapters, interest groups, please contact Leanetse on leanetse@saiee.org.za.

Even before lockdown, the SAIEE has been working feverishly in getting the CPD Online Training Courses off the ground, with the first course starting online on the 1st of June.

There is a saying that from every major crisis, opportunities will be created. Stay safe, use your time wisely, be generous and be active.

"A life lived in fear is a life half lived."

*S Gourrah I SAIEE President 2020*
*Pr. Eng I FSAIEE*

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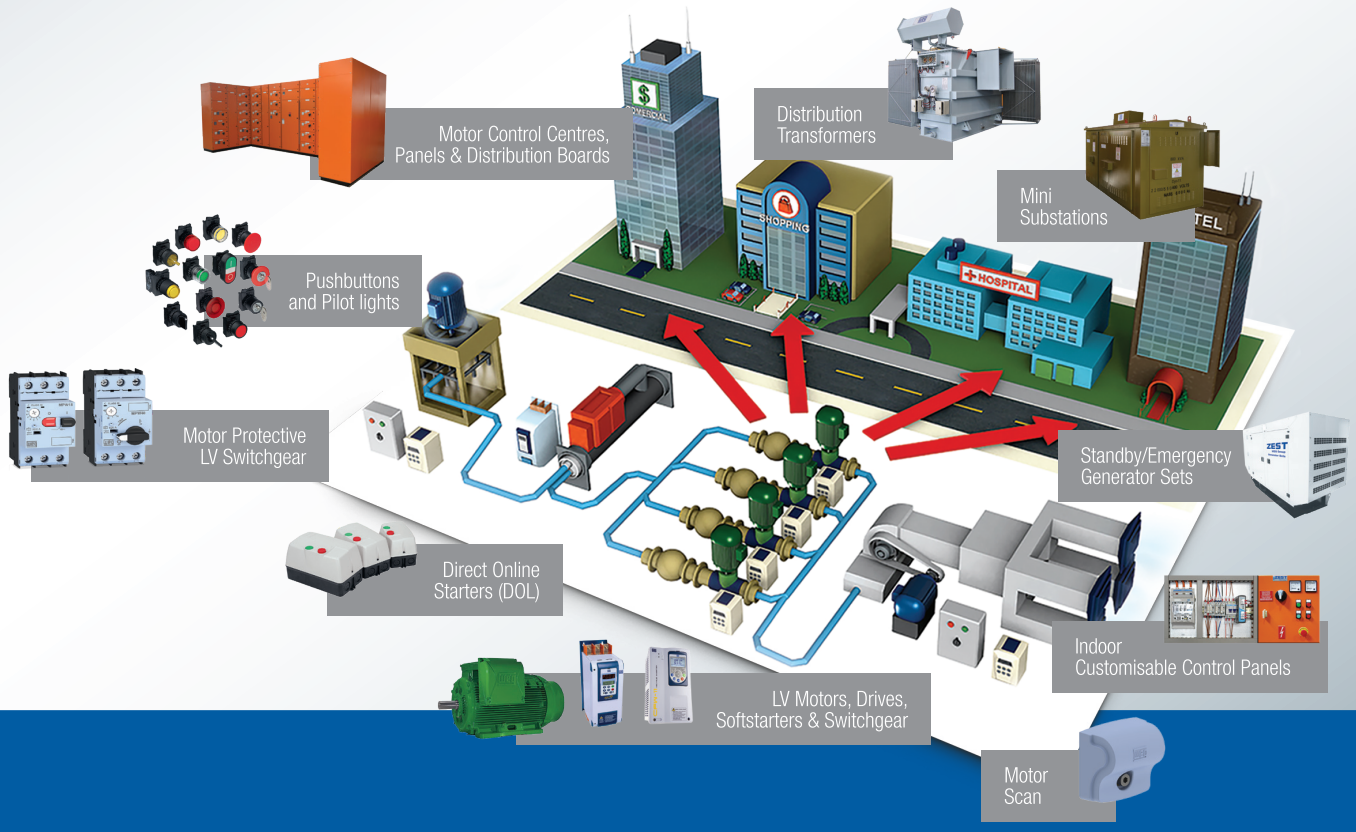


An in-depth understanding of the requirements for HVAC applications, access to quality product solutions and years of experience have ensured that the Zest WEG service offering is fit-for-purpose. From single product installations to individually customised solutions, our latest technology ensures optimal performance, increased reliability and the highest levels of energy efficiency. Reduced maintenance and ease of serviceability assist in lowering the total cost of ownership for operations.

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# INDUSTRY AFFAIRS

## SAIEE LIBRARY FUND UPDATE - Letter from the Historical Section

Dear Colleague,

You will recall that in the April issue of wattnow - I was appealing for assistance with the on-going work in the Historical Section Library.

It is my pleasure to be able to report that as of 30th April, a total of 50 members have responded to the appeal and that an amount of R21 350.00 now stands in the Fund.

On behalf of the members of the Historical Section, I record sincere appreciation and gratitude to all contributors. Your assistance will help to take us a further step along the road of re-organising the Library.

If any readers are still intending to contribute, I thank you in advance and hope to be able to report further growth in the Fund in the near future.

Quite simply, we ask if you are willing to make a once-off donation of R100 - or more if you are able - to a special SAIEE "Library Fund" to enable us to pay for the continued service of the current part-time assistance. If you can assist, please make an EFT to the Institute's bank account, marked "Library Fund."

Name: SA Institute of Electrical Engineers
Account number: 201547066
Bank: Standard Bank

I would appreciate hearing from you if you would like any further details.

Many thanks again,

**Max Clarke**
**Chairman, SAIEE Historical Section**
**Email: mppc@mweb.co.za or call 083 273 9519**

## Electrical loggers help reduce facilities' energy costs

One of the most significant costs at industrial facilities is energy. While many managers view energy as an unavoidable expense, in reality it is a variable cost that can be monitored and managed, significantly improving the bottom line.

COMTEST, local representative of Fluke has the 1732 and 1734 Three-Phase Energy Loggers - powerful tools designed to easily identify sources of electrical energy waste. Easy to set up and use, and capture key measurements — voltage, current, power, power factor, plus variables like temperature, the 1732/1734 enable managers to understand energy usage and correlate it to activities. These loggers are also Fluke Connect® compatible. Data can be viewed from anywhere via the Fluke Connect mobile App, potentially reducing the number of times a technician must open a panel while wearing full protective equipment.

The 1732 and 1734 also include the new Energy Analyze Plus App software, delivering more advanced analysis capabilities to better correlate data, and make better decisions. The loggers are rated 600 V CAT IV/1000 V CAT III — the highest safety rating in the industry — for safe use at the service entrance and downstream.

Contact COMTEST on 010 595 1821 or sales@comtest.co.za for information on Fluke 1732 and 1734 3-Phase Electrical Energy Loggers, or for upcoming seminars, demos or to locate the nearest dealer.

**WATCH**

*The new Fluke 1732 and 1734 Three-Phase Energy Loggers*

# Masta housings from BI are ideal for conveyor pulleys in mining


Such has been the success of the housings imported from the Masta Group of India that leading supplier Bearings International (BI) is offering these to be used in conjunction with its FAG, Koyo, KML, and Craft bearings. This forms part of BI's strategy to continually expand its product range with reputable global brands.

*"Masta housings have been used by most of our major Original Equipment Manufacturer (OEM) customers due to the exceptional quality,"* Product Manager Matthew Tyler highlights. In addition to the OEM sector, BI also supplies the aftermarket and major project houses. Key OEM customers are manufacturers of conveyor pulleys for the mining industry, including Hudaco Group company Bosworth.

BI carries the standard Masta range, comprising the SN, SD, and SNH/SNL housings with seals and locating rings. *"We will look to introduce the SDJ series, an extension of the SD design for carrying exceptionally heavy loads,"* Tyler reveals.

The SBD/BND series is a one-piece housing without any splits and two covers, which could include an end cover. Other items that BI will stock for specific customers are the THD/SPA one-piece take-up units and the PDN one-piece cylindrical housing, commonly referred to as a dual-fan housing.

The Masta housings boast some of the latest design features offered by major bearing manufacturers. The benchmark SNL housing has a flat base and sides, provision for an oil inlet, a drain plug, a connection for vibration, and a temperature probe as standard.

This housing also has a sturdier base, with a crossed rib and centre and side ribs for increased load-carrying capacity. It is available in standard-grade 200 cast iron, ductile (SG) iron or cast steel. Adding to its flexibility is that the seal is interchangeable with major bearing manufacturers.

The Masta housings conform to all international quality and dimensional standards in support of the company's zero-defect product policy, underpinned by its ISO 9001 quality certification. BI offers full aftermarket technical support for the range in South Africa, from standard to custom-made housings as per specific application and customer drawings.

*"We can assist with selections, drawings, designs, on-site fitting via our field service, or supply any other information that is needed by customers,"* Tyler concludes.

# Industrial UPS first for ABB at major local petrochemical company

Industrial sectors such as petrochemicals cannot afford production downtime due to electrical power failure or disturbances.

When a major petrochemical producer in Mpumalanga required an industrial UPS solution, Proconics selected the PowerLine DPA 20-120 kVA modular three-phase UPS system from ABB in South Africa. Many industrial sectors such as petrochemicals cannot afford any production downtime due to electrical power failure or disturbances. Not only does this require a complex and costly restart, but expensive end product is ruined. Equipment may also be damaged in such instances, which also raises health and safety concerns.

*"The main issue for such sectors is that a reliable supply of clean power cannot be guaranteed by the grid. We have seen this happening as the local utility accelerates its long-term maintenance programme, which means load-shedding is likely to increase. Thus the petrochemical industry, for example, must take proactive measures to safe-guard itself against such outcomes,"* explains Ivor Becks, ABB Sales Specialist for UPS Systems, Southern Africa.

Already a major supplier of electrical equipment and control gear to the petrochemical producer, this marks the first time that ABB South Africa has also been required to provide an industrial UPS solution. The PowerLine DPA from ABB is an online double conversion UPS that allows for the application of modular architecture in industrial envi-ronments that are typically very harsh on electronic equipment. It is based on ABB's Decentralised Architecture (DPA) for benchmark UPS design in terms of availability, flexibility, cost and ease-of-use.

Industrial plant environments pose specific design challenges such as high temperatures, dust, moisture and corro-sive contaminants. Therefore, the PowerLine DPA from ABB features a 15-year design life for maximum reliability and uptime. Each module has all the hardware and software necessary for autonomous operation, from rectifier to inverter, battery charger, static bypass switch, backfeed protection, control logic and HMI mimic display for control and monitoring.

The modular nature means that a single module's output is unaffected by failures elsewhere in the UPS, as the load is simply taken up by the remaining modules. *"In other words, what ABB has achieved is a true multi-module system that is totally fault-tolerant, as there are no single points of failure,"* highlights Becks.

Another major benefit is that the modules can be swopped online, meaning they can be removed or inserted without having to power down or transfer to raw mains supply, which removes any risk to the critical load. This allows for continuous uptime and reduces mean time to repair (MTTR) failures significantly. Less spare parts must be held in inventory, which also simplifies system upgrades.

Modularity also relates directly to serviceability, as local personnel do not need specialised skills and spend less time on-site as a result, which helps to reduce the risk of any production loss. The PowerLine DPA at the petro-chemical producer is expected to be commissioned in July this year.

Proconics executes projects to improve and extend the life of factories, mostly on an EPC basis. While ABB also offers complete turnkey solutions, it often partners with specialist service providers to ensure its diverse client base receives the best solutions possible for their specific requirements. Becks regards the supply of the industrial UPS as a major coup for ABB in this sector, due largely to its reputation for innovative and quality solutions.

# ZEST WEG PIONEERS REMOTE WITNESSED FACTORY ACCEPTANCE TESTING UNDER COVID-19 LOCKDOWN

In an innovative 'first' to keep a customer's mining project in the Democratic Republic of Congo (DRC) on schedule despite the impact of Covid-19, Zest WEG successfully conducted a remote witness test of Medium Voltage (MV) Variable Speed Drives (VSDs) in WEG's Brazil factory.

*"These are extraordinary times, and require extraordinary measures,"* says David Spohr, business development executive for high-voltage equipment at South African-based Zest WEG.

*"With the restrictions on international travel, we had to think creatively about how to complete this final step in the manufacturing process – the witnessed Factory Acceptance Test (FAT) – before the equipment could be shipped to the DRC site."*

Under normal circumstances, these tests would require the customer to travel to Brazil and spend a week at the factory witnessing and signing off a range of detailed test and equipment requirements.

This order comprised two 7MW 3300V WEG MVW01 VSDs for the ball and SAG mill drive application and two 1,2MW 3300V WEG MVW01 VSDs for the HPGR mill application. Both applications required non-standard features, namely "frozen charge protection" software on the ball and SAG mill application and a "master & follower" configuration on the HPGR mill application.

*"It was essential that we did not delay the customer's project, so we arranged to conduct the witness test using web-based communication software,"* says Spohr.

*"This allowed the participation of Zest WEG experts, the engineering contractor and the end-user, all from the safety of their homes in Johannesburg – communicating with five testing technicians in the WEG factory in Brazil."*

Using a high-definition camera and web-based communication software, the factory technicians were able to walk the contractor and end-user through each element of the FAT, with clear and real-time visual images of the test results and equipment on the factory floor. The tests continued for three days, beginning at 13h00 and ending at 19h00 to account for time zone differences.

*The testing facilities at WEG's extensive manufacturing operation in Brazil.*

*David Spohr*
*Business Development Executive*
*Zest WEG*

Testing covered three key areas – PLC communication software integration, full functional testing and full load testing.

*"As with any other witnessed FAT, the customer was provided with a comprehensive results report by WEG,"* Spohr says. *"This enabled the customer to check, in exactly the same way, that the remote FAT results were within the required tolerances."*

Spohr notes that this pioneering step is likely to influence the way that these tests are done in future. *"It has shown that the testing can be done to the same standards, but with significant savings in time and cost,"* he says.

# DEHN Africa addresses telecoms needs with addition of new business development manager

The telecommunications industry is an important tool for business, government and indeed the fabric of our society, allowing people to keep in touch with each other for both work and social purposes. And with so many people working from home right now, with this situation set to last for some time to come, the industry is arguably more important than ever.

Today's telecoms industry is a multi-faceted and complicated vertical and as such, its infrastructure needs to be protected from adverse physical conditions, including protection from lightning and power surges. And so, in recognition of the growing importance of the telecoms industry as part of its business strategy, surge and lightning protection specialist, DEHN Africa, has recently appointed Raymond Koekemoer as business development manager: telecoms.

Koekemoer says, *"I started my career in the telecommunication industry in 2012, having joined Eaton Towers as a property coordinator before being promoted over time to site acquisition specialist. At that stage, I was managing consultants, site build contractors and building relationships with the mobile network operators Vodacom, MTN and Cell C.*

*"In 2016, I had the opportunity to broaden my horizons with Huawei Technology as site acquisition specialist, and was one of the turnkey vendors for the network operators. Over time, my role evolved further so that my main focus was to deliver on network requirements and new site build (NSB) rollout for 2019 and 2020."*

Koekemoer is excited to be on board at DEHN Africa at this new phase in its business strategy. *"I was attracted to the work environment and the positive attitude that is evident, which allows an employee the opportunity to excel in their career. I would say my management style is allowing team members to get involved in the direction of the project, giving them the opportunity to grow, and using open discussions to solve problems."*

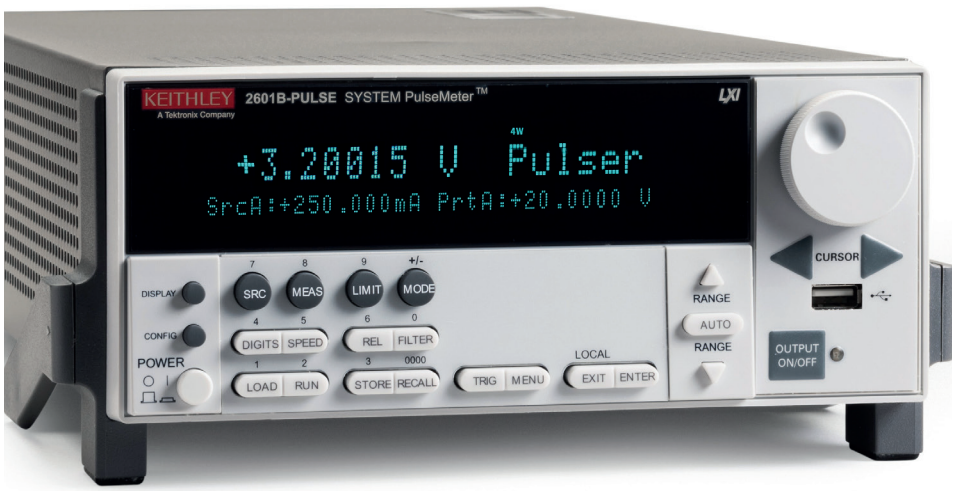
In his personal life, Koekemoer enjoys being fit and healthy, citing as one of his personal best achievements the fact that he was the first prize winner in a 10-week body transformation competition. He says taking part in this competition was about more than winning the contest itself: *"I learned lessons about commitment, discipline and self-motivation, as well as being inspired to never give up. I am more focused now on what needs to be done in order to achieve my goals, rather than focusing only on the end result."*

Koekemoer says being in the telecoms industry is challenging and that time is always against you: *"So many things are out of your control and can make or break a project. I'm proud to acknowledge that during the past four years, I gained a lot of experience, including building customer relationships."*

*Raymond Koekemoer*
*Business Development Manager: Telecoms*
*Dehn Africa*

Hano Oelofse, managing director at DEHN Africa, adds, *"We are very pleased to welcome Raymond on board. We look forward to being on this journey together as DEHN Africa takes its place in the local telecoms industry, and acknowledge the critically important part that telecoms plays in South Africa's ongoing economic development. We believe that Raymond will be a vital cog in the ongoing evolution of DEHN Africa as we continue to expand our expertise and our commitment to South Africa's well-being."*

# Tektronix' Industry-First with New All-In-One 2601B-PULSE System SourceMeter®




Poised for VCSEL and LIDAR advancement, new PulseMeter™ technology sources current pulses as short as 10µsec, minimizing joule heating effects, at 10A and 10V.

COMTEST is pleased to announce Tektronix Inc.'s new 2601B-PULSE System SourceMeter® 10µs Pulser/SMU Instrument, integrating a high-speed current pulser with DC source and measurement functions in one instrument. The new system incorporates PulseMeter™ technology for sourcing current pulses as short as 10µsec at 10A and 10V without the need to manually tune the output to match device impedance up to 3µH. This is critical for minimizing device self-heating, which for optical devices, can result in erroneous measurements and the potential for damaging test equipment. The new 2601B-PULSE also includes all current and voltage source measure unit (SMU) ranges that are available in Keithley's standard Model 2601B System SourceMeter® (40V, 3A DC, 10A Pulse). In addition, Tektronix is also releasing version 2.3 of Keithley's Instrument Control Software "KickStart" to support the pulsing function of the 2601B-PULSE.

*"The 2601B-PULSE System SourceMeter® affirms Tektronix's commitment to the advancement of technology through leading test and measurement solutions,"* says Chris Bohn, vice president and general manager at Keithley/Tektronix. *"This new instrument will bring better testing capabilities for engineers, including those who rely on industry-first technology to take innovative strides in automotive applications, connected vehicles and autonomous driving."*

## ADVANCEMENT IN TESTING WITH LIDAR IN MIND

The 2601B-PULSE System SourceMeter® was developed to serve the needs and complications of testing vertical-cavity surface-emitting lasers (VCSELs), which are mission-critical for automotive light detection and ranging (LIDAR) applications. The instrument is ideal for testing VCSELs and LEDs, semiconductor device characterization, fault power management testing, surge protection testing and beyond.

Built-in dual 1 MS/sec,18-bit digitizers enhance the pulser's measurement function, enabling users to acquire both pulse current and voltage waveforms simultaneously, without the need to use a separate instrument.

Unlike competitive instruments that require pulse tuning to minimize overshoot and undershoot on the pulse, the patent-pending 2601B-PULSE control loop system eliminates the need to manually tune for load changes up to 3 µH. This ensures that the current pulse has no overshoot or ringing when sourcing pulses ranging from 10 µsec to 500 µsec at a current up to 10 amps, resulting in a fast rise time, accurate pulse output and high fidelity.

## INDUSTRY-FIRST TECHNOLOGY

New PulseMeter™ technology eliminates manual pulse output tuning no matter the amplitude and pulse width to ensure pulse fidelity. For automated system applications, the 2601B-PULSE's Test Script Processor (TSP®) technology runs complete test programs from inside the instrument for industry-best throughput. In larger, multi-channel applications, the Keithley TSPLink® technology works together with TSP scripting to enable high-speed, pulser/SMU-per-pin parallel testing.

Because the 2601B-PULSE System SourceMeter® offers full isolation that does not require a mainframe, it can be easily reconfigured and re-deployed as test applications evolve.

Contact COMTEST– for more on the Tektronix' products and solutions on 010 595 1821 or sales@comtest.co.za

# Returning to work? COVID-19 reinfection fears addressed with new app

As the government considers how soon to lift the lockdown, the prospect of more South Africans returning to work is both a welcome and worrying prospect.

The question is this: how to fight a potential second spike in infections in compliance with government safety protocols as we attempt to reopen the economy?

That's where a new smartphone app by Solution House comes in – helping us all return to a post-COVID-19 work environment with confidence, knowing the threat of reinfection is being moderated effectively in a way we can all control.

