STEM SPECTRUM

INNOVATION
Through Insight

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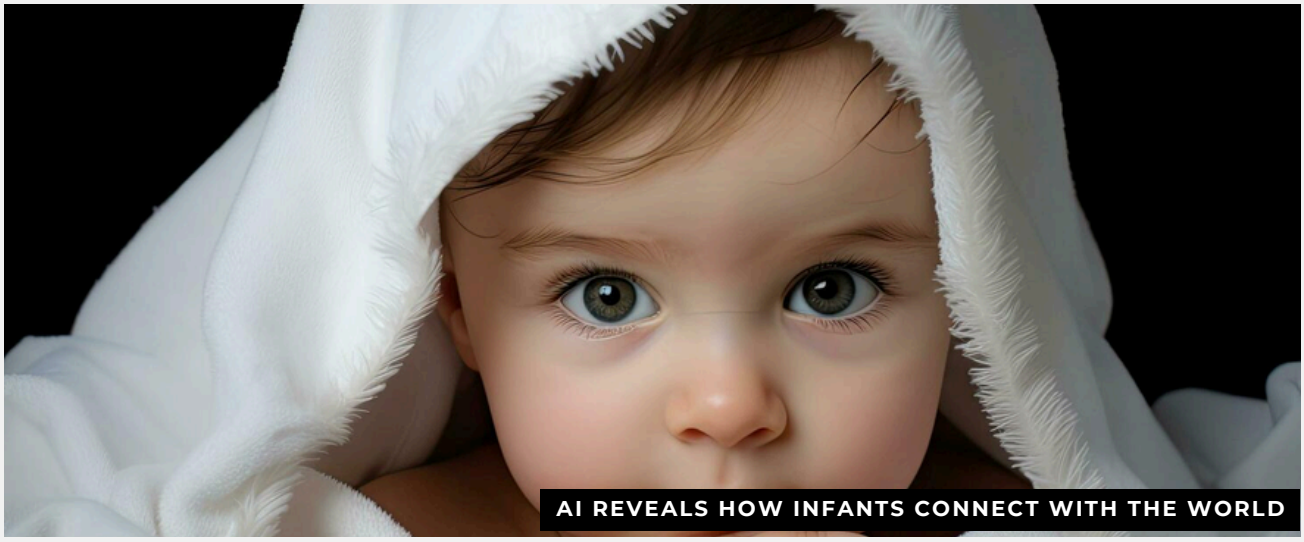

Here's some exciting things that happened recently in the scientific community!

Welcome to this issue of the STEM Newsletter!
We are thrilled to bring to you the latest developments and groundbreaking research currently being conducted by the scientific community across the world. Each issue is dedicated to keeping you informed about the exciting discoveries, technological advancements and innovative solutions from all different fields of STEM.
Our mission is to keep you updated on the ongoings in the complex world of STEM, in hopes of providing a platform where knowledge meets curiosity. We hope this issue helps you foster a deeper understanding of the world around you, inspire you to become the next generation of thinkers and innovators.

In addition to updates the newsletter will also explore the constant discussions of current scientific issues, offering nuanced perspectives on topics that are beginning to and will shape our future.
Whether you're a seasoned professional, an educator, a student, or simply someone passionate about STEM, there's something here for everyone. We hope you find this newsletter both informative and inspiring, and we look forward to exploring the world of STEM with you.
Enjoy this issue, and let's dive into the wonders of science together!

Rosalyn C

In this newsletter you can expect:

THE EFFECTS OF AIR POLLUTION ON A CHILD'S BRAIN DEVELOPMENT

Air pollution, as many may know, has often been associated with *cardiovascular morbidity* and *morality*. Data from the World Health Organization (WHO) suggest that an estimated 4.2 to 7 million people die from air pollution worldwide every year. According to a 2023 study, air pollution in South Asia – one of the most polluted areas in the world – cuts life expectancy by about 5 years. In Europe, a recent report by the European Environment Agency (EEA) showed that more than half a million people living in the European Union died from health issues directly linked to toxic pollutants exposure in 2021. Inadequate infrastructure and funding for the high levels of pollution in some countries as well as a combination of factors such as high *fossil fuel combustion* and *industrial agricultural processes* are responsible for such pollution. Emerging evidence throughout the years has raised concern regarding the potential harm of inhaled pollutants to the *central nervous system.*

Furthermore, *epidemiological studies* suggest a connection between TRAP exposure and *cognitive decline*, as well as dementia, in elderly.[1]
A recent study published in Vol 69 of Developmental Cognitive Neuroscience, completed by a research team in University of California Davis, which performed a systematic review 40 empirical studies, suggested an association between outdoor air pollution and differences in children's brains. These differences include that of varied volumes of *white matter*, often associated with *cognitive function* and early markers for *Alzheimer's disease.* The studies surveyed included measures of outdoor air pollution and brain outcomes for children ranging from newborns to 18 year old adults.