## HOW IT WORKS

The COVID-19 People Management Solution app helps employers to manage their compliance with government-stipulated COVID-19 safety protocols by giving them an easy way to identify and manage information around employee infections.

Tiaan Janse van Rensburg, Solution House Director: Business and Commercialisation, says the app is based on Incident Desk, a global service request, routing and management engine used for national urban management and public safety.

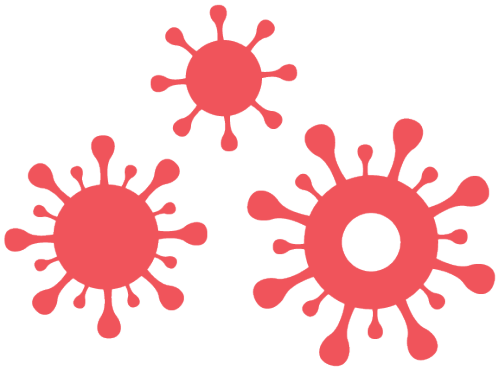
The app enables employers to easily register staff, log daily health checks and screenings, and identify Persons Under Investigation (PUIs).

*"Working in conjunction with the Incident Desk back-end management portal, it enables quick retrieval of employees' status, history and personal information. In addition, it helps companies using outsourced service providers such as security, cleaning and maintenance services to ensure that they, too, comply with government regulations and have completed daily health checks and screenings."*

## WHAT ARE MY RESPONSIBILITIES AS EMPLOYER?

The government requires adherence with the following COVID-19 health and safety practices when employees return to work:

- All employees must be screened daily for symptoms, submitting to symptom and temperature checks at work.
- There must be workplace protocols in place for disease surveillance and preventing the spread of infection.



# COVID-19
## CORONAVIRUS

These protocols and screenings must be documented and logged on a daily basis for each individual employee.

*"While the last requirement is possible with productivity applications like Excel, or as part of a more advanced payroll or HR solution, these applications do not provide for quick and easy unique identification of employees, their status history and personal information,"* says Janse van Rensburg.

*"More sophistication is needed in a solution managing that, and yet more if a company makes use of outsourced workers and needs to be satisfied that they comply with health checks and screenings, have themselves been checked, and are healthy."*

### HOW DOES THE APP HELP?

The Incident Desk COVID-19 People Management Solution manages all stages of the COVID-19 information process, including daily health checks; screenings; identifying PUIs (Person Under Investigation); testing; medical management; contact tracing; and outcomes.

The app offers role-based access and security for various user roles:

- Employees who log their own health checks
- Managers who log health checks on behalf of an employee, and
- Medical professionals who receive alerts regarding PUIs and who can perform further functions such as tests or medical management on the same platform.

Health checks and incidents can be logged and shared between multiple service providers and entities such as companies and their outsourced service providers, as well as viewed on a national, provincial or employer level, depending on access rights. The user registering their employees on the app has complete control to select who they want to share the employee information and health history with.

Facial recognition is used to identify employees, individuals being scanned and service providers, in compliance with the Protection of Personal Information Act (POPIA) to uniquely identify, register and retrieve a person's information. wn

*Tiaan Janse van Rensburg*
*Solution House Director:*
*Business and Commercialisation*

# Restart Your Business with BV

Bureau Veritas is on hand to support business resumption with appropriate health and safety conditions across all sectors

Bureau Veritas, a world leader in testing, inspection and certification (TIC) services, has developed a suite of solutions to support companies of all sizes as they restart business activity.

Didier Michaud-Daniel, Chief Executive Officer, commented: *"More than ever, our role as an expert, independent third party is crucial to creating the conditions for trust in this restart period. Bureau Veritas is committed to deploy all efforts worldwide to help its clients protect the health and safety of their employees and customers. Our geographical presence in 140 countries and unrivalled experience in certification processes are considerable assets as they enable us to provide companies, public authorities and society as a whole with our services and our in-depth knowledge of local specificities and regulations."*

"Restart Your Business with BV" has been developed in collaboration with a range of experts and stakeholders to support companies and government recommence operations with the legislated health protocols and sanitary conditions in place.

Bureau Veritas' objectives are to:

- Ensure that health, safety, and hygiene procedures put in place for the resumption of activity meet local and international regulations, as well as recognized best practices
- Confirm that the procedures defined are relevant to the specific needs of the company's area of business, and that they are effectively implemented
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"Restart Your Business with BV" is a digital platform offering a suite of solutions enhanced by a digital ecosystem, designed to address the risks specific to all places where people live and work from construction sites and factories to offices, hospitality, restaurants, shops and public facilities. The ecosystem includes operational assistance tools for companies who want to reassure stakeholders of their compliance with regulations to ensure their health and safety are safeguarded.

Leveraging on its expertise in certification processes and management of health, safety and hygiene risks, Bureau Veritas is committed to supporting economic recovery and robust business practices. A Certificate of Compliance and a Site Label Sticker complete with QR code and validity date, both valid for a six-month period, will be issued acknowledging regulatory compliance.

*Sal Govender*
*Vice-President*
*Bureau Veritas Southern Africa*

Sal Govender, Vice-President for Bureau Veritas Southern Africa commented: *"Increasingly, we are here to support our valued customers resume their business operations in a safe manner, with the health and safety protection of their employees and clients being our top priority. Using industry leading local and global expertise, we will conduct independent risk assessments and audits, putting the requisite health, safety, and hygiene steps in place to ensure their business is compliant with local and international regulations. We remain committed to the construction, mining and commodities, manufacturing, healthcare (pharmaceutical), buildings and infrastructure, agriculture, food, oil and gas, marine, power and utilities sectors. We can assure our stakeholders, the successful resumption of their business is of crucial importance to us as a trusted partner, working together to create a safer and more sustainable environment."* wn

# THE SAIEE STAFF BIDS FAREWELL

On the afternoon of the 28th of May, the SAIEE staff came together via webinar to bid a sad farewell to one of our own. Sue Moseley, who started working for the SAIEE in 2008, leaves us after 12 years of service, as she retires.

During this current lockdown, we couldn't get together like we usually would've, with eats and champagne, sending one of our family members off into the world.

Sue was a dedicated staff member of the SAIEE and worked with integrity and diligence in ensuring things happen precisely, and as per legislation, always upholding the SAIEE's constitution and bylaws.

Each staff member said a view words, in between all the tears in their own experience working with Sue, and then we showed her a presentation of everyone's messages.

Sue, very emotional, shared the memories she has of us individually.

"In the past two years I have worked with Sue, she has taught me a lot, and always showed me the right way, and for that, I will be eternally grateful," said Leanetse Matutoane, Ops Manager.

Sue, we wish you all the best for your future endeavours and may you enjoy your retirement blissfully!

# The quest for person-specific computational models for custom interventions in cochlear implants

A cochlear implant is an electronic device that is surgically placed under the skin behind the ear. It provides a sense of sound to a person who is profoundly deaf or severely hard of hearing by bypassing the damaged cochlea and sending sounds electronically to the brain. A cochlear implant can give a deaf person useful hearing of environmental sounds and help him or her to understand speech, as well as communicate orally.

BY PROF TANIA HANEKOM &
PROF JOHAN J HANEKOM
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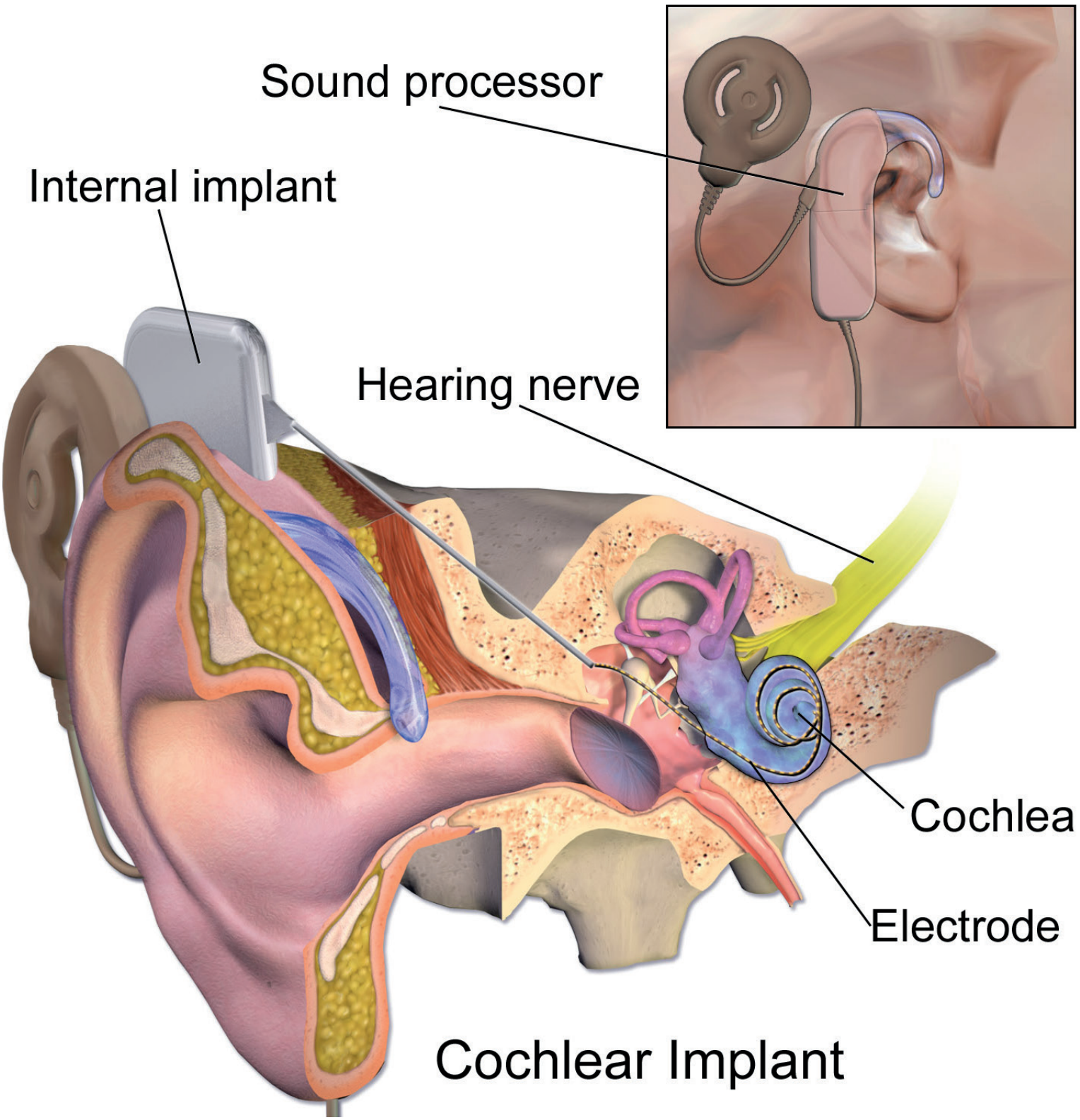
## THE SUCCESS OF COCHLEAR IMPLANTS AS A NEUROPROSTHETIC DEVICE

The cochlear implant (CI) is arguably the most successful neuroprosthetic device to date. A CI is a device that aims to cure deafness for an individual suffering from sensorineural hearing loss. These devices replace the entire auditory system from the external ear up to the point where the inner hair cells, which are specialised transducer cells that are responsible for conveying the incoming sound to the auditory nervous system, connect to the peripheral auditory neurons. An electrical connection to the peripheral auditory neurons of a hearing-impaired person is established through a miniature electrode array that is implanted into the inner ear (cochlea). Current injection through the electrode array is driven through one or more current sources that are controlled by an external unit. The external unit, which is worn behind the ear, contains a microphone to capture incoming sounds and a speech processor that encodes these sounds as a stimulation protocol to target appropriate neural populations. A telemetric link between the internal and external parts of the device is used to transfer data and power [1].

By the end of 2015, the largest implant manufacturer had sold more than 400 000 devices since their first-generation devices became commercially available in 1981. In 2016, global implants across all manufacturers were estimated at around 600 0000, with approximately 45 000 added to this number annually.

## EVERY USER IS UNIQUE

Despite the wide-spread use of CIs, hearing performance varies among individuals and may range from mere awareness of environmental sounds to almost 100% open speech understanding in quiet. However, while many CI users demonstrate good speech understanding in quiet, the perception of speech in adverse situations (e.g. in an environment containing competing speakers) and the appreciation of music remain inadequate [2]. On average, the word perception ability of adult users improves from 8.2% before,




to 53.9% after implantation [3], which is still far from typical hearing performance. Factors that describe the characteristics of implant users, such as age at implantation and duration of hearing impairment, only account for about 20% of the variance in speech perception scores, leaving nearly 80% thereof unexplained [4]. Apart from these general characteristics, it is known that user-specific factors related to the biophysical interface between the implant and the auditory system may also account for some of the variations observed in outcomes. The characteristics of the biophysical interface, such as the state of degeneration of the auditory neurons and detailed cochlear morphology are often not accessible for investigation because of the invasive nature of the methods that would be required for their assessment.

Because of the uniqueness of each implant user's hearing impairment and biophysical interface characteristics, it

is necessary to customise each device for optimal use by a particular user. (Customisation of a device primarily refers to the programming or mapping of device parameters to a user's individual physiological responses.) Although standard clinical procedures are mostly successful in producing this customisation, many users experience confounding effects at a neuro-electrophysiological level that may be difficult to untangle in a non-invasive way. This is where the key value of computational modelling comes into play since it provides a virtual invasive window to observe and investigate the auditory system subjected to electrical stimulation [5]. This unique window into the hearing system of a CI user may be useful in optimising the customisation of a device for a specific user and also to unravel the underlying mechanisms that complicate some cases. Furthermore, a computational model-based approach to the customisation of a device may eventually also extend to the personalised design of the device even before surgery.

## USER-SPECIFIC COMPUTATIONAL MODELS

Bioengineering at the University of Pretoria has been working on the development of three-dimensional (3D) user-specific computational models of cochlear implants for more than two decades [5]. The objectives of our modelling efforts are (i) to contribute to the scientific knowledge base about the mechanisms that underlie the functioning of the auditory system and cochlear implants, and (ii) to apply our models to improve the hearing performance of cochlear implant users on an individual basis.

Our 3D models of the auditory periphery firstly consist of a volume conduction (VC) model that describes the cochlear anatomy, the type and intracochlear location of the electrode array, and their combined effect on current distributions resulting from intracochlear stimulation. The electric potential distribution at the location of the target neurons is predicted by the VC models and used as input to a second-stage physiologically-based computational model of the target auditory nerve fibres (ANFs). The output of the ANF model is the spatial and temporal neural excitation response that results from the simulated stimulus.

At the core of the 3D models is the reconstruction of a living CI user's cochlea and implanted electrode array from clinical images of the temporal bone. Three-dimensional reconstruction of the cochlear anatomy is one of the primary challenges in the modelling process because the resolution of clinical computed tomography (CT) images from which landmarks for reconstruction must be derived is severely limited. A human cochlea (which resembles a coiling shell) is on average about 6.8 mm wide at its base by 4.2 mm in height. The voxel size of clinical CT scans is typically 200 µm x 200 µm x 200 µm which means that there are only about 34 voxels over the width of an average cochlea and 21 voxels along its length with which to represent the anatomy.

It is therefore generally only possible to observe the outline of the cochlea in the enveloping bone. Still, very little (if any) of the soft-tissue internal structures that affect the current distribution and, consequently, neural activation patterns are visible. Also, the metal electrodes cause artefacts in the images that further compromise their quality.

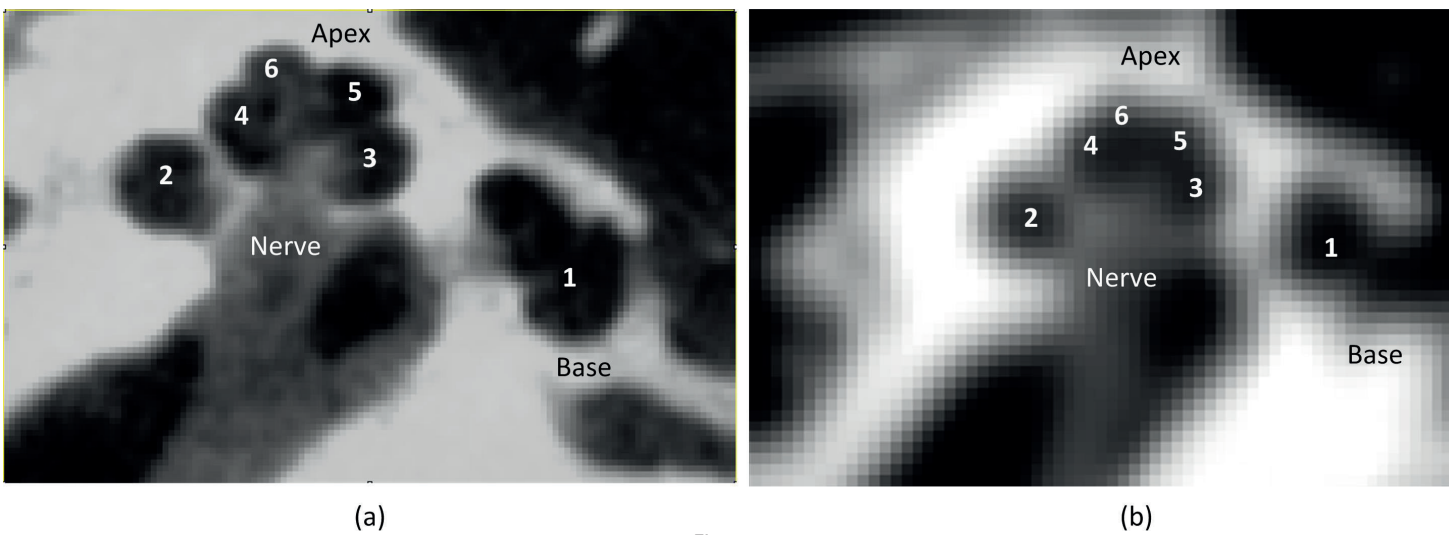



*Figure 1*

Figure 1a shows a high-resolution microcomputed tomography image of a section through the cochlea. The base and apex of the cochlea are indicated. The cochlear canal coils from the lower-basal section (1) through the upper-basal (2), lower-middle (3), upper-middle (4), and lower apical (5) sections to the upper apical section (6). Figure 1b shows a clinical CT image of a similar section through a human cochlea for comparison. The poor resolution of the CT compared to the µCT image is evident. Unfortunately, µCT is not suitable for imaging of live users' cochleae as it requires high doses of radiation.

## PREDICTING OBSCURED ANATOMICAL FEATURES

To be able to make accurate user-specific predictions about neural excitation, a hi-fidelity representation of the cochlea is essential. In a previous study, we showed that the effect of variations in the anatomy of the cochlea on the prediction of nerve fibre excitation thresholds is comparable to that of the relative location of the electrode array to the surviving ANFs [6]. This last parameter is known to be one of the critical factors to influence neural excitation. The implication is that errors in the reconstruction of the cochlear anatomy may also compromise the accuracy of model predictions. In a collaborative study with the Department of Anatomy at the University of Pretoria, an anatomical reference framework was developed for the human cochlea that allows prediction of obscured landmarks for a specific user. The reference framework used landmark data measured from micro-computed tomography (µCT) scans of human skulls and temporal bones that were taken at voxel sizes of between 25 µm and 50 µm. Mathematical equations were derived to describe the spiralling trajectory of landmarks on the boundaries of cochlear structures that are discernible on clinical CT images. A set of predictor equations were subsequently derived for structures that are visible on µCT images but obscured on clinical images, e.g. the bony spiral lamina from which the nerve fibres protrude. The predictor equations operate on landmark data that are visible on a specific user's CT images to approximate the location of obscured structures.

Figure 2a shows a 3D reconstruction of a human cochlea from raw landmark data measured from CT images of a user's cochlea. Irregularities in the data are introduced by measurement errors resulting from the low resolution of the source images (refer to Figure 1b). Figure 2b shows a prediction-based reconstruction of the same cochlea that is suitable for 3D modelling.

## AUTOMATED MODEL GENERATION

While it is possible to construct 3D user-specific models of the electrically stimulated cochlea, the manual landmark-based approach that is required to optimise the accuracy of the models is time-consuming and therefore not suitable for scaling to clinical application (which is the second objective for our modelling work in the field). To be able to generate user-specific models on demand for clinical use, an automated model generator (AMG) is necessary. A first-generation landmark-based AMG was thus developed by our research group to reconstruct a user's cochlea and the implanted electrode from CT scans [7]. This tool can construct a user-specific model in less than 10 minutes compared to several days that are required for manual model construction. However, when tested against the anatomical reference as described in the previous paragraph, it

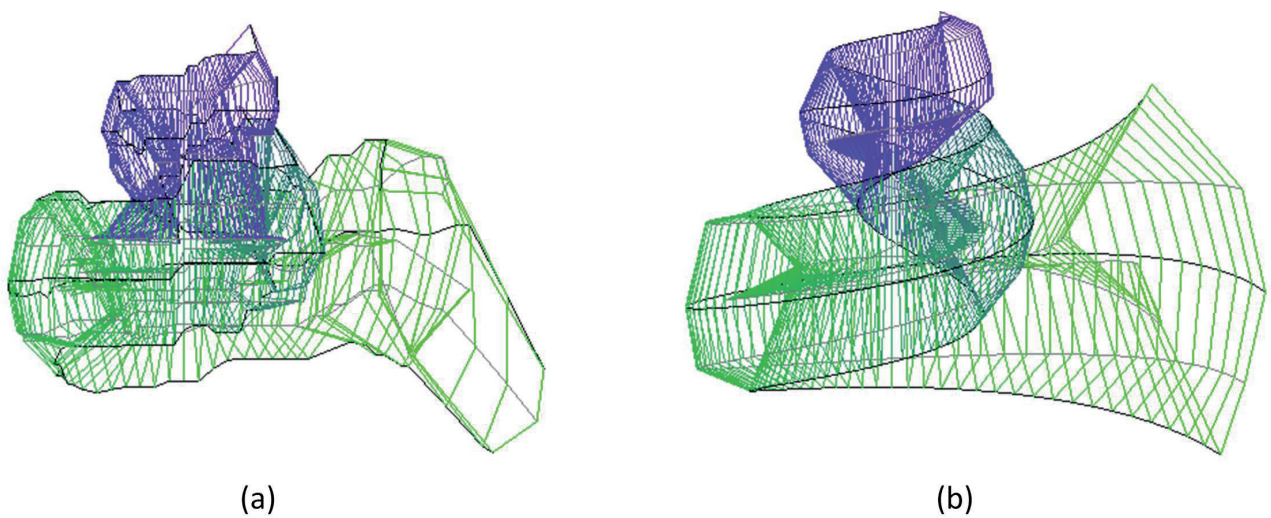



*Figure 2*

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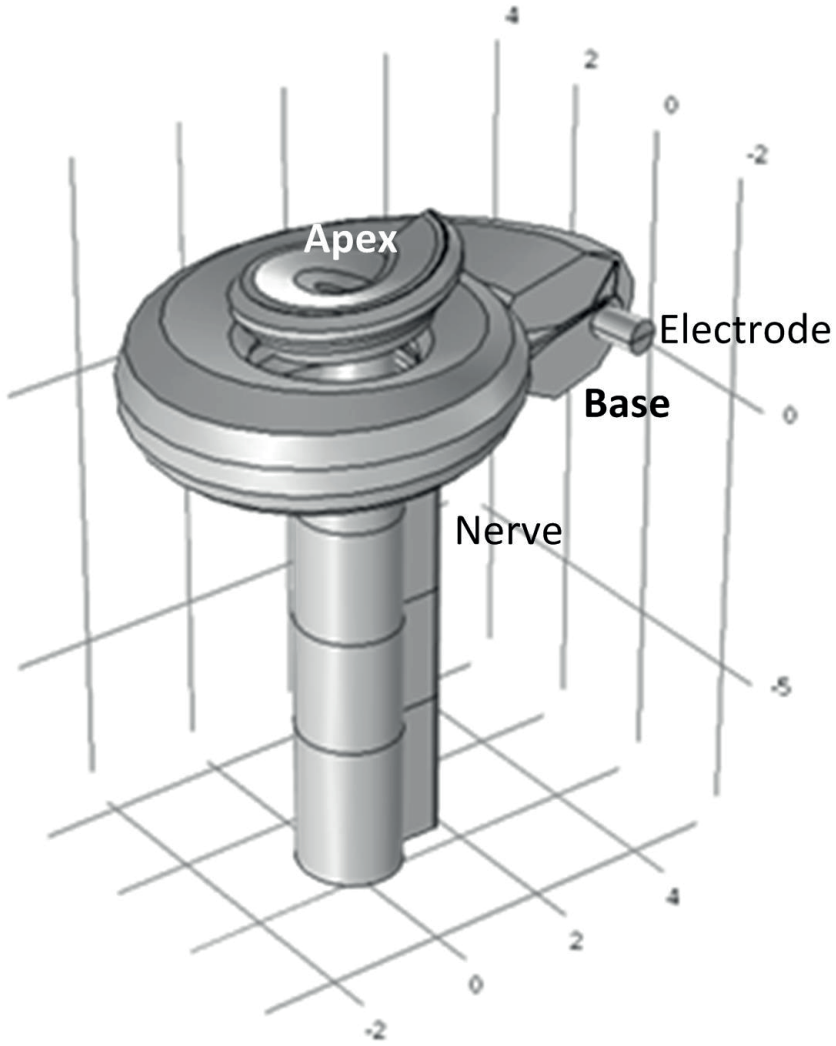


*Figure 3*

was found that the current AMG is too fragile to be employed as a diagnostic tool. Ongoing work, therefore, focuses on the development of a robust second-generation AMG to allow the deployment of computational models in a clinical setting.

Figure 3 shows a 3D model of a cochlea that contains an electrode array (cylinder protruding at the base), and that was constructed using the tools developed in our research group.

## CONCLUSION

There is much need for translational research in biomedical engineering that focuses on the application of advanced research methodology within a clinical setting. The work done by the Bioengineering research group at the University of Pretoria builds on a strong scientific foundation in electronic and computer engineering, medical imaging, hearing sciences, anatomy and physiology to create specialised tools that may assist clinicians in the management and maintenance of hearing performance of individual cochlear implant users. wn

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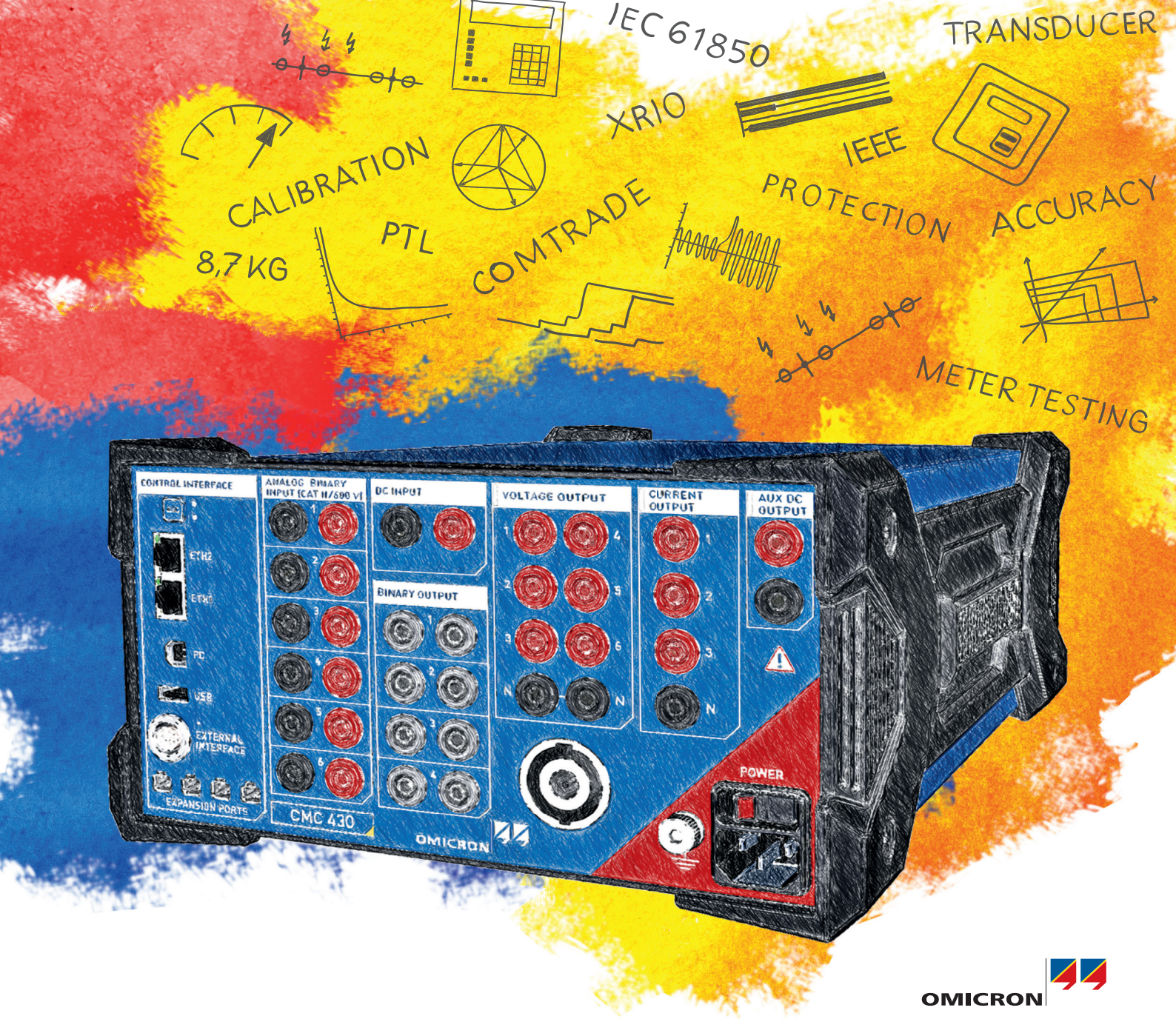


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# Organ-on-a-chip

## - recent breakthroughs and future prospects

The organ-on-a-chip (OOAC) is in the list of top 10 emerging technologies and refers to a physiological organ biomimetic system built on a microfluidic chip. Through a combination of cell biology, engineering, and biomaterial technology, the microenvironment of the chip simulates that of the organ in terms of tissue interfaces and mechanical stimulation.

**BY I** QIRUI WU, JINFENG LIU, XIAOHONG WANG, LINGYAN FENG, JINBO WU, XIAOLI ZHU, WEIJIA WEN XIUQING GONG
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This reflects the structural and functional characteristics of human tissue and can predict response to an array of stimuli, including drug responses and environmental effects.

OOAC has broad applications in precision medicine and biological defence strategies. Here, we introduce the concepts of OOAC and review its application to the construction of physiological models, drug development, and toxicology from the perspective of different organs. We further discuss existing challenges and provide future perspectives for its application.

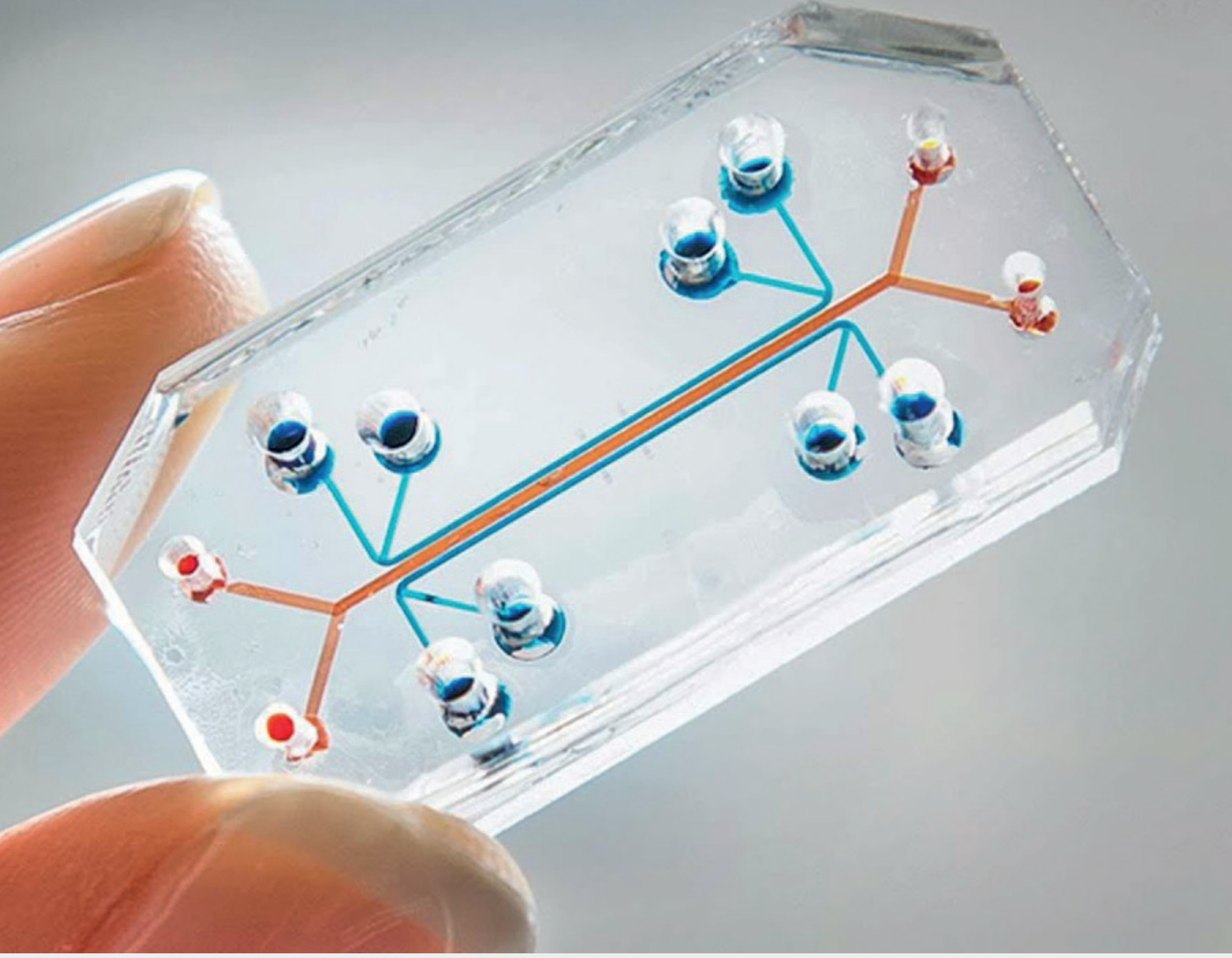
### BACKGROUND

Microfluidics is a science and technology that precisely manipulates and processes microscale fluids. It is commonly used to precisely control microfluidic (10–9 to 10–18 L) fluids using channels that range in size from tens to hundreds of microns and is known as a "lab-on-a-chip" [1–4].

The microchannel is small but has a large surface area and high mass transfer - favouring its use in microfluidic technology applications including low regent usage, controllable volumes, fast mixing speeds, rapid responses, and precision control of physical and chemical properties [1, 5, 6].

Microfluidics integrates sample preparation, reactions, separation, detection, and underlying operating units such as cell culture, sorting and cell lysis [7]. For these reasons, interest in OOAC has intensified [8]. OOAC combined a range of chemical, biological and material science disciplines [9] and was selected as one of the "Top Ten Emerging Technologies" in the World Economic Forum [10].

OOAC is a biomimetic system that can mimic the environment of a physiological organ, with the ability to



regulate critical parameters including concentration gradients [11], shear force [12], cell patterning [13], tissue-boundaries, [14] and tissue–organ interactions [15]. The primary goal of OOAC is to simulate the physiological environment of human organs [16].

Human physiology is the science of studying the functions of the human body and its organ systems. This is of great significance in understanding the dysfunction and pathogenesis of the body, and therefore closely aligns with the fields of medicine, drug development and toxicology [17]. The most relevant and direct methods for studying human physiology are in vivo experiments that study human or model organisms. Bodily functions rely on the interaction and adaptation of many lower-level components such as tissues, cells, proteins and genes. It is, therefore, challenging to reveal the underlying mechanisms of physiological phenomena only through in vivo studies [18]. Besides, drug development and toxicology require the assessment of the physiological effects of thousands of compounds [19]. Due to the limitations of low-throughput in vivo testing, biologists use in vitro cell culture. Cell culture refers to the growth and maintenance of cells in a controlled environment [20]. For decades, traditional two-dimensional (2D) cell culture systems formed an essential platform for life science research. Using 2D systems, the functions of various cells are studied by culturing cells or cell products. However, 2D systems fail to accurately simulate the physiological manifestations of living tissues/organs, intra-organ interactions and microenvironmental factors [21, 22] and often require verification in vivo animal models. Due to species differences, animal experiments often fail to replicate human experiments [23], and due to both high costs and ethical issues, the use of animals as models for drug testing has come under scrutiny [24]. In preclinical testing, inadequate description of the human tissue environment may lead to inaccurate predictions of the

combined effects of overall tissue function [25]. OOAC was designed to overcome these shortcomings by providing more physiological model systems [26]. OOAC was proposed as a future replacement technology for experimental animal models [27].

This review introduces recent advances from OOAC technology and discusses its future perspectives for cell biological assessments.

Organs-on-a-chip design concept and critical components

Design concept

Culture systems require the control of external and internal cell environments [28]. OOAC combined with micromachining, and cell biology can control external parameters and accurately simulate physiological environments [16]. Dynamic mechanical stress, fluid shear and concentration gradients are required on the chip. Cell patterning should also be realised to reflect physiological processes fully.

Fluid shear force Microfluidics enables the dynamic culture of cells through micro- pump perfusion, which facilitates the administration of nutrients and timely waste discharge. The dynamic environment in which cells are located is more comparable to in vivo conditions than static culture. Also, fluid shear stress induces organ polarity [29]. Importantly, OOAC exerts necessary physical pressure on the normal biological functions of endothelial cells [30] by activating cell surface molecules and associated signalling cascades. Similarly, the incorporation of fluid into the OOAC device permits biological assessments at the single organ level [31]. The OOAC system summarises flow-through a straightforward "rocker" on a chip fluid motion, or through a more complex programmable "pulsatile" format, arranged in a single loop for organisation-specific configurations [32].

## CONCENTRATION GRADIENT

At the microscale level, the fluid acts primarily as a laminar flow, resulting in a stable gradient of biochemical molecules, controlled both spatially and temporally. Various biochemical signals driven by concentration gradients exist in biological phenomena, including angiogenesis, invasion, and migration [33–35]. Microfluidics simulates complex physiological processes in the human body by altering flow velocity and channel geometry using microvalves and micro-pumps to achieve stable, three-dimensional (3D) biochemical concentration gradients.

## DYNAMIC MECHANICAL STRESS

Normal day-to-day organ pressure includes blood pressure, lung pressure, and bone pressure. These pressures play a significant role in maintaining mechanically stressed tissues such as skeletal muscle, bone, cartilage and blood vessels [36–38]. Microfluidics enables the use of elastic porous membranes to create periodic mechanical stresses. This mechanical stimulation is considered a key determinant of differentiation during physiological processes [39, 40].

Cell patterning The organisation of the human body requires a complex and ordered arrangement of multiple cells to form a functional whole-body interaction. Microfluidics control cell patterning for the construction of in vitro physiological models with complex geometries. Surface modifications [41], templates [42], and 3D printing [43] contribute to cell patterning on the chip. The 3D printing method enables multi-scale cell patterning by permitting the formation of hydrogel scaffolds with multiple channels. The advantage of 3D printing is to allow user-defined digital masks to provide versatility in cell patterns, critical for the in vitro reconstruction of the cellular microenvironment. Li et al. [44] developed methods to achieve rapid heterotypic cell patterning on glass chips using controlled topological manipulations. This method combines a polyvinyl acetate coating, carbon dioxide laser ablation, and continuous cell seeding techniques on a glass chip. This method enables controlled epithelial-mesenchymal interactions. In addition, mesenchymal cells with similar properties can also be patterned on glass chips. This method can be helpful for large-scale investigation and pharmaceutical testing of cutaneous epithelial-mesenchymal interaction and can also be applied to the patterning of other cells.

## KEY COMPONENTS

The OOAC involves four key components, including (1) microfluidics; (2) living cell tissues; (3) stimulation or drug delivery; and (4) sensing [45]. The microfluidic component refers to the use of microfluidics to deliver target cells to a pre-designated location and includes a system of culture fluid input and waste liquid discharge during the culture process. Typically, this component is characterised by miniaturisation, integration, and automation [7]. The living cell tissue component refers to elements that spatially align a particular cell type in the case of 2D or 3D systems. The 3D arrangements are typically created by the addition of biocompatible materials such as hydrogels. These materials can prevent mechanical damage and shape three-dimensional arrangements. [42]. Although the 3D tissue structure more accurately simulates the in vivo

situation compared to 2D models, due to the limitations of technology and cost and the assembly of extracellular matrix and the presetting and formation of the vasculature, living cell in organ tissues are still mostly cultivated in 2D. For specific tissues, physical or chemical signals are required to simulate the physiological microenvironment, which promotes micro-tissue maturation and function. For example, electrical stimulation can help myocardial tissue maturation [46]. Different signal stimuli can be derived from drug screening approaches [47]. The sensing component for detecting and compiling data can be an embedded sensing output component or a transparent chip-based visual function evaluation system. Peel et al. [48] used automated systems to image multicellular OOACs, producing detailed cell phenotypes and statistical models for measurements. Kane et al. [49] developed a cell system to monitor cells in a 3D microfluidic setting. These assays featured time-lapse imaging microscopy to assess cellular electrical activity through quality control. A meaningful human-on-chip cell model cannot be described and accessed without microsensors-mediated reading of the metabolic state at characteristic points in the system.

## EMERGING OOAC TECHNOLOGIES

LIVER OOAC

The hepatic system is the primary site of drug/toxin metabolism. The liver constitutes a series of multiple hepatic lobules that confer multicellular functional communication [50]. Maintaining the physiology of hepatocytes over an extended period is challenging [51]. Kane et al. designed the first liver-based system that consisted of microfluidic pores in which 3T3-J2 fibroblasts and rat liver cells were co-cultured to mimic an airway interface (Fig. 1) [52]. Rat hepatocytes cultured in the chip could continuously and stably synthesise albumin and undergo metabolism. Lee et al. [53] designed a chip that mirrored the interstitial structure of endothelial cells and cultured primary hepatocytes, with culture media perfused outside the gap. This permeable endothelial gap separated hepatocytes in cord-based structures permitting their separation from the external sinusoidal region, simultaneously maintaining efficient substance exchange.

Ho et al. [13] used radial electric field gradients that were produced using electrophoresis to pattern cells onto circular polydimethylsiloxane (PDMS) chips. These novel techniques simulated the hepatic lobule structure. Hegde et al. [54] fabricated a 2-layer chip that separated the channels using a porous polyethylene terephthalate (PET) membrane and continuously perfused collagen and fibronectin-sanded rat primary hepatocytes into the lower channel through the upper chamber.