"Children and teens are especially vulnerable to air pollution because their brains and bodies are still developing. They tend to spend more time outdoors, and their bodies absorb more contaminants relative to their bodyweight than adults."

Exposure to traffic-related air pollution (TRAP) has been linked with negative impacts on mental development and behavioural functions, including attention deficits, reduced global IQ, memory decline, and decreased academic performance.
There is also a higher prevalence of *Attention Deficit Hyperactivity Disorder* (ADHD) and *Autism Spectrum Disorder* (ASD) among those exposed.

With the majority of the studies from the United States, Mexico and Europe, there were also one from both Asia and Australia. Studies from Mexico City that compared children from high- and low-pollution areas also found significant differences in brain structure.
Spanning over 40 studies, brain differences were measured through a vast range of methods. From *magnetic resonance imaging* (MRI) to testing changes in chemical compounds that aid brain function and health and even looking for *tumours* in the brain and or *central nervous system*.

[1]https://link.springer.com/article/10.1007/s40572-018-0209-9

All studies showed brain differences linked measures of air pollution to the child's neighbourhood or address whether it be places of both high levels of air pollution or places where pollution levels met local standards
The review, contrasting from most others, focused on the effects of air pollution on children, rather than adults or animals. Further links between outdoor air pollution and differences in the brain can be seen through experimental research on animals showing pollution does, in fact, lead to similar outcomes established by the studies reviewed, of which including markers for Alzheimer's disease.
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This suggests that air pollution may slow down normal brain development, as the effects of pollution contrasted with the *brain maturation pattern*s observed with age. As seen, within the same group, the caudate nucleus was found to be vulnerable to air pollution. Exposure to airborne copper and *polycyclic aromatic hydrocarbons* (PAHs), especially *benzopyrene*, was linked to specific brain changes. Airborne copper was associated with alterations in the *caudate nucleus*, with an increase in grey matter (GM) at the expense of *white matter* (WM). Advanced imaging techniques like DTI and MRI revealed possible damage to white matter pathways in the caudate nucleus and disrupted connections between the caudate and the *frontal lobe operculum*. Furthermore, exposure to PAHs was linked to a subtle decrease in the volume of the caudate nucleus, suggesting potential early damage to this brain region.

"A lot of these studies include children in places with air pollutant levels that are well below limits set by U.S. or European regulations," said Anna Parenteau, a Ph.D. student in psychology at UC Davis and the study's co-first author.

The BREATHE Study investigated the effects of air pollution on brain development in primary schoolchildren using multiple MRI techniques. Among 263 children, no significant links were found between school-based measures of *elemental carbon* (EC) and *nitrogen oxides* (NO) and changes in the brain's anatomy, structure, or metabolism. However, functional MRI showed that higher levels of EC and NO were associated with reduced functional connectivity and efficiency in key brain networks involved in both internal thinking processes (the default mode network) and responses to *external stimuli.*

Animal studies have found that inflammatory and *oxidative stress*, identified as common and basic mechanisms through which air pollution causes damages, may also affect the CNS through *neuronal death* (the death of brain cells) and *synaptic toxicity* (damage to synapses), disrupting and or damaging the communication between *neurons*, essential for thinking, memory and learning. Moreover, through *systemic inflammation* (inflammation that spreads throughout the body) caused by air pollution, circulating *cytokines levels* may increase, affecting the proteins used to regulate *immune responses*, hence having a peripheral impact on the brain.

"We can't necessarily apply findings from adults and assume that it's going to be the same for children," said Johnna Swartz, an associate professor of human ecology and co-author on the study. "We also have to look more at different developmental windows because that might be really important in terms of how air pollution might impact these brain outcomes."