To improve the physiological models, 3D hepatocyte culture techniques have been used to form microfluidic chips [55]. Ma et al. [56] produced a biomimetic platform for the perfusion of hepatic spheroids in situ. Yum et al. [57] presented systems to study how hepatocytes affect other cell types. High-throughput assays were developed to assess liver cell drug toxicity. Riahi et al. [58] produced microfluidic electrochemical chip immuno-sensors to detect the biomarkers produced during hepatotoxicity. Chong et al. [59] presented assays to monitor drug skin sensitisation through the assessment of metabolite production and the activation of antigen-presenting cells (APCs). This system holds value as a drug screening platform to identify compounds that produce systemic skin reactions. Lu et al. [60] developed biomimetic liver tumours through integrating decellularised liver matrixes (DLM) with gelatin methacryloyl (GelMA) to mirror the 3D tumour microenvironment (TME). This system provides an improved disease model for a range of future anti-cancer pharmacological studies.

Furthermore, several diseases or injury states were tested. Kang et al. [61] used their system to analyse viral replication of the hepatitis B virus. Zhou et al. [62] developed a method for modelling alcohol injury. Further characterisation of cultured cytoplasm in metabolomics, proteomics, genomics, and epigenomic analysis will help improve the functional outcome of these studies.

LUNG-ON-A-CHIP

Gas exchange in the lungs is regulated by the alveoli, which can be challenging to reproduce in vitro. Microfluidics can establish extra-corporeal lung models and lung pathologies through accurate fluid flow, and sustained gaseous exchange. Current studies have focused on the regulation of mechanical airway pressure, the blood–blood barrier (BBB), [63] and the effects of shear force on pathophysiological processes. Huh, et al. produced a lung-on-a-chip model (Fig. 2) [64] using soft lithography to divide the chip into regions separated by 10 μm PDMS membranes with an extracellular matrix (ECM). The upper PDMS regions had alveolar epithelial cells, while the lower areas contained human pulmonary microvascular endothelial cells, thus mimicking the alveolar-capillary barrier. The structures

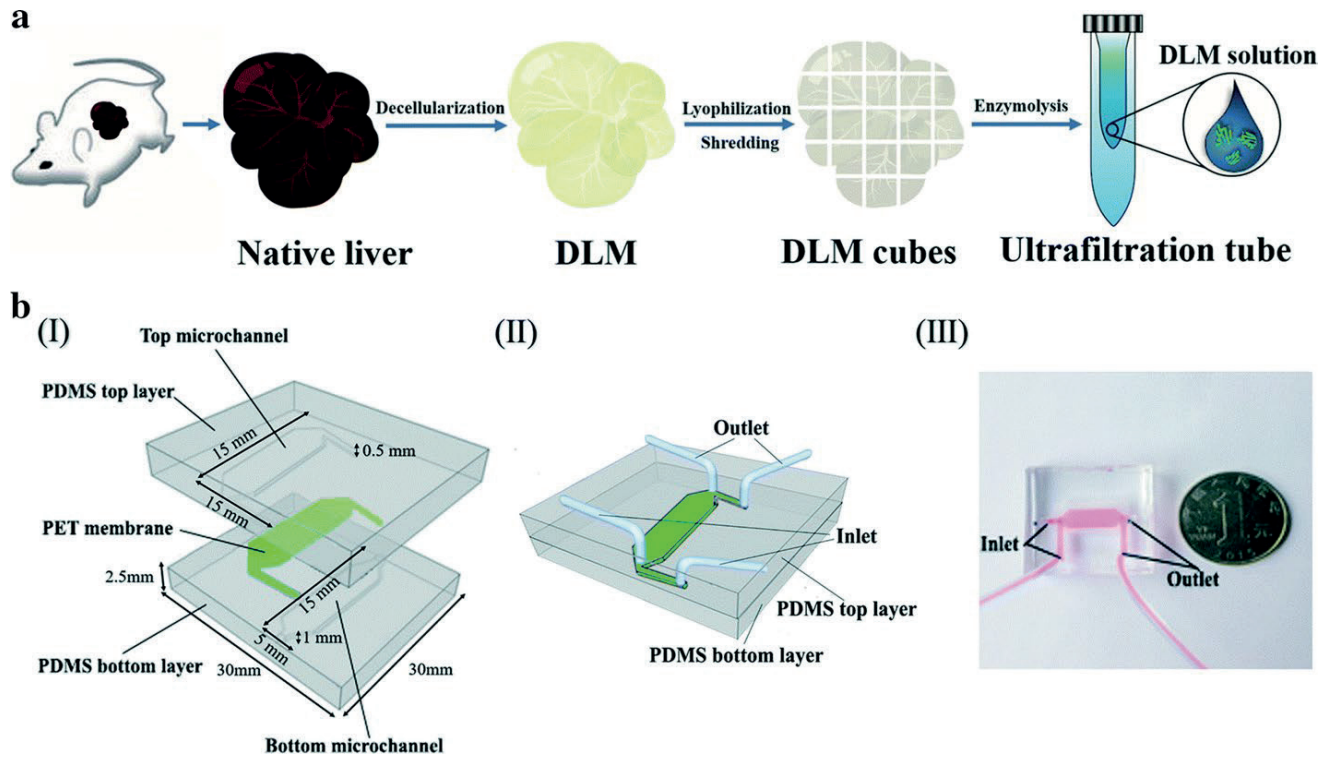



**Fig. 1** Schematic of the DLM-based liver tumor-on-a-chip. **a** Preparation of the DLM solution from a natural liver; **b** 3D schematic representation of the various components of the equipment (top and bottom, top and bottom microchannels, PET membrane, air inlet, and outlet) and their respective dimensions (reprinted with permission from [52] Copyright © 2006, Royal Society of Chemistry)

of the membranes were altered under a vacuum to simulate expansion/contraction of the alveoli during respiration. Inflammatory stimuli were introduced into the system through neutrophils that were passed to the fluid channels. This produced a pathological model of pulmonary oedema through the introduction of interleukin-2 (IL-2) [65]. This highlights the utility of the OOAC models to improve current in vivo assays.

In 2015, Stucki et al. [66] reported a lung chip that mimicked the lung parenchyma. The system included an alveolar barrier and 3D cyclic strain that mimicked respiration representing the first elastic membrane expansion model to simulate breathing. Blume et al. [67] produced 3D airway culture models that simulated pulmonary interstitial flow through the exchange of both fluid and media. This permitted more in-depth physiological studies of the epithelial barrier. This model utilises a stent with a porous filter as a single tissue culture chamber and combined multiple chambers for improved integration. In the lung-on-a-chip, while simulating lung gas-liquid interfaces and respiratory dilation through the microfluidic system, pressure can be applied to the alveoli and attached capillaries, providing a shear flow profile. This realistically simulates the lung environment. Humayun et al. [68] cultured airway epithelial and smooth muscle cells at different sides of a hydrogel membrane to assess their suitability as a physiological model. The system was combined with microenvironment cues and toxin exposure as a physiological model of chronic lung disease. Yang et al. [69] produced a poly(lactic-co-glycolic acid) (PLGA) electrospinning the nanofiber membrane as a chip matrix for cell scaffolds. Given the ease of the system, it applies to lung tumour precision therapy, and tissue engineering approaches were highlighted.

Lung tissue organ chips are useful as implantable respiratory assistance devices. Peng et al. [70] designed lung assist devices (LAD) to permit additional gas exchange in the placenta for preterm infants during respiratory failure. The concept of large-diameter channels was achieved in the umbilical arteries and veins, providing LAD with high extra-corporeal blood flow. This has added utility because clinical trials for umbilical vasodilation thresholds

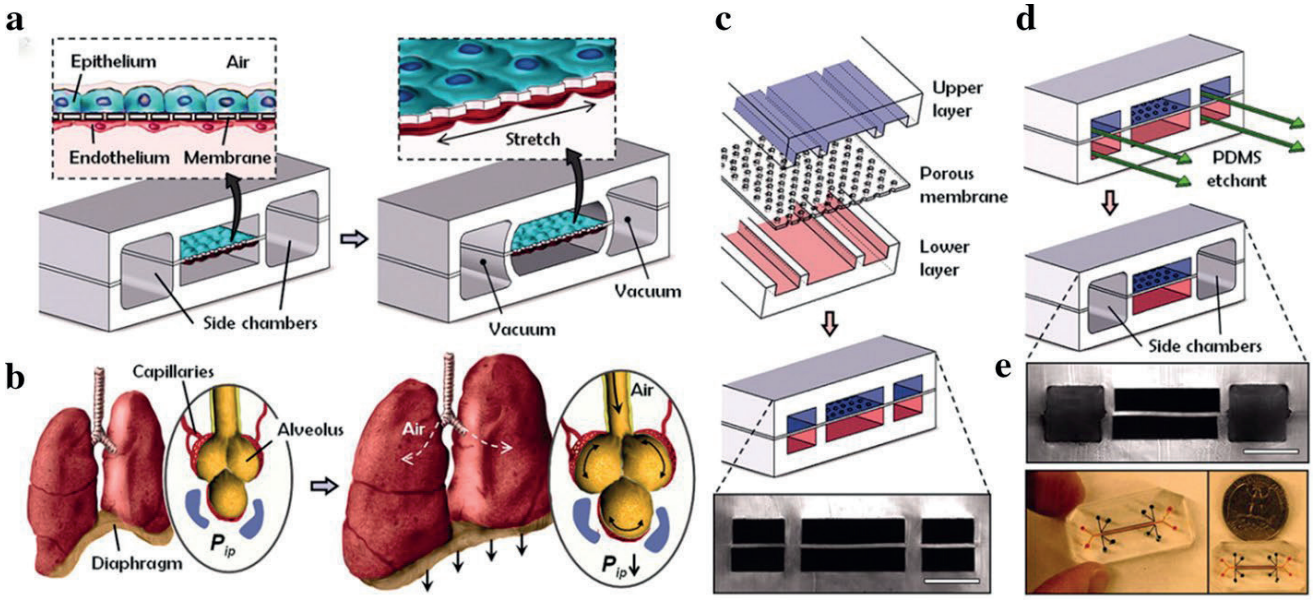



**Fig. 2** Lung-on-a-chip system. **a** An alveolar–capillary barrier was produced on porous flexible PDMS membranes coated with ECM using spaced PDMS microchannels. The device reproduced respiratory motion through a vacuum leading to mechanical stretching and the formation of an alveolar–capillary barrier; **b** following inhalation, the diaphragm contracts, reducing pleura pressure. The alveolar–capillary interface became stretched due to alveoli tension; **c** device development: a porous membrane between the upper and lower channels bound irreversibly following plasma exposure; **d** PDMS moved through the side of the channels and then was removed following vacuum pressure. **e** Actual images of the device (reprinted with permission from [64] Copyright © 2010, American Association for the Advancement of Science)

were unethical. This study was the first to systematically quantify umbilical vessel damage as the result of expansion by catheters. Dabaghi et al. [71] performed microfabrication for microfluidic blood oxygenators using double-sided gas delivery to improve gas exchange. Oxygen uptake increased to 343% in comparison to single-sided devices. Xu et al. [72] used a microfluidic chip platform to mimic the microenvironment of lung cancer with cancer cell lines and primary cancer cells and tested different chemotherapeutic drugs. Another recent study simulated asthma in a "small airway-on-a-chip" model [73]. With the models of human asthmatic and chronic obstructive pulmonary disease airways, therapeutics were tested, and the chip model recapitulated in vivo responses to a similar therapy.

KIDNEY OOAC

The kidney is responsible for the maintenance of osmotic pressure drug excretion. Kid- ney toxicity leads to an irreversible loss of renal filtration, highlighting the need for drug screening systems. Filtration and reabsorption take place in the nephrons that consist of the glomerulus, renal capsule, and renal tubule. Microfluidics can simulate the fluid environment that supports tubular cell growth and provides porous membrane support for the maintenance of cell polarity [16].

Jang et al. [74] produced the first multi-layered microfluidic system (Fig. 3a) in which mouse kidney medullary collecting duct cells were used to simulate renal filtration. The device provided a biomimetic environment that enhanced polarity of the inner medullary collecting duct through promoting cytoskeletal reorganisation and molecular transport in response to hormone stimulation. In 2013, the same microfluidic device was used to culture human primary renal epithelial cells [75]. These were the first toxicity studies of primary kidney cells. This device enables direct visualisation and quantitative analysis of diverse biological processes of the intact kidney tubule in ways that have not been possible in traditional cell culture or animal models. It may also prove to help study the underlying molecular mechanisms of kidney function and disease.

The disadvantage of conventional cell culture systems is that cell

differentiation into functional cells requires extended culture times and an external signal detection system. Musah et al. [76] described methods to induce pluripotent stem cell-derived podocytes to form human glomerular chips (Fig. 3b) in organ culture devices. These mimicked the structure and function of the glomerular capillary wall, which was not possible with previously employed methods.

The chip was applicable for nephrotoxicity assessments, therapeutic development, regenerative medicine, and kidney development and disease. Sakolish et al. [77] produced a reusable microfluidic chip in human proximal tubules and glomeruli that permitted renal epithelial cells to grow under various conditions. Shear stress causes nephrotoxicity. Schutgens et al. [78] designed stable tubule culture systems that allowed extended expansion and human kidney tissue analysis. Based on the system, a multi-purpose primary renal epithelial cell culture model was developed that enabled rapid and individualised molecular and cellular analysis, disease modelling, and drug screening. Tao et al. [79] presented a powerful strategy to generate human islet organoids from human induced pluripotent stem cells. This strategy applied to a range of applications for stem cell-based organic engineering and regenerative medicine.

## HEART-ON-A-CHIP

Cardiovascular deaths are the leading cause of human mortality. The emergence of microfluidics has enabled in vitro bionic studies of cardiac tissue. The myocardium is a significant component of the heart. The beating of cardiomyocytes (CMs) can be used to assess drug effects directly and is directly related to heart-pumping [80]. In 2012, Grosberg et al. [81] used PDMS to produce an elastic film with a surface texture and implanted neonatal rat CMs on the membrane to form a muscle membrane. As

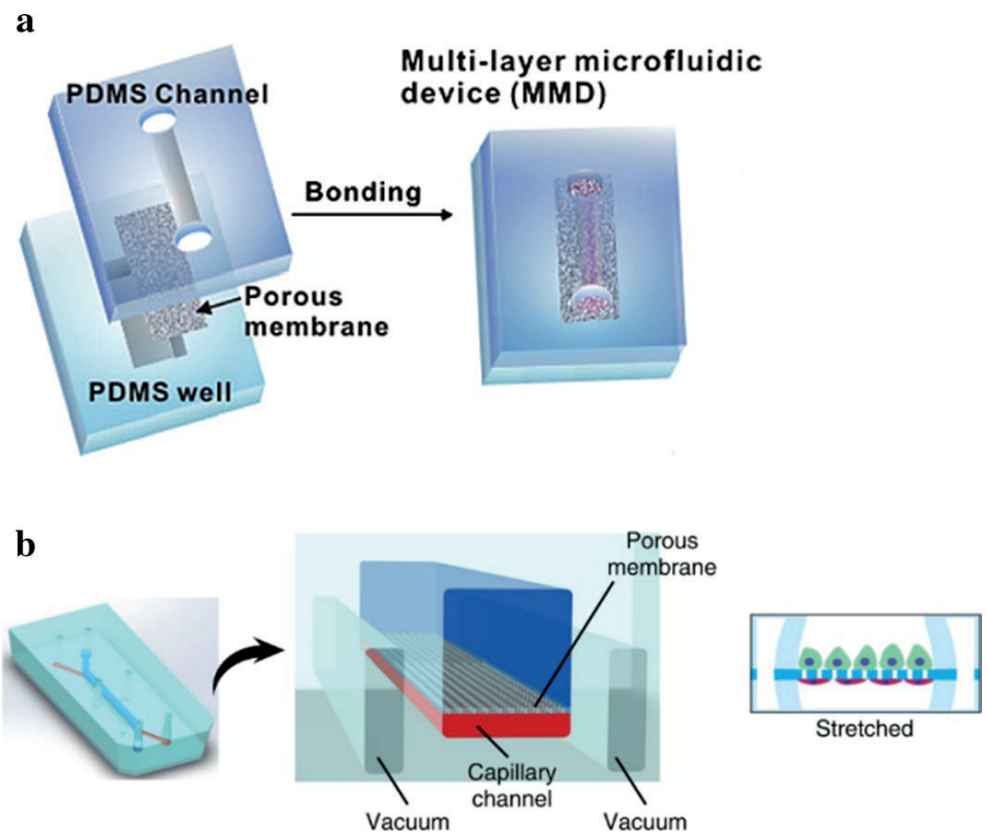



**Fig. 3** **a** Kidney tubular chip. Sandwich assembly of the PDMS channel, porous membrane, and PDMS reservoir (reproduced from [74]); **b** the channel can replicate the urinary cavity and capillary lumen of the glomerulus. The porous flexible PDMS membrane can be used to functionalize the protein laminin to mimic the glomerular basement membrane. Cyclic mechanical pressure to the cell layer via vacuum stretching of the flexible PDMS film can be produced (reprinted with permission from [76] Copyright © 2018, Royal Society of Chemistry)

the CMs contract, the muscle film curled to one side. By measuring the degree of this curl, it was possible to analyse the differences in the size of the cell contractile capacities on the PDMS film. The experimental system was suitable for both single muscle membrane measurements and high-throughput automated multi-plate assays. Subsequently, in 2013, Zhang et al. [82] utilised hydrogels to produce self-assembled myocardial sheets in a PDMS model. The CMs were derived from differentiated myocardium. Micro-organ tissue chips were produced from 3D printing technology that permitted the integration of myocardial and vascular systems [83]. The model utilised vascular endothelial cells to form vascular networks, and CMs were added to the vascular network gap. The organ chip produced a screening platform for CV-related drugs.

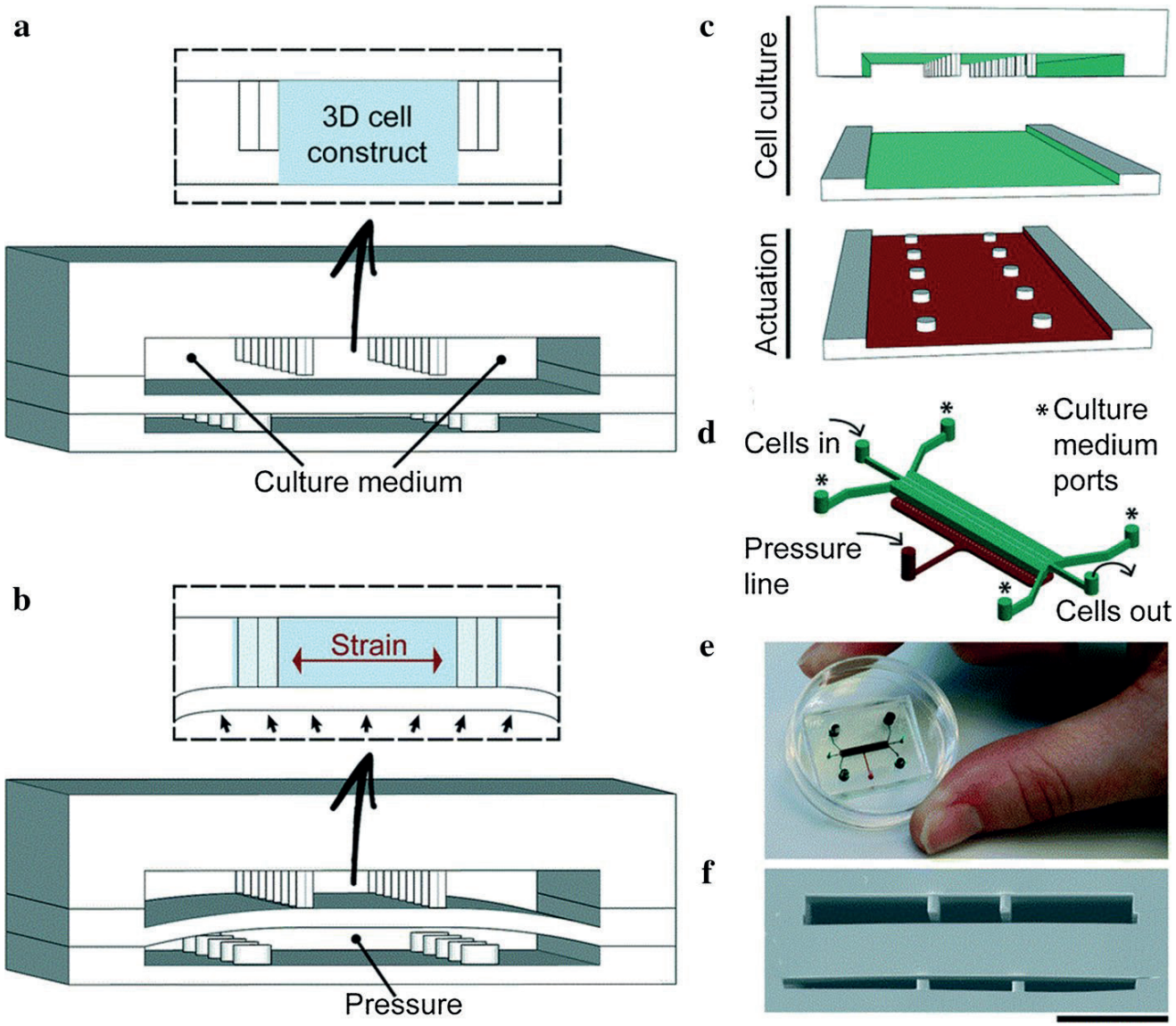



**Fig. 4** 3D heart-on-a-chip. **a** Two separate PDMS microchambers were employed. The CMs are positioned in the central channel to create a 3D construct, whilst the medium is replaced trough side-channels; **b** the lower end of the compartment is pressurized to deform the PDMS membrane and compress the 3D structure. Compression is converted to uniaxial strains applied to the 3D cell structure; **c** PDMS layers are aligned and irreversibly combined. Upper layers are present in the culture chamber and the drive chambers represent the lower layers; **d** 3D illustration; **e** real-life chip; **f** SEM of the chip cross section (reprinted with permission from [85] Copyright © 2016, Royal Society of Chemistry)

Zhang et al. [84] introduced the heart-on-a-chip device that used high-speed impedance detection to assess cardiac drug efficacy. The device records the contraction of CMs to reveal drug effects. The chip represented a preclinical assessment of cardiac drug efficacy. Marsano et al. [85] built a heart organ platform (Fig. 4) that mimicked the physiological and mechanical environment of CMs.