Key Words:

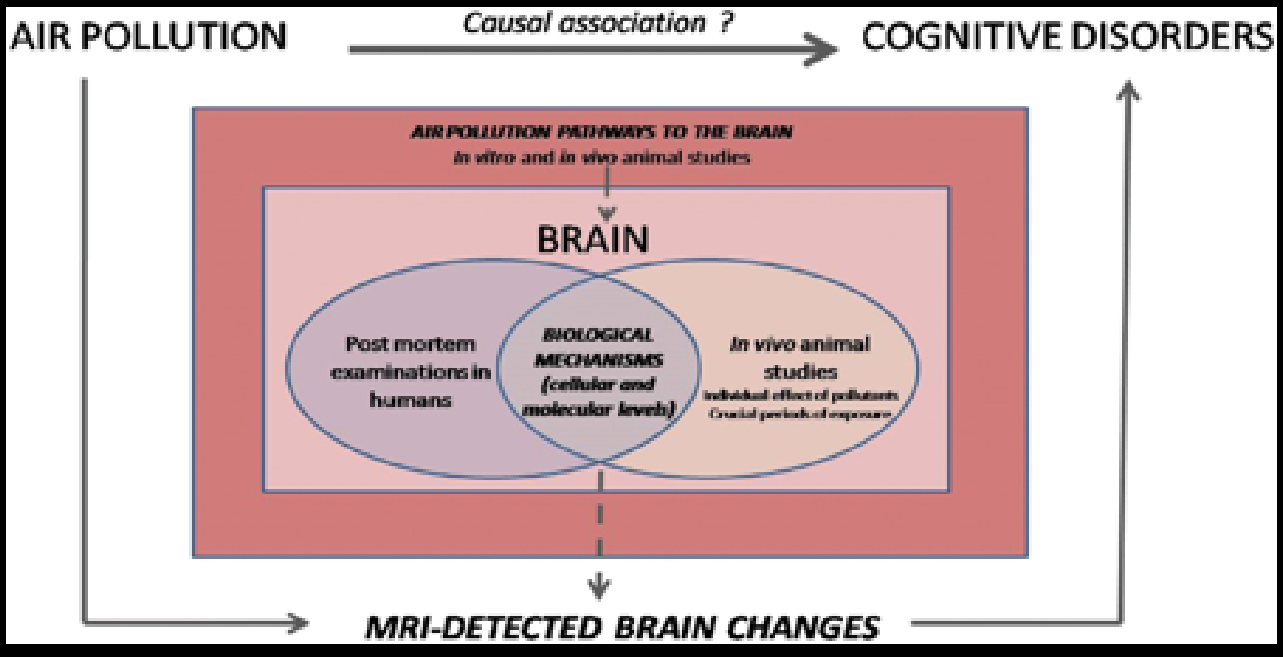
Elemental Carbon (EC)
☀️ A component of particulate matter found in air pollution, mainly produced by vehicle emissions and other combustion processes. It is a marker of traffic-related air pollution.

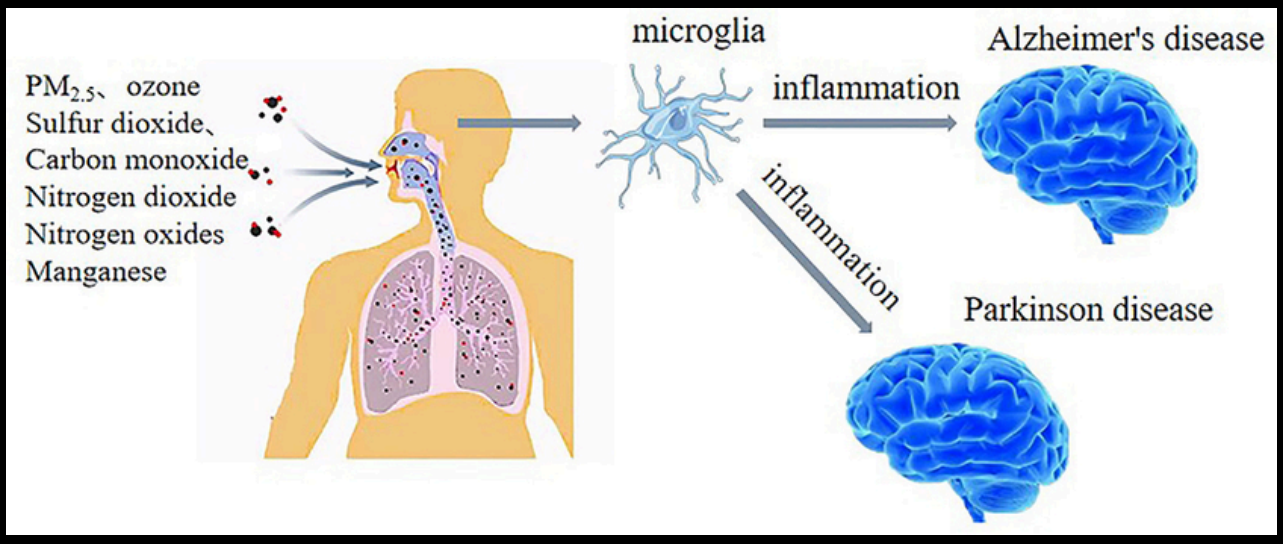
Default Mode Network (DMN)
💭 A network of brain regions active when you're not focused on the outside world, involved in daydreaming, self-reflection, and memory.