Direct visualisation and quantitative analysis was performed, which was not permitted in traditional cell culture or animal models. This platform represents an advance in the field and provides standard functional 3D heart models. This makes the device an innovative and low-cost screening platform to improve the predictive power of in vitro models. Schneider [86] designed convenient and efficient chips to generate heart tissue in a controlled environment based on human induced pluripotent stem cells.

The viability and function of myocardial tissue were maintained for an extended period, and detailed spatiotemporal pulsation dynamics were optically detected. This platform can be used for a variety of biomedical applications. Also, Tzatzalos et al. [87] reported that the hiPSC-CMs could represent an unlimited potential for healthy and disease-specific CMs to assess the efficacy of drugs for dilated cardiomyopathy. These advances in drug development have important implications for cardiovascular tissue because cardiotoxicity is often seen in drug trials and is one of the main reasons clinical trials are suspended or drugs are withdrawn from the market.

INTESTINE-ON-A-CHIP

Oral drugs have to transverse the small intestine to enter the bloodstream. Villi are essential to absorption, and their morphology must be maintained on the chip [88]. Imura et al. [89] developed chips to simulate the intestinal system, consisting of a glass slide permeable membrane and PDMS sheet containing the channels. Caco-2 cells were cultured on the chips. Sung et al. produced the first 3D hydrogel structure to simulate the human intestinal villi [90]. Kim et al. presented bionic devices (Fig. 5) [91].

The microenvironment of the intestine was reconstructed through sheer force and cyclic strains. Caco-2 cells show prolonged growth and maintained the microbial flora in the human gut. The complex structure and physiology of the intestine provided a platform for drug screening and the role of the intestinal microbiome, inflammatory cells and peristaltic-related mechanical deformation during intestinal disease.

The device permitted the exploration of the aetiology of intestinal illness and identified therapeutic targets and drugs. This study demonstrates the potential of the intestine- on-chip for personalised medicine studies on intestinal cells.

Intestinal cells were cultured alone or with endothelial cells, including HUVECs [91]. Genome fidelity was low, so the chips mimicked intestinal function. Kasen- dra1 et al. [93] combined intestinal tissue engineering [94] and OOAC technology to establish in vitro biological models of the human duodenum. The intestinal epithelial cells cultured in the chip were obtained from endoscopic biopsies or organ resections. This chip represented the closest model to the living duodenum and reproduced vital features of the small intestine. Recent findings enhanced our knowledge of the intestinal microbiome [95] and intestinal morphology [96].

MULTI-ORGANS-ON-A-CHIP

An array of physiological pathways requires continuous media circulation and inter-tissue interactions. Single organ chips fail to fully reflect the complexity, functional changes, and integrity of organ function [97]. The "multi-organ-on-a-chip", otherwise referred to as the "human-on-a-chip" [98] simultaneously constructs multiple organs attracting apparent research attention. Multi-organs-on-a-chip culture cells of different organs and tissues simultaneously which are connected by channels (bionic blood vessel [99]), to achieve multi-organ integration, permitting the examination of interactions to establish a system [100, 101].

These can be separated into static, semi-static and flexible approaches [102]. Static multiple organs are integrated into single connected devices. In semi-static systems, the organs are joined via fluidic networks with Transwell -based [103] tissue inserts. In the flexible order, individual organ-specific platforms are interconnected using flexible microchannels. In such systems, flexible nature is advantageous and recreates multiple organs [102]. Although the multi-organs-on-a-chip concept remains in its infancy, significant breakthroughs have been made, including the design of two-organs [104, 105], three-organs [106, 107], four-organs [108, 109], and ten organs on the chip [110].

In 2010, Van et al. [104] were the first to combine liver and intestines in a microfluidic device. The intestine and liver slices functioned on the chip and demonstrated its applicability to organ interactions, including the regulation of bile acid synthesis. This system enabled in vitro studies and provided insight into organ–organ interactions. A more significant

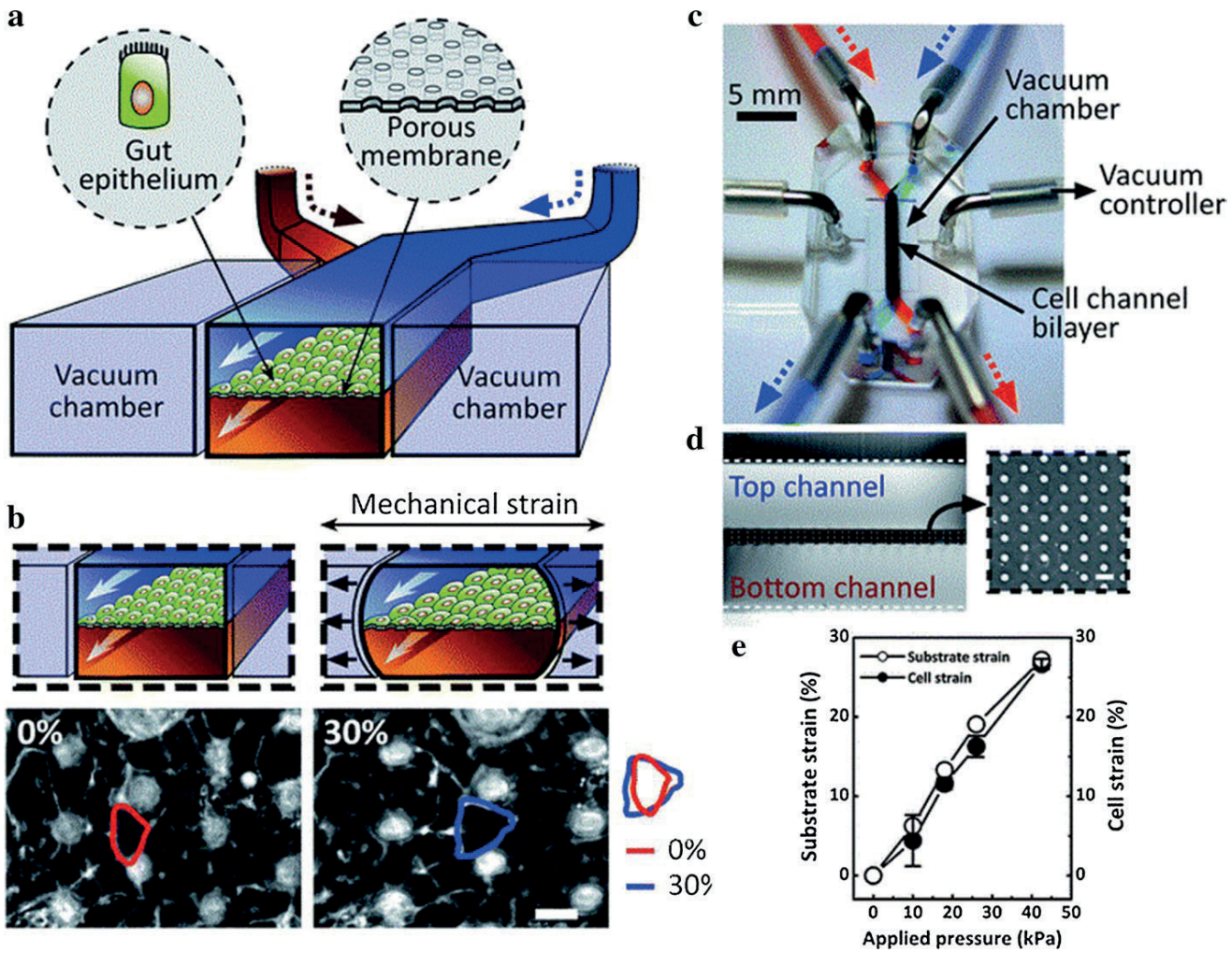



**Fig. 5** **a** Illustration of the intestine-on-a-chip device; **b** images of the device composed of transparent PDMS elastomers; **c** cross-sectional view of the channels and square illustrations showing a top view of the porous film; **d** schematic of intestinal monolayers cultured on the chips (top) and phase contrast images (bottom) plus (left) or minus (right) mechanical strains (30%); arrows indicate the direction). **e** pressure quantitation (reprinted with permission from [91] Copyright © 2012, Royal Society of Chemistry)

number of organs have since been concentrated onto individual chips. Organ chips are required to maintain a stable fluid connection, avoid bacterial contamination, and monitor cell viability throughout the culture process. As the number of organs on the chip increases, the complexity of the system is enhanced, inevitably leading to unpredictable results. Simplifying existing systems is critical to achieving a more extensive range of applications. Lee et al. [111] fabricated pumpless, user-friendly multi-organs-on-a-chip, which were quickly assembled and operated. Satoh et al. reported a multi-throughput multi-organ- on-a-chip system formed on a pneumatic pressure-driven medium circulation platform that was microplate-sized (Fig. 6) [112]. This system possesses the following advantages for application to drug discovery: simultaneous operation of multiple multi-organ culture units, the design flexibility of the microfluidic network, a pipette-friendly liquid handling interface, and applicability to experimental protocols and analytical methods widely used in microplates. This multi-organ culture platform will be a helpful research tool for drug discovery.

The continued development of OOAC was dependent on advances in design, modelling, manufacturability, and usability. Lantada et al. [113] produced an innovative combination of laser technologies. The assessment of human mesenchymal stem cells verified the effectiveness of the technique and the resultant chip

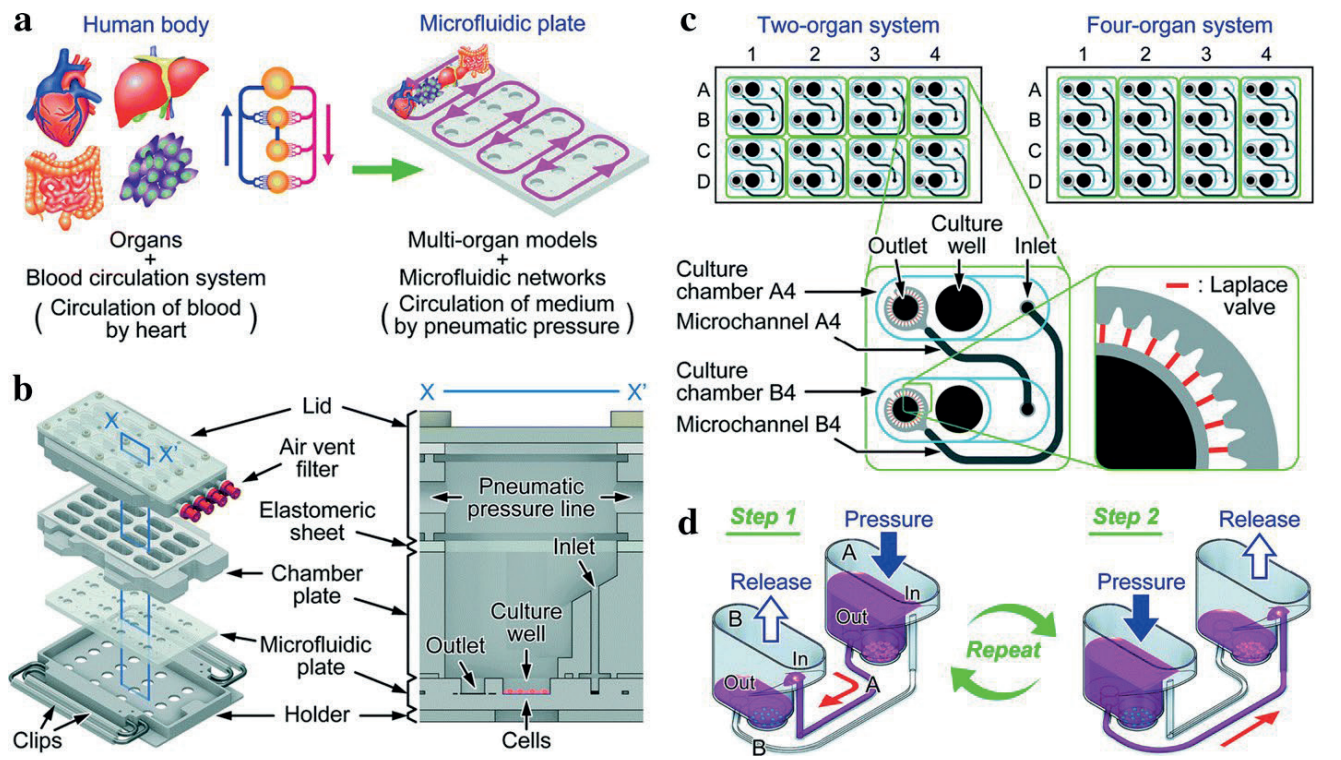



**Fig. 6** **a** Multi-throughput multi-organ-on-a-plate systems; **b** projection of a culture device containing a 4 × 4 culture chamber illustrated through a culture chamber of an X–X′ cross section; **c** design of microfluidic networks in the microfluidic plates for 8-throughput 2-organ systems and a 4-throughput 4-organ system. Design of the microfluidic networks in microfluidic plates for eight-channel dual-organ systems and four-flux four-organ systems. Closed circles indicate the location of the hole leading to the top surface of the microfluidic plate. Dark and light-shaded areas are deep and shallow microfluidic channels, respectively. Areas surrounded by green lines represent the circulation culture unit. Blue lines indicate the wall of the culture room. Thin red lines surrounding the exit indicate the Laplace valve. **d** Media circulation was performed using pneumatic pressure in the two-organ system. Red arrows indicate the direction of media flow (reprinted with permission from [112] Copyright © 2017, Royal Society of Chemistry)

was transparent, facilitating imaging procedures. Such technologies are feasible for mass-produced chips and hold utility for energy, transportation and aerospace industries.

OOAC technology has developed rapidly in recent years and has enhanced our knowledge of all the major organs. Others not discussed in this review include blood vessels [99, 114, 115], the skin [116, 117], the BBB [118, 119], skeletal muscle [120, 121], and the CNS [122, 123].

## STEM CELL ENGINEERING

The source of biological tissue is one of the most critical parameters in OOAC design. Stem cells can be extracted from humans without tissue biopsy [124]. By definition, a stem cell is any cell that is self-renewing and has the potential to differentiate into one or more specialised cell types. The most common examples include embryonic stem cells (ESCs), induced pluripotent stem cells (iPSCs), and adult stem cells (ASCs). These cells can be used as a biological tissue source for OOAC (Fig. 7) [125]. The most common human ASCs are mesenchymal stem cells (MSCs) which are pluripotent stem cells extracted from adult tissue [126]. Bone marrow mesenchymal stem (bMSCs) cells are typically derived from bone marrow or adipose tissue, making them an attractive option due to their ease of extraction from tissue biopsies [127].

Due to their limited ability to differentiate, lack of consistent derivation protocols and clear biological responses, MSCs are less useful in OOAC models than their pluripotent

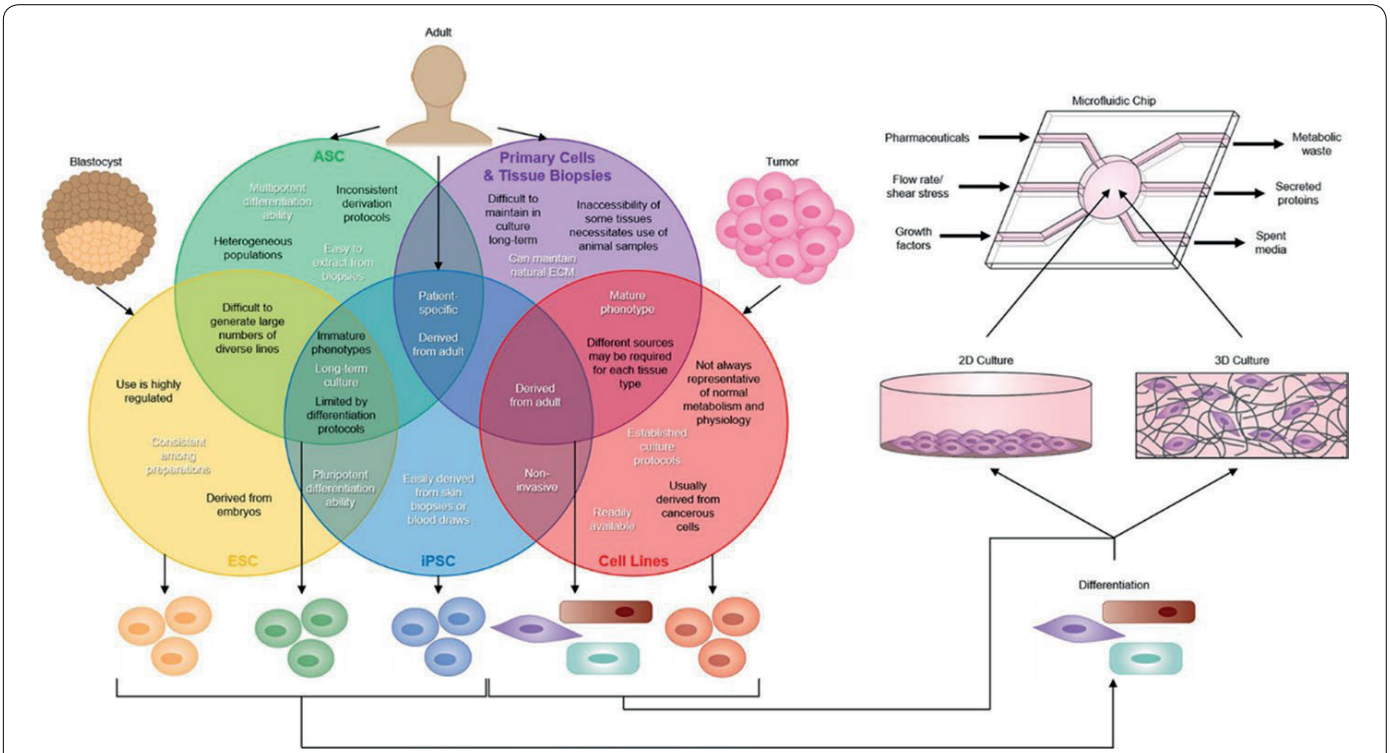



**Fig. 7** Tissue sources for the organ-on-a-chip (OOAC) devices. Embryonic stem cells (ESCs), induced pluripotent stem cells (iPSCs), and adult stem cells (ASCs) can be differentiated and integrated into microfluidic chips as for cell lines and primary cells. The figure illustrates the advantages (white) and limitations (black) of ESCs, ASCs, iPSCs, primordial and tissue biopsies, and cell lines in OOC devices. Cell lines and primary cells are more common in oocytes as they typically display good biological response characteristics. However, cell lines do not represent normal physiological conditions and primary cell culture time is limited, and the quality is unstable. In contrast, stem cells are readily available and are an infinite cell source. Even with current limitations on differentiation and maturation protocols, stem cells represent a promising technology that can be incorporated into OOC devices (reprinted with permission from [125] Copyright © 2019, Elsevier)

counterparts. Human ESCs originate from blastocysts or internal cells of the embryo. Dependent on the source, they can be pluripotent and differentiate into any type of adult cell from any of the three germ layers [128]. However, human ESCs must be derived from human embryos which are ethically controversial, in turn leading to regulations and restrictions.

Due to the ethical debate surrounding ESCs and the technical difficulties of producing large numbers of genetically diverse cell lines, it is more challenging to apply human ESCs to clinical trials than their use as precision drug replacements in disease models for therapeutic drug evaluation [129]. Like ESCs, MSCs are pluripotent and can differentiate from all three germ layers [130]. As iPSCs are derived from adult tissue rather than embryonic tissue, they avoid the ethical issues associated with ESCs. No significant differences in gene expression levels, surface marker expression, and morphology between ESCs and iPSCs are observed in cells from the same genetic background [131, 132]. In addition to circumventing ethical controversies, another advantage of iPSCs over ESCs is that they can be obtained from donors of known disease phenotypes, which can be used for patient-specific disease models and drug screening.

Since stem cells are more readily available than many primitive cell types and tissue biopsies, and they are more physiologically representative than other cell lines and are likely to become the primary tissue source for future OOAC (Fig. 8) [133]. Continued research into the methods by which

stem cells differentiate into functional organ models on chips will contribute to improvements in stem cell methods and advances in OOAC technology [125, 134].

## CONCLUSION AND FUTURE PERSPECTIVES

We have reviewed recent progress in OOAC technology. Microfluidic chips provide favourable support for the development of OOAC. Its development has attracted worldwide research attention, and significant scientific advances have been made.

A large number of OOACs have been designed and prepared. An array of human organs has been studied. The ultimate goal of OOAC is to integrate numerous organs into a single chip, and to build a more complex multi-organ chip model, finally achieving a "Human-on-a-chip".

Although OOAC technology has developed rapidly, the human-on-a-chip theory remains distant. PDMS is the most widely employed material but comes with disadvantages as the resultant film is thicker than the in vivo morphology. A decreased absorbance of small hydrophobic molecules influences solvent efficacy and toxicity. It is thus necessary to identify suitable alternative materials. At present, the cost of manufacturing and experimental implementation is relatively expensive, which is not conducive to the widespread use of organ chips, so components must be of low cost and easy to dispose of.

More costly components should be reusable. In terms of integrated system components, the media volume and connector size must be reduced for general use. Collecting samples on the chip may interfere with its operation, resulting in changes in the concentration of various metabolites.

More suitable sensors are thus required. Universal cell culture mediums ideal for all organs is also needed. Most critically, as the number of organs on the chip increases, functionality becomes more complex and generated data carry artefactual and non-translatable risks.

This is currently unsolvable. In the case of long-term repeated administration or on-chip studies, the biomarkers identified in vitro may not fully reflect the in vivo equivalent. wn

## REFERENCES

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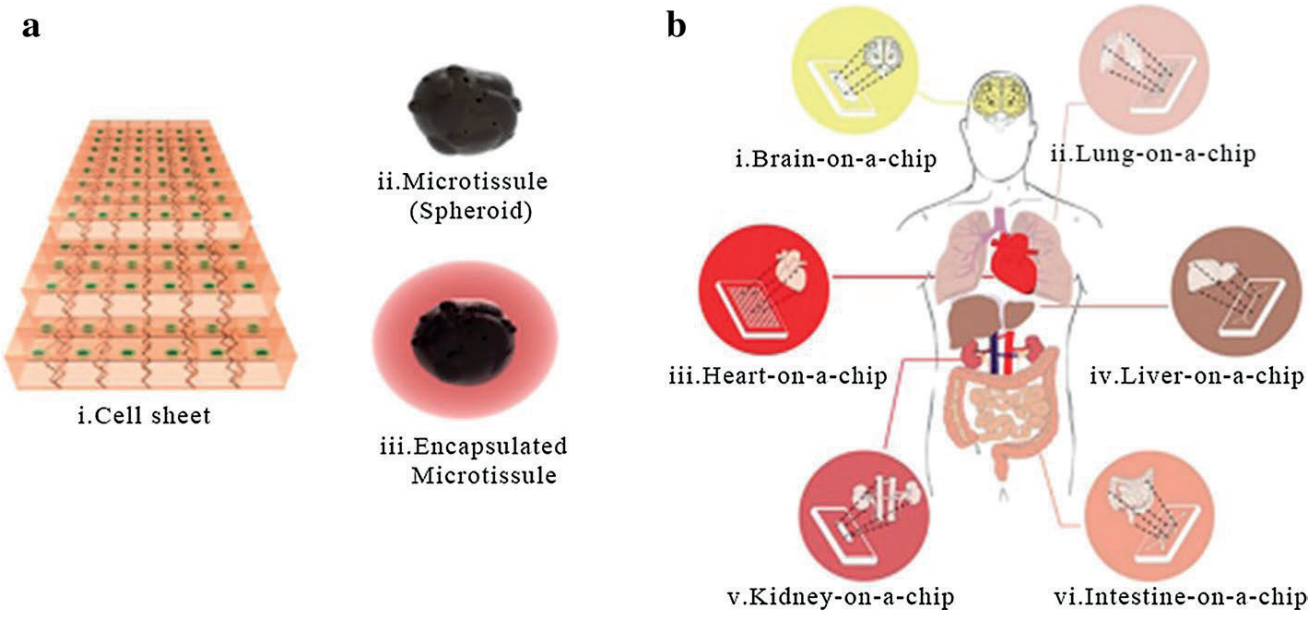
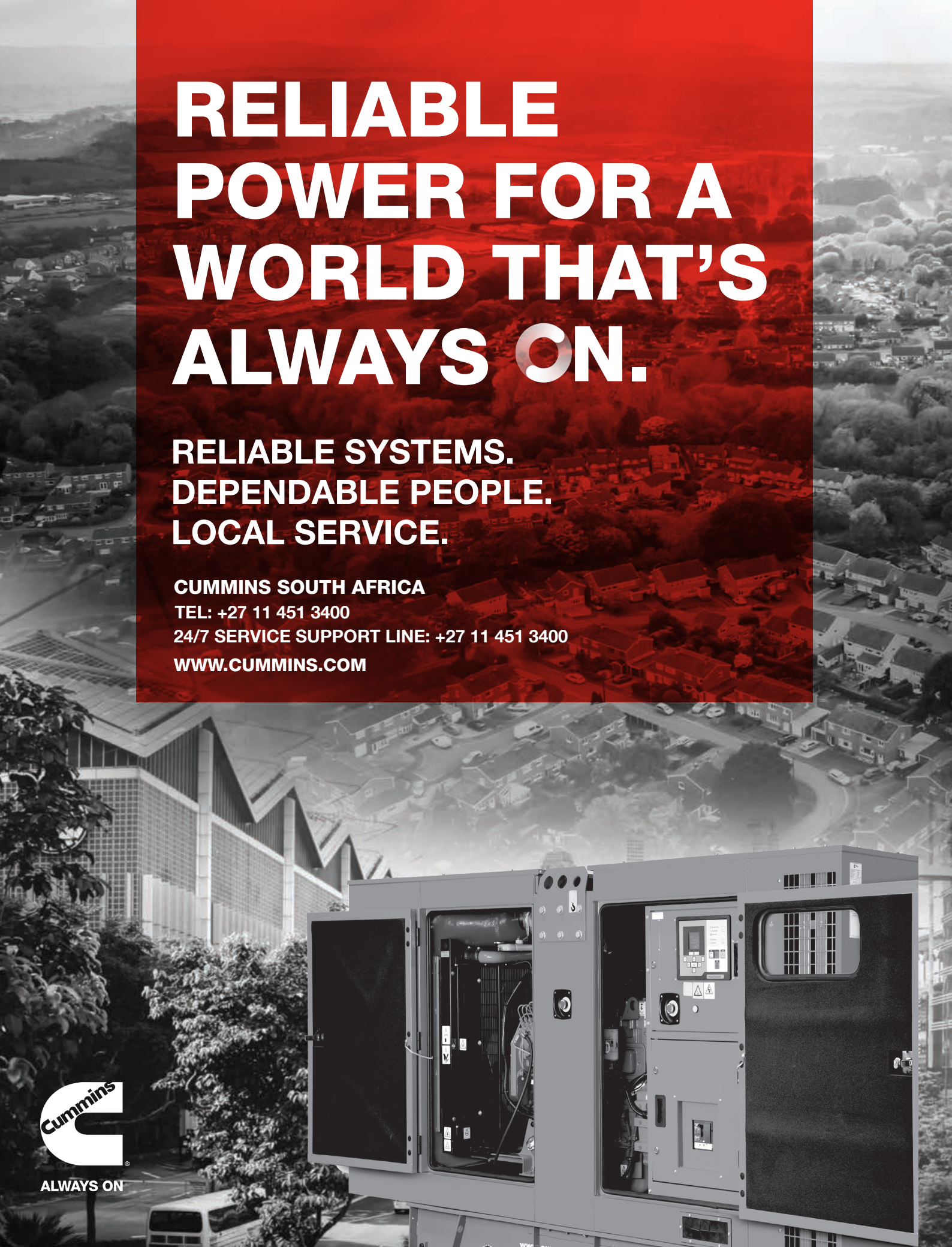



**Fig. 8** Future trends in stem cell research. **a** Building blocks. **b** Organ-on-a-chip techniques can mimic real-life in vivo states (reprinted with permission from [133] Copyright © 2015, John Wiley and Sons)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# The Understanding of Laboratory Equipment

Laboratory equipment refers to the various tools and equipment used by scientists working in a laboratory: The classical equipment includes tools such as Bunsen burners and microscopes as well as specialty equipment such as operant conditioning chambers, spectrophotometers and calorimeters.

**BY** KARABO SETLHAPELO
LABOTEC

In this article, we dicuss various vital laboratory equipment.

## WATER QUALITY IN YOUR LAB

Water is a standard reagent, used in various laboratories for different techniques and applications. For most laboratory and clinical applications, water is purified from tap water. Different technologies are used to remove impurities and manage additional contaminants effectively. Depending on the combination of techniques used, dirt can be removed down to deficient levels, while some applications require the removal of specific pollutants.

Activated carbon, Reverse Osmosis (RO) and Electrodeionization (EDI) are only a few of the technologies used in the Elga Water systems. Activated carbon is used in the removal of chlorine from water. RO is the act of forcing water through a semi-permeable membrane in the opposite direction of the natural osmotic flow. This is applied to ensure the dissolved particles behind in the more highly concentrated solution.

EDI is a technology that combines ion exchange resins and ion-selective membranes with direct current to remove ionised species from water. These technologies are combined cost-effectively to achieve the ideal water quality for your application. Combining these technologies, and optimising the operation, time is saved without compromising on the quality of the water.

## QUALITY TESTING OF ASPHALTED STREETS

When it comes to high-quality streets, grip, stability and longevity are only a

few keywords that come to mind—a defined mixture containing bitumen and aggregate particles from the top layer of an asphalted street. The combination is always different - depending on if the road is a mountain pass or an ocean drive and exposure conditions has to be taken into account. The proportion of these components in the mixture is essential for determining the quality of the asphalted streets.

For quality testing of asphalted streets, bitumen is separated from the aggregate particles and further tested. The process flow for this separation includes sample preparation and bitumen recovery.

A rotary evaporator is used as a central element in the recovery of soluble bitumen from bituminous mixtures used in road, airfield or similar applications.

## SPRAY DRYING FOR ROBUST, RELIABLE MATERIALS PROCESSING

Application of existing materials and technologies will continue to influence our daily life. Spray drying solutions are found to be popular, reliable and appreciated systems to be used in many fields of materials research. Combining the robust quality of the Buchi spray dryer instruments with a multitude of accessories and professional application support, there will be a tailored solution to almost every need.


Cemented carbide is well-known for its good fracture toughness and extraordinary wear resistance. Tungsten carbide (WC) and cobalt (Co) are significant components of cemented carbide. Due to the high strength, at elevated temperature, as well as mechanical and chemical resistance, carbide tools are found suitable for cutting, drilling, mining and machining. Other material carbides, such as titanium carbide, tantalum carbide and chrome carbide, could also be added. A combination of carbides is usually added to alter the properties of the product. Depending on the combination of carbides, the toughness, hardness and strength of the carbide tool can be changed.

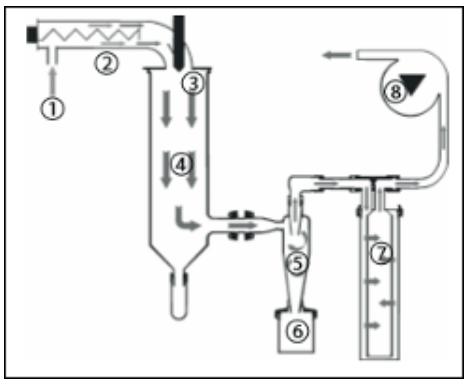
Wet milling of raw materials, spray drying, pressing, de-binding and pre-sintering, sintering, and finishing forms part of the process flow for conventional manufacturing of cemented carbide. Although a spray dryer can be used for traditional production of cemented carbide, it is also an important step to obtain graphene-based composites for research purposes.

Since the Nobel Prize in Physics was awarded to Andre Geim and Konstantin Novoselov in 2010 for their research into graphene, this material has attracted a great deal of research interest. Graphene, a thin, hexagonal lattice material, has many exciting features. These include high electric conductivity, superior mechanical properties, excellent chemical tolerance, and high surface area, which makes graphene a functional composite material for rechargeable Li-ion batteries. Although Li-ion batteries are seen as the typical type of energy storage systems, they exhibit a short cycle-life as well as a relatively low electric conductivity.

A large amount of research has been done to develop both anode and cathode materials to improve the performance of Li-ion batteries. Various graphene-based composites, such as

$TiO_2$/graphene, $CO_3O_4$/graphene. $SnO_2$/graphene, $Co(OH)_2$/graphene. $Mn_3O_4$/graphene. $Li_4Ti_5O_{12}$/graphene, $Fe_3O_4$/graphene, $LiFePO_4$/graphene, etc., have been researched and have shown superior performance compared to current anodes. Below is a diagram showing the principle of a spray dryer.

## FUNCTIONAL PRINCIPLE OF A SPRAY DRYER




The spray dryer consists of the following components:

1 Gas inlet
2 Electric heater
3 Concentric inlet of the hot gas around the spray nozzle
4 Spray cylinder
5 Cyclone to separate particles from a gas stream
6 Product collection vessel
7 Outlet filter
8 Aspirator to pump gas through the system

The inlet air is heated to the desired temperature (max 220˚C). The feed solution (sample) is pumped through a peristaltic pump to the integrated two-fluid nozzle. Compressed gas (usually air or $N_2$) is used to disperse the liquid body into fine droplets.

In the drying chamber, conductive heat exchange takes place between the drying gas and the sample droplets. Particle collection takes place through the cyclone technology, where the particles are separated from the gas stream and collected in the product collection vessel.

Very fine particles that cannot be separated in the cyclone are collected in the outlet filter. The outlet filter consists of polyester textile that prevents environmental pollution and the possible corrosion of the aspirator.

The outlet filter prevents fine particles from being released into the air where the spray dryer is positioned, thus preventing environmental pollution in the area and protecting the operators and equipment.

The second filter included consists of a polytetrafluoroethylene (PTFE) membrane. By counter-pulsing the filter with pressurised air, some of the collected particles can be recovered, resulting in a higher yield.

## CORROSION FIRMLY UNDER CONTROL

Corrosion resistance is an important quality indicator and safety feature for many products. High humidity, salty air, seawater, and gritting salt all contribute to corrosive atmospheres. Many items and products are exposed to corrosive atmospheres daily. Base metals, high-alloyed, tempered materials, plastics, and painted surfaces are all affected by corrosion.

Corrosion chambers, with recirculating air and alternating climate control, allows for the simulation the effect of salt spray, condensation, and standard climates. The alternating climate control refers to alternating temperature and humidity control. These parameters can be controlled individually, combined, and automatically – to deliver reproducible results, under certified, and accelerated conditions.

A precision two-component nozzle ensures optimal spray mist distribution. The two material nozzles are used to nebulise the salt solution in the testing chamber. These are arranged in specialised spraying channels in the walls of the chambers.

Humidified/heated compressed air is used to nebulise the salt solution in the testing chamber via the 2-material nozzles based on an injector principle. The salt spray will then fall on the test specimens from above. The double-shell construction, with internal insulation and heated compressed air, humidified with the water level, control and guarantees extremely stable temperatures.

Any droplets created by the spray are also prevented from dripping on the samples being tested, ensuring reliable results. wn

*For more information on the products depicted in this article, please contact Karabo at Labotec - Your partner in Science and Technology.*

Thomas, the youngest of ten children was born in Milverton, Somerset on 14 June 1773. He was a precocious learner of languages – before his fifth birthday he had read the entire Bible twice and wrote in Latin by age six.

By the age of fourteen he was fluent in Greek and Latin and was acquainted with French, Italian, Hebrew, German, Aramaic, Syriac, Samaritan, Arabic, Persian, Turkish and Amharic. He later went on to review about 400 languages for the Encyclopaedia Britannica, in addition to the articles that he wrote on the natural sciences.

Young began to study medicine in London in 1792 and moved in 1794 to Edinburgh, the capital of a country whose cultural ties have often been with the Continent as much as England. A year later he went to Göttingen, a seat of learning which had strong links with Hanoverian Britain, where he obtained the degree of doctor of physics in 1796. In 1797 he entered Emmanuel College, Cambridge. In this same year he inherited the estate of his grand-uncle, Richard Brocklesby, which made him financially independent.

In the spring of 1799 he established himself as a physician in London. Young took a low profile with his published academic articles as he thought that these may deter patients from his medical practice.

In 1801 he was appointed as professor of natural philosophy at the Royal Institution where in two years he delivered 91 lectures. Young's work on vision was revolutionary, writing several papers on the human eye. He explored accommodation – the eye lens changing shape to focus on objects at various distances. Young also researched astigmatism and hypothesized that it was the result of an improperly curved cornea.

Young additionally discovered that the human eye sees only three colours, red green and blue and that other colours are made up of those three. He also explained the iridescent nature of soap bubbles. He produced a machine for measuring blood corpuscles and also worked on acoustics.

Great advances in colour theory were later made by James Clerk Maxwell who was also the first scientist to produce a colour photograph. He used the method of taking three photographs through coloured filters which would also later be used by Technicolour cinematography.

# Thomas Young... The Man who knew Everything

Thomas Young (1773-1829) was a polymath whose astonishing breadth of knowledge and expertise led to his becoming known as 'The man who knew everything.'

**BY** DUDLEY BASSON

In 1802 Young was appointed foreign secretary of the Royal Institution. He resigned his fellowship in 1803 to devote himself fully to his medical practice.

On June 14, 1804, Young married Eliza Maxwell, an intelligent woman who understood and supported his work throughout his life. No children were born of the marriage.

Young enjoyed a lively social life. He often dined with the most august company in London, and, busy as he was, easily communicated with the great minds in his social circle.

He was well-respected, if not always well understood, and managed to avoid controversy, particularly as he feared the effect it might have on his medical practice.

Also in 1804, Young developed the theory of capillary phenomena on the principle of surface tension. He also observed the constancy of the angle of contact of a liquid surface with a solid, and showed how from these two principles to deduce the phenomena of capillary action. In 1805, Pierre Simon Laplace, the French mathematician and philosopher, discovered the significance of meniscus radii with respect to capillary action.

In 1811 he became physician to St. George's Hospital, and in 1814 he served on the committee appointed to consider the dangers involved by the general introduction of gas into London. In 1816 he was secretary of a commission charged with ascertaining the length of the second's pendulum to define the time unit. In 1818 he became secretary to the board of longitude and superintendent of the Nautical Almanac Office.

Young took a keen interest in music theory.

On 9 July 1799 Young sent a letter to the London Royal Society describing a pair of musical circulating temperaments which were read at the Society's January meeting and included in its Philosophical Transactions for that year. Young argued that these would make the harmony most perfect in those keys that are most frequently used.

For details of Young's tuning, click here.

To the mathematically minded, the tuning of the twelve notes of an octave presents a teasing and intractable problem. The practice of dividing

musical sounds into octaves where each following octave has double the frequency seems intuitive and has been in use since ancient times. Dividing the octave into several musical intervals is another matter altogether. The earliest recorded method of tuning is the Pythagorean temperament which used the familiar twelve semitone octave which remains in use to this day.

The Pythagorean tuning provided musical chord intervals which were in simple integer ratios of frequencies which gave the most pleasing results and is known as 'just' tuning.

The octave is the basic ratio of 1:2. The next most important interval is the 'fifth' which is the fifth note on the major scale, which spans 7 semitones, and on the C major scale would be G which should ideally have a frequency ratio of 3:2. This would multiply the frequency of C by 1,5. To complete the octave would require adding a 'fourth' of 5 semitones.

The even temperament tuning which is used on all keyboard instruments has the frequency of each successive semitone increase by the twelfth root of 2, which is an irrational number and cannot produce intervals which are exactly in simple integer ratios, but the differences are very small.

Each successive semitone increases by multiplying the frequency by 1,05946… and for seven semitones would be 1,498307… which is very close to 1,5. If all the notes are tuned by going around the circle of fifths several times this will not end well. Another important interval is the 'third' which spans 4 semitones with an ideal ratio of 5:4 or 1,25. The even temperament value would be 1,259921… which is also very close.

See this video for the Pythagorean tuning by fifths and the Pythagorean comma.

See this excellent video of the circle of fifths and key signatures.

See Pythagorean just tuning in the strings.

The Ptolemaic scale also provides 'just' tuning. For the difference see.

For more details of the Thomas Young tuning, click here.

Violin open strings are tuned to G, D, A and E which are spaced in fifths. The violinist will have no difficulty in playing in 'just' intervals or in even temperament if accompanied by a piano.

The ancient Greeks defined seven 'modes' or scales: Ionian, Dorian, Phrygian, Lydian, Myxolidian, Aeolian and Locrian. All of these can be started on a white key of the keyboard. The Ionian corresponds the present 'major' scale and the Aeolian to the present 'minor' scale. Composers and songwriters can and do use the Greek modes by using a major or minor key and adding accidental sharps or flats as required. When a musical piece is played in a major key, and then played again in the corresponding minor key, it seems to acquire a touch of sadness.

For an excellent video of the details and sounds of the Greek modes, click here.

Many other divisions of the octave have been tried over the years. A recent attempt is the 31 tone scale which divides the octave into 31 notes without semitones. Another is the 12 tone scale of 24 semitones. Other divisions that have been suggested are: 15-tone, 17-tone, 19-tone, 22-tone, 23-tone, 34-tone, 41-tone, 53-tone, 58-tone 72-tone and 96-tone.

For some oscilloscope lissajous figures showing the difference between 'just' and even tempered tuning, click here.

Young also did much work on assigning numeric values to the Italian tempo indications.

Sir John Herschel singled out Young's insight into sound interference as:
*"The key to all the more abstruse and puzzling properties of light which alone would have sufficed as to place its author in the highest rank of scientific immortality, even were his other almost innumerable claims to such a distinction disregarded."*

In 1801 Young performed his ground breaking double slit experiment which proved that light has a wave nature which seemingly contradicted Newton's theory that light was of corpuscular nature. Young passed a beam of light split into two beams around a small piece of cardboard which then illuminated a screen.

The screen showed an interference pattern of stripes which could only be produced by constructive and destructive wave interference between the two light sources. If light were of corpuscular nature the screen would only show two stripes corresponding to the two sources. This experiment requires the use of monochromatic coherent light such as a laser, but Young used sunlight which was sufficiently coherent to provide a conclusive result. Young also suggested that light consisted of transverse waves rather than longitudinal waves.

Young, speaking on 24 November 1803, to the Royal Society of London, began his now-classic description of the historic experiment:
*"The experiments I am about to relate ... may be repeated with great ease, whenever the sun shines, and without any other apparatus than is at hand to everyone."*

The wave nature of light was taken further by James Clerk Maxwell, who achieved what was possibly the greatest ever advance in theoretical physics, with his mathematical electromagnetic theory of light.

This showed that light propagated as transverse waves of electric and magnetic fields oscillating at right angles to each other. Maxwell was also able to express the speed of light in terms of the electric permittivity and magnetic permeability of space.

This was by no means the last word on the nature of light. Louis Victor Pierre Raymond duc de Broglie proved in 1927 that electrons also had a wave nature, for which he was awarded the 1927 Nobel prize in physics. It was subsequently found that electrons fired one at a time through the slits would eventually also produce an interference pattern. It has been found that even large molecules can exhibit a wave nature.

WATCH: A video clip of Young's double slit light experiment.

For a detailed treatment of the double slit experiment click here.

Despite the experimental and theoretical proof that light and other electromagnetic radiation have a wave nature, the corpuscular theory would simply not go away.

In 1900, while studying black-body radiation, physicist Max Planck claimed that the energy carried by electromagnetic waves could only be released in "packets" of energy, which later came to be known as photons. The photons were energy quanta and the energy value could be simply obtained by multiplying the frequency by the famous "Planck's Constant h". In 1905 Albert Einstein published a paper also advancing the hypothesis that light energy is carried in discrete quantized packets to explain experimental data from the photoelectric effect. This was a key step in the development of quantum mechanics.

In 1914, Millikan's Experiment supported Einstein's model of the photoelectric effect, and also determined the value of the charge of the electron. In 1922 Einstein was awarded the Nobel Prize in Physics for "his discovery of the law of the photoelectric effect", and Robert Millikan was awarded the Nobel Prize in 1923 for "his work on the elementary charge of electricity and on the photoelectric effect".

The world was left with the fact that electromagnetic radiation has a 'wave/particle' duality.

The existence of photons is easily demonstrated by considering the light from a remote galaxy. If this were waves in a mysterious 'ether' the light would be too attenuated to be detectable by any means at all. Photons however retain their frequency, energy and velocity unchanged despite travelling for millions of years through space and can easily be detected.

The energy of light quanta is almost incomprehensively small. Let us consider a point source radiating 5W of visible light of 700 THz in all directions. At a distance of 1 km this would give a photon flux of 850 photons per millisecond through one square mm.

Young announced his modulus of elasticity for solid material in a paper in 1807. This was simply a re-statement of Hook's law of elasticity which stated that strain was proportional to stress, which was also mentioned by Euler, who also derived the formula for the buckling load of a slender column.

The modulus is the ratio stress/strain which can be given as a property of the material and which is expressed in pascals. This is in widespread use being required for designing springs, calculating deflections in loaded structures, reinforced concrete design etc. The closely related Poisson ratio gives the deformation of the object at right angles to the applied stress.

Other moduli added later are the Shear Modulus and Bulk Modulus. Elasticity does of course work within limits and falls away when the material is stressed to its yield point.

Young did not always express himself clearly, as can be seen in his bizarre description of his elasticity modulus:
*"The modulus of the elasticity of any substance is a column of the same substance, capable of producing a pressure on its base which is to the weight causing a certain degree of compression as the length of the substance is to the diminution of its length."*

When this explanation was put to the Lords of the Admiralty, their clerk wrote to Young saying: *"Though science is much respected by their Lordships and your paper is much esteemed, it is too learned ... in short it is not understood."*

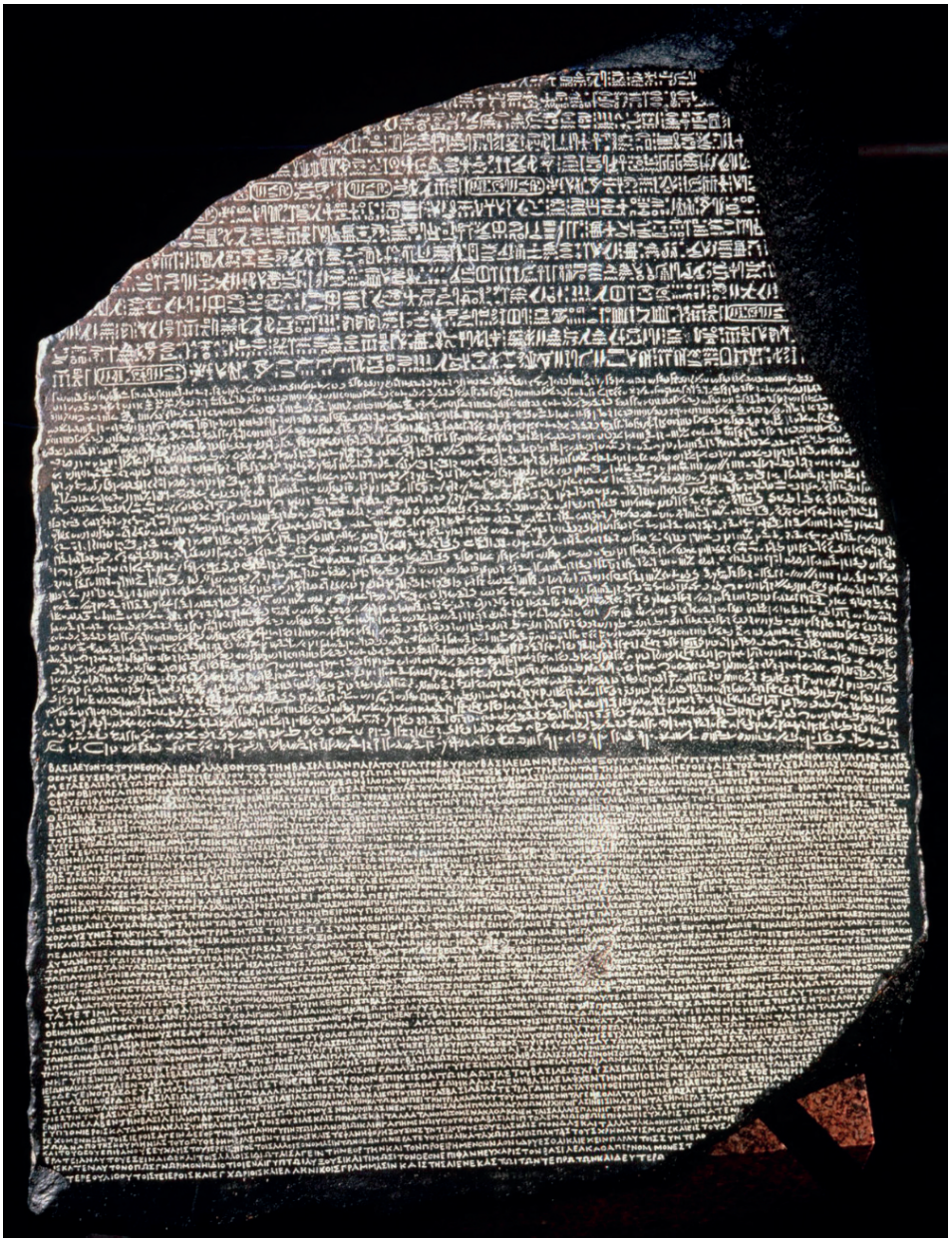
Young took an interest in the ancient Egyptian languages in 1814 when he was shown a demotic papyrus which had newly arrived from Thebes. This led him to a study of the middle section of the Rosetta stone.

The Rosetta stone is possibly the most famous object in the British Museum. According to the inscription on the stone, an identical copy was to be placed in every sizeable temple in the land. The original stone would have been considerably taller than it is today. The lost uppermost register would have been decorated with figures of the king and the gods of the temple.

Of the hieroglyphic text only a third is left. The demotic register is the most complete with only a small corner being lost. The bottom register contains the Greek text with also a corner being lost. When the French officers found the stone they immediately recognised its importance. It was being used as building material. As fate would have it, the stone was not taken to the Paris Louvre – Napoleon's humiliating defeat at the Battle of the Nile resulted in the stone being taken to the British Museum.

Young noticed that the demotic was derived from the hieroglyphs and contained phonetic elements as well as signs and groups of signs. Young was aware of the possibility that the clue to the ancient language lay in Coptic, which he turned to learning as well, which also provided a key to the pronunciation of the Egyptian names.

Young proceeded to identify words and phrases in the demotic version with similar expressions in the Greek equivalent. In 1819 he published an article in the Encyclopaedia Britannica in which he offered equivalents for 218 demotic words as well as 200 hieroglyphic groups. French Egyptologist François-Joseph Chabas remarked that this was the 'Let there be Light' of Egyptology.



*The Rosetta Stone*

Young's posthumously published work 'Rudiments of an Egyptian Dictionary in the Ancient Enchorial Character' contains his translation of an entire demotic contract as well as considerable portions of the demotic Rosetta text. The notion that the oval frames or cartouches of inscriptions being discovered contained the names of kings, and a study of the Greek text, strongly suggested that this was the case. The ultimate triumph of deciphering the hieroglyphic language was announced by Champollion in 1822. Egyptologists are now able to read the hieroglyphs with ease.

WATCH: This video of the decipherment of the Rosetta stone.

WATCH an excellent video of the hieroglyphic alphabet.

Another ancient language found in Egyptian excavations has been identified as Carian – a dead language from the southern coast of Anatolia. This has defied decipherment despite containing some Greek characters and being thought to have Indo-European origins.

When looking at ancient unintelligible scripts it is impossible to get any grasp of the richness an expressiveness of the language. Many ancient Egyptian texts have been found which include decrees, letters, poetry, nursery rhymes, shopping lists, calculations and also adult-only material. A good translation however, switches on the lights. Let us take a look at a letter from the mayor of Sennufer to tenant-farmer Baki:

*The mayor of the southern capital Sennufer speaks to the tenant-farmer Baki son of Kyson, to the following effect. This letter is brought to you to tell you that I am coming to see you when we moor at Hu in three days' time. Do not let me find fault in you in your duties. Do not fail to have things in perfect order. Also, pick for me numerous plants, lotuses and flowers, and others worth offering. Further you are to cut 5000 boards and 200 timbers; then the boat which will bring me can carry them, since you have not cut any wood this year – understood? On no account be slack. If you are not able to cut them then you should approach Woser, the mayor of Hu. Pay attention: the herdsman of Cusae and the cowherds who are under my authority, fetch them for yourself in order to cut the wood, along with the workmen who are with you. Also, you are to order the herdsmen to prepare milk in the new jars in anticipation of my arrival – understood? You are not to slack, because I know that you are a wiwi, and fond of eating in bed.*

Hermann Ludwig Ferdinand von Helmholtz (1821 - 1894) was a physician and physicist who made significant contributions in several scientific fields. In 1852 Helmholtz wrote a somewhat over-the-top tribute to Young for his colour theory:

*The theory of colours, with all these marvellous and complicated relations, was a riddle which Goethe in vain attempted to solve; nor were we physicists any more successful. I include myself among the number; for I long toiled at the task, without getting any nearer my object, until I at last discovered that wonderfully simple solution had been discovered at the beginning of this century, and had been in print for anyone to read who chose. This solution was found and published by the same Thomas Young who first showed the right method of arriving at the interpretation of Egyptian hieroglyphics. He was one of the most acute men who ever lived, but had the misfortune to be too far advanced of his contemporaries. They looked on him with astonishment, but could not follow his bold speculations, and thus a mass of his most important thoughts remained buried and forgotten in the Transactions of the Royal Society until a later generation by slow degrees arrived at the rediscovery of his discoveries, and came to appreciate the force of his arguments and the accuracy of his conclusions.*

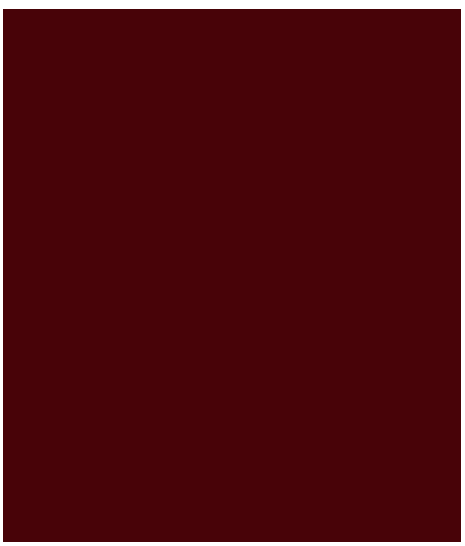
A telling vignette of Young's life was written by a young friend, Mary Somerville, the first woman scientist and mathematician to win an international reputation in her own right.

In her memoirs, she recalls how she and her husband William were stargazing with a telescope until about two o'clock in the morning when they happened to notice a light in the window of Young's house in nearby Welbeck street; clearly Dr Young was burning midnight oil again. William rang the doorbell. Dr Young appeared in his dressing gown and they were invited in to see a piece of Egyptian papyrus which he was busy translating – which appeared to be a Ptolemaic horoscope.

Not everyone was overawed by Young's brilliance. Physicist David Park wrote:

*Like other members of the Royal Society, Thomas Young was a wealthy dilettante. Unlike most of them he possessed fabulous intelligence and a capacity for hard work, but he was a dilettante nonetheless. Though he wrote poetry in Latin and Greek he never learned to express himself clearly in English. Everything he wrote, and by report everything he said in his lectures, was vague and offhand.*

A few years before his death, Young became interested in life assurance, and in 1827, he was chosen one of the eight foreign associates of the French Academy of Sciences. In the latter part of his life, he devoted his leisure to work on deciphering Egyptian hieroglyphics, and at the time of his passing, was at work on a dictionary of hieroglyphics. wn



# A Timeline of Genius and Innovation

The timeline given on page 50 & 51 has been drawn up to illustrate the huge wave of creative genius that surged over Europe in the 19th century. This timeline is by no means comprehensive or complete but will suffice to illustrate the phenomenal intellectual endeavour. Several other categories could also have been included. This was also a period of political instability and horrific military conflict.

**BY** DUDLEY BASSON

As can be seen on the timeline, Thomas Young was an almost exact contemporary of Fourier, Gauss, Ampere, Ørsted and Beethoven, and a partial contemporary of many other great names of intellectual genius.

Beethoven is of particular significance - Biographer Robert Haven Schauffler said of him: *He donated such a profound charge of thought and passion that the world still vibrates with the shock.*

At this point it seems appropriate to play a work of Beethoven, but how can we select anything typical from the vast treasure available? I can remember being in London in August 1971. A concert was advertised with Barenboim, Zukerman and Jacqueline du Pré performing the Archduke trio in the Royal Albert Hall on the 3rd September.

It was disappointing to not be able to attend due to booked travel plans, but my loss was compounded when it later transpired that the concert had to be cancelled for tragic reasons.
Let us listen to an earlier recording of the same work performed by the same artists.

This was the last work in which Beethoven performed as a pianist in public.

Physicist Lise Meitner wrote of a memorable concert at Max Planck's home where this work was performed by Planck, Einstein and a professional cellist.

For a tribute to Jacqueline du Pré see.

The great innovators of mathematics, science and engineering set the foundations for phenomenal development in the 20th century.

Unprecedented advances were made in electronics, electrical engineering, civil engineering, mechanical engineering, automotive engineering, aeronautical engineering, chemical engineering, robotic manufacturing, physics, computer science, information technology, telecommunications, medical science, materials, astronomy, space exploration - the list is endless. The developments in military weaponry have held the world in thrall for nearly a century.

Perhaps an explanation would be in order for the inclusion of the Hollywood actress Hedy Lamarr in the timeline of engineers.

Born in Austria as Hedwig Kiesler and after a career which included 30 movies, six husbands, and problems with drugs and shoplifting, she went on to help with developing frequency-hopping spread spectrum telecommunications which came into widespread military use.

Strangely, the music category cannot be included in the surge of development.

The composer Georg Perle observed when Stravinsky died, that the world was without a great composer for the first time in six hundred years. A situation which persists to this day.

Physicist Werner Heisenberg, himself an accomplished concert pianist remarked:

# Timeline of Gen

Mathematicians | Scientist

1670 | 1680 | 1690 | 1700 | 1710 | 1720 | 1730 | 1740 | 1750 | 1760 | 1770 | 1780 | 1790 | 1800 | 1810 | 1820

Newton (1643-1727)
Laplace (1749-1827)
Leibniz (1646-1716)
Lagrange (1736-1813)
Boole (181
Euler (1707-1783)
Weierstras
Bernoulli brothers & sons
Fourier (1768-1830)
Gauss (1777-1855)
Wronski (1779-1853)
Lavoisier (1743-1794)
Bessel (1794-1846)
Cassini (1625-1712)
Galvani (1737-1798)
Hamilton (1805-1
Huygens (1629-1695)
Volta (1745-1827)
Rie
Boyle (1627-1691)
Thomas Young (1773-1829)
Hooke (1635-1703)
Ampere (1775-1835)
Ørsted 1777-1851)
Carnot (1796-1832)
Babbage (1791-1871)
Faraday (1791-1867)
Savery (1650-1715)
Watt (1736-1819)
Ke
Newcomen (1664-1729)
Telford (1757-1834)
Trevithick (1771-1833)
George Stephenson (1781-1848)
Robert Stephenson
I K Brunel (1806-
Schubert (1797-1828)
Rossini (1792-1868)
Schumann (18
J S Bach (1685-1750)
Vivaldi (1678-1741)
Mozart (1756-1791)
Mendelssohn (1
Handel (1685-1759)
Liszt (1811-1
Haydn (1732-1809)
Chopin (1810-
Gluck (1714-1787)
Wagner (18
Verdi (181
Beethoven (1770-1827)
Boieldieu (1775-1834)
Hummel (1778-1837)
John Field (1782-1837)
Donizetti (1797-1848)


Newton


Fourier


Watt


Maxwell


Faraday


Ampere


Bach


Mozart


Schubert


Beethoven

1670 | 1680 | 1690 | 1700 | 1710 | 1720 | 1730 | 1740 | 1750 | 1760 | 1770 | 1780 | 1790 | 1800 | 1810 | 1820

# ius and Innovation

s | Engineers | Musicians

1830 1840 1850 1860 1870 1880 1890 1900 1910 1920 1930 1940 1950 1960 1970 1980

Cantor (1845-1918)

15-1864

Von Neumann (1903-1957)

s (1815-1897)

Turing (1912-1954)

Boltzmann (1844-1906)

Hilbert (1862-1943)

Gödel (1906-1978)

Poincaré (1854-1912)

1865)

Ramanujan (1887-1920)

Mandelbrot (1924-2010)

emann (1826-1866)

Hausdorff (1868-1924)

Maxwell (1831-1879)

de Brogli (1892-1987)

Planck (1858-1947)

Tesla (1865-1943)

Heaviside (1850-1925)

Einstein (1879-1955)

Schrödinger (1887-1961)

lvin (1824-1887)

Heisenberg (1901-1976)

Diesel (1858-1913)

Dirac (1902-1984)

Benz (1844-1929)

Lee de Forest (1873-1961)

(1803-1859)

Marconi (1874-1937)

-1859)

van der Bijl (1887-1948)

Otto (1832-1891)

Whittle (1907-1996)

Daimler (1834-1900)

Hedy Lamarr (1914-2000)

Rachmaninov (1873-1943)

10-1856)

Debussy (1862-1918)

809-1847)

Puccini (1858-1924)

1883)

Stravinski (1882-1971)

1849)

Elgar (1857-1934)

313-1883)

Bartok (1881-1945)

3-1901)

Brahms (1833-1897)

Bizet (1838-1875)

Ravel (1875-1937)

Bruch (1838-1920)

Tchaikovsky (1840-1893)

Hindemith (1895-1963)

Grieg (1843-1907)

Dvorak (1841-1904)

Sibelius (1865-1957)

Mascagni (1863-1945)

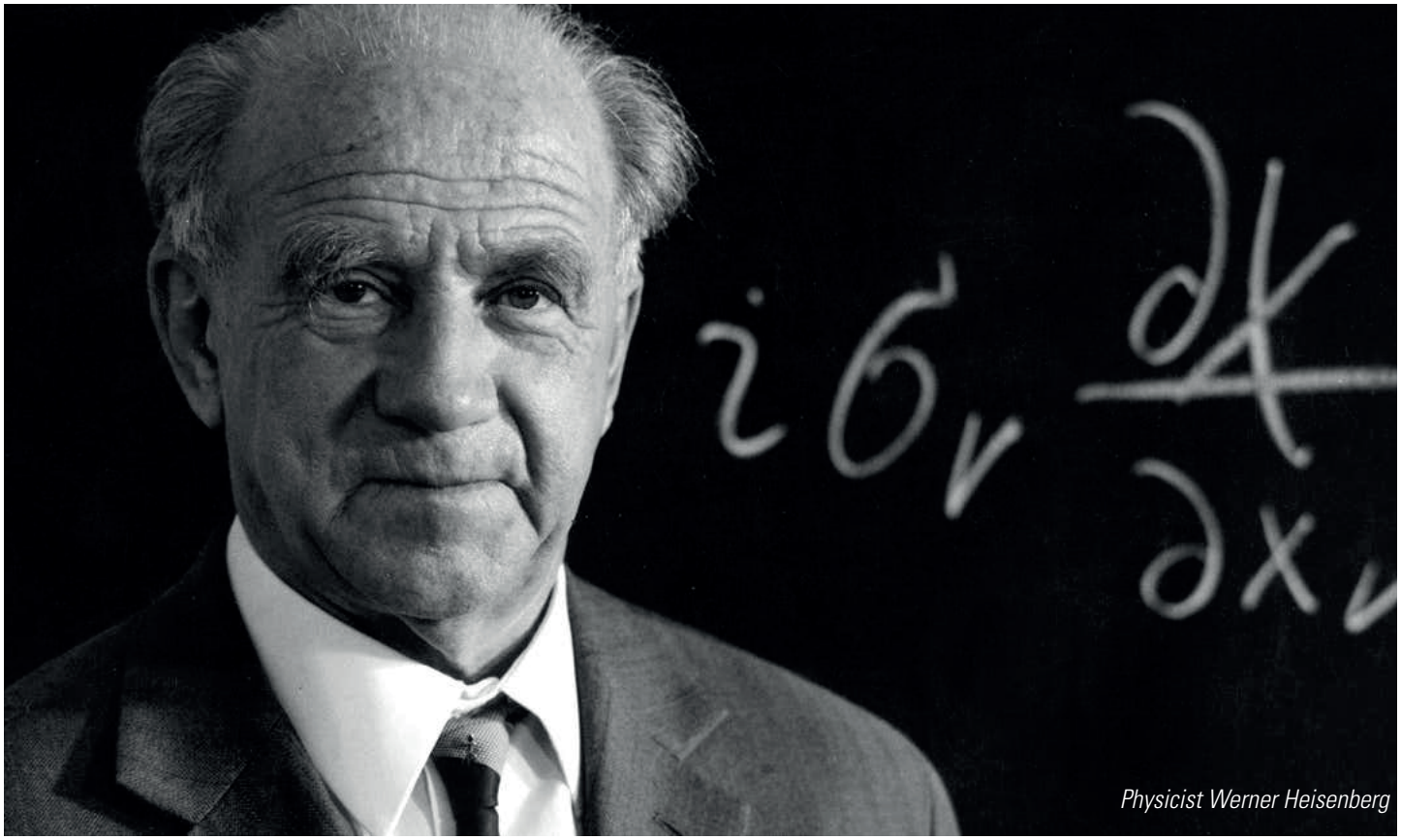
Laplace

de Brogli

Brunel

Wagner

1830 1840 1850 1860 1870 1880 1890 1900 1910 1920 1930 1940 1950 1960 1970 1980



Physicist Werner Heisenberg

*In music I find that the compositions of recent years are no longer as compelling as those of earlier times. During the 17th century music was still largely orienting itself on the religious core of life at the time; in the 18th century there was a transition into the emotional realm of the individual, and the romantic music of the 19th century has penetrated the innermost depths of the human soul, but in recent years music seems to be caught in a noticeably restless and rather feeble stage of experimentation, in which theoretical notions play a more important role than the secure awareness of progressing along a predetermined course.*

On one occasion, after playing Beethoven's last piano sonata (op. 111) at a party, Heisenberg stood up and told the spellbound audience, *"If I had never lived, someone else would probably have formulated the uncertainty principle. If Beethoven had never lived, no one would have written opus 111."*

In his autobiography Heisenberg mentions the sadness as when he and his friends were thinking of the great epoch of European music as gone forever.

Assigning the mantle "The man who knew everything" to Thomas Young may seem rash, as this is simply not possible, and he did not even seem to bother much with astronomy which had seen much development by Copernicus, Galileo, Kepler, Cassini, Huygens, Newton et al.

Of the thousands of academic papers which are now published every year, who could possibly claim to know everything about even one of them?

In the chapel of St Andrew in Westminster Abbey is a white marble tablet, with a profile medallion, to the memory of Thomas Young, physician, physicist, writer and Coptic scholar. The sculptor was Sir Francis Chantrey and it was erected in 1834.

The inscription by Hudson Gurney reads: *Sacred to the memory of Thomas Young M.D. Fellow and Foreign Secretary of the Royal Society, Member of the National Institute of France. A man alike eminent in almost every department of human learning. Who, equally distinguished in the most abstruse investigations of letters and of science, first established the undulatory theory of light and first penetrated the obscurity which had veiled for ages the hieroglyphics of Egypt. Endeared to his friends by his domestic virtues, honoured by the World for his unrivalled acquirements, he died in the hopes of the Resurrection of the just. Born at Milverton in Somersetshire June 13th 1773, died in Park Square London May 10th 1829, in the 56th year of his age.* wn

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# May in History

**COMPILED BY |**
JANE BUISSON-STREET
FSAIEE | PMIITPSA | FMIITSPA

**1 MAY**

1885 The first recorded celebration of May Day in South Africa which was organised by the Johannesburg District Trades Council.

1928 May Day was taken up by African workers en masse.

**2 MAY**

1933 A local Inverness newspaper "The Inverness Courier" publishes an account by a local couple who claimed to have seen "an enormous animal rolling and plunging on the surface" of Loch Ness (Scotland, UK).

**3 MAY**

1991 One of the most well-known television shows of its time, "Dallas", went off air after 13 seasons. A revival of this television series ran from June 2012 to September 201.

**4 MAY**

1933 Karl Jansky described the discovery of radio waves from the centre of the Milky Way galaxy in a paper he read to the International Radio Union in Washington, USA.

**5 MAY**

1834 William Whewell wrote a letter to Michael Faraday concerning names to describe the process of electrolysis which he was investigating. Whewell suggested the names Anode and Cathode. Faraday replied that he was *"delighted with the facility of expression which the new terms give me and I shall ever be your debtor for the kind assistance you have given me."*

**6 MAY**

1851 John Gorrie, an American physician, was issued the first US patent for his invention of an "Improved Process for the Artificial Production of Ice" (No. 8080) (i.e. a mechanical refrigerator). His British patent, No. 13,124, had been granted on 22 Aug 1850.

**7 MAY**

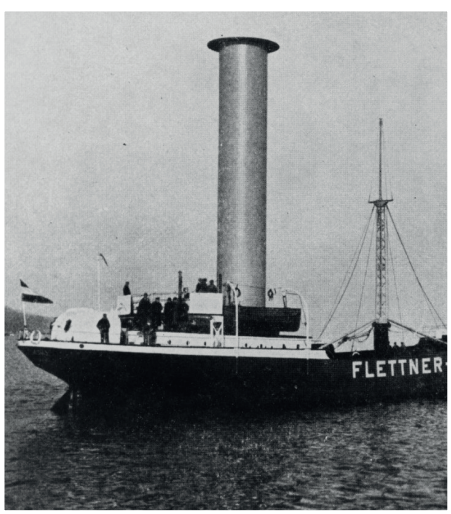
1660 Isaack B Fubine of Savoy, in The Hague, patented macaroni.

**8 MAY**

1962 The era of the trolleybus in London, England ended. Just as they replaced London's trams from 16 May 1931, they were themselves have been superseded by diesel-fuelled buses as economical alternatives.

**9 MAY**

1926 The Baden-Baden, a rotor ship that had been invented by Anton Flettner, arrived in New York, USA having left Hamburg, Germany on 2 April 1926.



**10 MAY**

1975 The first home videocassette recorder, the Betamax, began sales in Japan. The format was made by Sony and used one-hour tapes. A competing system was introduced by JVC the following year called VHS (Video Home System) that was capable of two-hour recording.

**11 MAY**

1951 Jay Forrester filed a patent application for the matrix core memory. Up until then computers were large, memory relied on cathode ray tubes and primarily used by the military.

**12 MAY**

2004 Zahi Hawass, president of Egypt's Supreme Council of Antiquities, announced, during a conference at the University of California, the discovery of what was believed to be the world's oldest seat of learning, the Library of Alexandria. A Polish-Egyptian team had uncovered 13 lecture halls featuring an elevated podium for the lecturer. Such a complex of lecture halls had never before been found on any Mediterranean Greco-Roman site.

**13 MAY**

1913 The first four-engine airplane was first built and flown by Igor Sikorsky of Russia. He is also considered to be the inventor of the helicopter.

**14 MAY**

1963 For the first time a laser light beam link was used to carry the TV signal during a network broadcast. Nowadays laser light beams are now routinely used to transmit signals along optical fibres.

**15 MAY**

1935 At the Franklin Institute, Philadelphia, Albert Einstein was awarded the Benjamin Franklin Medal for his outstanding fundamental contributions to theoretical physics, especially his relativity theory. According to Time magazine, *"A throng of scientists and dignitaries was assembled to hear what the medallist had to say. Einstein genially informed the chairman that he had nothing to say, that inspiration which he had awaited until the last moment had failed him. The chairman, much more embarrassed than the medallist, conveyed this information to the audience."*

**16 MAY**

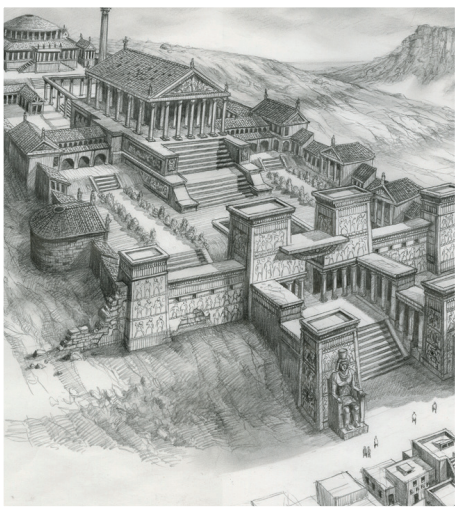
1992 Space shuttle Endeavour completed its maiden voyage with a safe landing on runway 22 at Edwards Air Force Base in the California desert. It was the first use of a drag-chute for a Shuttle landing. The mission STS-49 included the first three-person spacewalk, which captured Intelsat VI, a private communications satellite, for repair and reboost as it had been stranded in an unusable orbit since it was launched on Mar 1990. After capture, it was equipped with a new perigee kick motor. When released, the satellite reached an operational geosynchronous orbit.

**17 MAY**

1954 The official ground-breaking ceremony took place at the Meyrin site of the new CERN (the European Organization for Nuclear Research)Laboratory in Geneva.

**18 MAY**

1969 Apollo 10 was launched to be a complete staging of the Apollo 11 mission without actually landing on the Moon. The mission was the second to orbit the Moon and the first



# May in History

continues from page 63

to travel to the Moon with the entire Apollo spacecraft configuration. It made a successful eight-day dress rehearsal for the first manned moon landing.

**19 MAY**

1959 The first submarine with two nuclear reactors was completed. The USS Triton had two water-cooled General Electric nuclear reactors to power electricity generators which powered the propellers. The Triton was 236m long, 11m wide, manned by 148 officers and crew and had a cruising range of 1 777 000km.

**20 MAY**

1940 Inventor Igor Sikorsky demonstrated his helicopter invention to the public. (See 13 May 1913)

**21 MAY**

1853 The Aquatic Vivarium, the world's first public aquarium, was opened in Regent's Park, London. It was the brainchild of an English self-taught naturalist, Philip Henry Gosse, who wrote popular illustrated books on nature, and especially marine biology. He invented the institutional aquarium when he opened the Aquatic Vivarium.*

**22 MAY**

1899 Plain Dealer reporter, Charles Shanks, first used the French word "automobile" in a series of articles he wrote about a road trip with car magnate Alexander Winton from Cleveland to New York. From thereon, the word has been used in the USA.

**23 MAY**

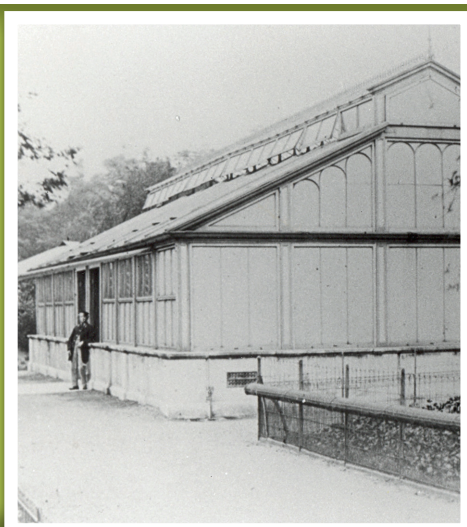
1785 A letter from Benjamin Franklin referred to his bifocal glasses. Writing from France to George Whatley, a friend, Franklin described his "double glasses" solution to needing two pairs of glasses of different focussing power to see objects far or near. He wrote, *"I had the glasses cut and half of each kind associated in the same circle. ... I have only to move my eyes up and down as I want to see far or near, the proper glasses always being ready."*

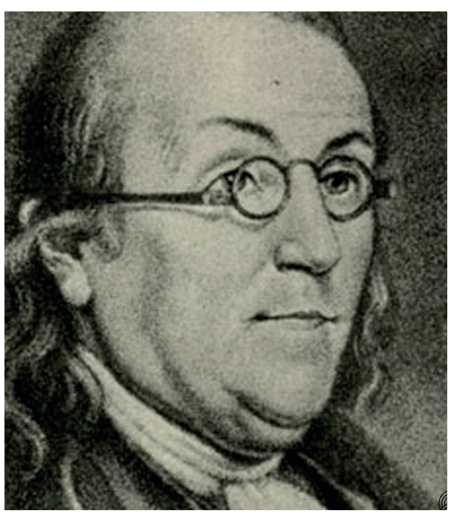
**24 MAY**

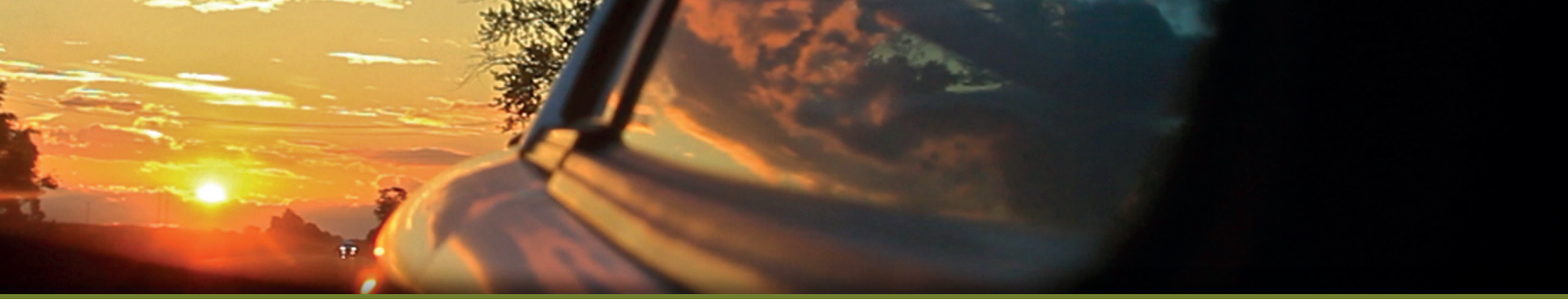
1921 Thomas A. Edison received yet another one of his various patents concerning a "Storage Battery" (U.S. No. 1,379,088) and another relating to the "Production of Thin Metallic Sheets or Foils" (No. 1,379,089).

**25 MAY**

1967 John Lennon's psychedelic Rolls Royce was delivered. This caused an uproar which included Rolls Royce Company who had raised a formal complaint. John Lennon had bought the car new from Rolls Royce in 1965, and had become bored with the colour so had a







psychedelic paint job. The car was later sold at Sotheby's in 1985 for $2,299.000.00 the most expensive car ever sold at the time.

**26 MAY**

1896 Following the death of his father Czar Alexander III in 1894, the last Czar of Russia, Nicholas II, was crowned ruler of Russia,

**27 MAY**

1923 The first Le Mans 24-Hour race ended with a win for Andre Lagache and Renee Leonard after having covered 1,372.928 miles in a Chenard-Walker car.

**28 MAY**

1928 The Dodge Brothers, Inc. and the Chrysler Corporation merged. Prior to this:-

- both of the Dodge brothers died during 1920, and
- Walter P. Chrysler created Chrysler Corporation on 6th June 1924.
- Dodge Brothers, Inc., was sold to a New York banking firm for $146 million in 1925.
- Chrysler Corporation purchased the company for $170 million in 1928 resulting in Dodge became a Chrysler division.

**29 MAY**

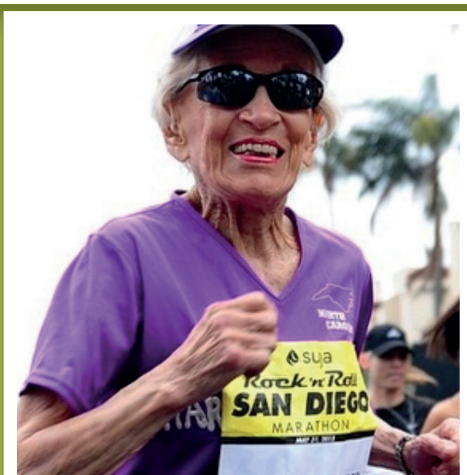
1898 Alfred Nobel's heirs signed a "reconciliation agreement" so that lawyers and accountants could execute his will. The will's major bequest was to create the Nobel Prizes, but first, there were disputes that needed to be settled.

**30 MAY**

1987 North American Philips Company introduced the compact disc video (CD-V), a 12 cm CD-sized implementation of the earlier Laser Vision format (previously available in 20 cm and 30 cm since 1977). The CD-V discs were gold rather than silver. They were marketed as "CDs with pictures". Most of the titles that were released were music. CD-V required a special CD-V drive, which was used mostly in the music industry and commercial video production arena. Despite the higher picture quality when compared to videotape, the CD-V format was never commercially successful.

**31 MAY**

2015 Finishing a marathon is difficult at any age, but if you want to know how hard it is at 92 you'll have to ask Harriette Thompson. The Charlotte, N.C., resident completed the San Diego Rock 'n' Roll marathon on Sunday (31 May 2015) with an unofficial finishing time of 7:24:36, making her the oldest woman to run a competitive 26 miles and 385 yards. wn

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# SAIEE CALENDAR

## JUNE 2020

| | |
|---|---|
| 1 | **SAIEE Training Academy - Online CPD course** Finance Essentials for Engineers - 1st session |
| 2 | **SAIEE Training Academy - Online CPD course** Finance Essentials for Engineers - 2nd session |
| 3 | **SAIEE Training Academy - Online CPD course** Finance Essentials for Engineers - 3rd session |
| 4 | **AM Series - Webinar ISO55k:** CIGRE TB 787: Implementation in Electric Utilities P Moyo / T Mokwana |
| 5 | **SAIEE Training Academy - Online CPD course** Finance Essentials for Engineers - 4th session |
| 9 | **SAIEE Training Academy - Online CPD Course** Incident Investigation & Management - 1st EP |
| 10 | **SAIEE Training Academy - Online CPD Course** Incident Investigation & Management - 2nd EP |
| 11 | **AM Series - Webinar ISO55k:** Maintenance Strategies - T Mokwana |
| 17 | **SAIEE Training Academy - Online CPD Course** Substation Design & Equipment Selection - 1st |
| 18 | **SAIEE Training Academy - Online CPD Course** Substation Design & Equipment Selection - 2nd |
| | **AM Series - Webinar ISO55k:** Expansion & Operations Strategies - L Naidoo / M Kopa |
| 19 | **SAIEE Training Academy - Online CPD Course** Substation Design & Equipment Selection - 3rd |
| 23 | **President's Invitation Lecture Webinar** Presenter: Mr Dave Nicholls |
| 25 | Centre Chairs Meeting |
| | **WATTNOW ST-TALK: Biomedical Webinar** |
| | **AM Series - Webinar ISO55k:** Asset Condition Assessment - P Moyo / G Fogel |

To organize a webinar on the SAIEE Platform, please complete the **Webinar Booking form**.

## JULY 2020

| | |
|---|---|
| 2 | **Power & Energy Section Monthly Meeting** "Opportunities in the energy storage space" |
| | **AM Series - Webinar ISO55k:** Project Portfolio Optimisation - B Neijens |
| 9 | **SAIEE Training Academy - Online CPD Course:** SANS 10142-1. Edition 3 2019 - 1st session |
| 10 | **SAIEE Training Academy - Online CPD Course:** SANS 10142-1. Edition 3 2019 - 2nd session |
| 15 | **SAIEE Training Academy - Online CPD Course:** Fundamentals of Practical Lighting Design - 1st sess |
| 16 | **SAIEE Training Academy - Online CPD Course:** Fundamentals of Practical Lighting Design - 2nd sess |
| 15 | **Power & Energy Section - Webinar** Electric vehicles |
| 21 | **Load Research Chapter** "Electrification planning case studies and tools" |
| | **SAIEE Training Academy - Online CPD Course:** Financial Evaluation of Projects - 1st session |
| **23** | **WATTNOW ST-TALK - Power Engineering** |
| 24 | **SAIEE Training Academy - Online CPD Course:** Financial Evaluation of Projects - 2nd session |
| 27 | **SAIEE Training Academy - Online CPD Course:** Financial Evaluation of Projects - 3rd session |
| 28 | **SAIEE Training Academy - Online CPD Course:** Financial Evaluation of Projects - 4th session |
| 29 | **SAIEE Training Academy - Online CPD Course:** Power Systems Protection - 1st session |
| 30 | Centre Chairs Meeting |
| | **SAIEE Training Academy - Online CPD Course:** Power Systems Protection - 1st session |
| 31 | **SAIEE Training Academy - Online CPD Course:** Power Systems Protection - 1st session |
| | **Load Research Chapter - Webinar** "National & Regional electricity planning models" |

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