Functional Integration and Segregation
🔄 Terms describing how different brain areas communicate and work together (integration) or operate separately (segregation) during different tasks.

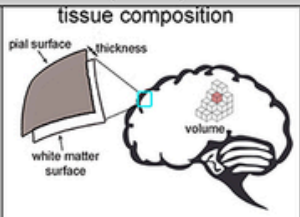
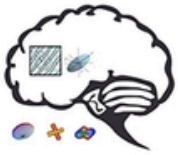
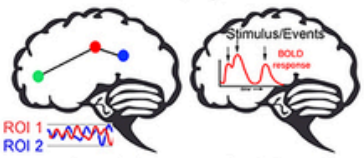
Caudate Nucleus
🧠 A part of the brain involved in motor control, learning, and memory. It's sensitive to air pollution and environmental factors.

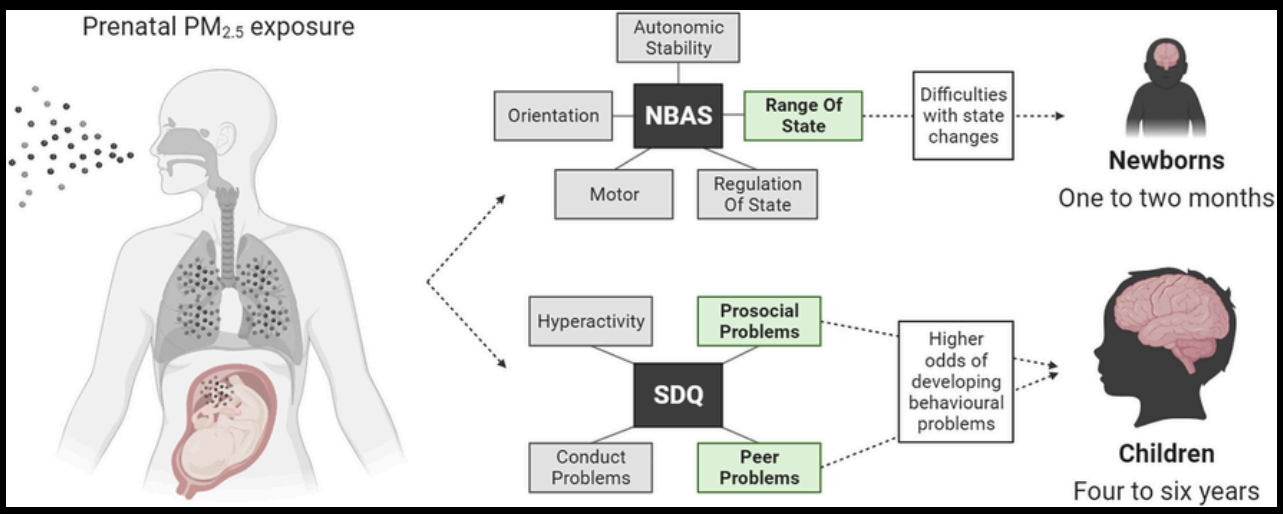
PAHs (Polycyclic Aromatic Hydrocarbons)
⚠️ Harmful chemicals found in pollution from burning fossil fuels. PAHs can negatively impact the brain and body.
Benzopyrene
🧪 A specific type of PAH linked to a reduction in brain volume, particularly in the caudate nucleus.
Grey Matter (GM)
⚫ Brain tissue with most of the brain's neurons, involved in muscle control, sensory perception, and decision-making.
White Matter (WM)
⚡ Brain tissue composed of axons that facilitate communication between different brain regions.
DTI (Diffusion Tensor Imaging)
📊 An advanced MRI technique that tracks water molecules in the brain to detect changes or damage in white matter pathways.
Frontal Lobe Operculum
🔍 A region of the brain involved in language, decision-making, and other cognitive functions, sensitive to pollutants like copper.





"WE'RE SEEING DIFFERENCES IN BRAIN OUTCOMES BETWEEN CHILDREN WITH HIGHER LEVELS OF POLLUTION EXPOSURE VERSUS LOWER LEVELS OF POLLUTION EXPOSURE," SAID CAMELIA HOSTINAR

	Structural MRI (sMRI)	Diffusion MRI (dMRI)	Functional MRI (fMRI)		Spectroscopy (MRS)
MRI Technique	tissue composition 	water diffusion 	blood-oxygen-level- dependent (BOLD) signal 	resting-state correlations task-based brain activity	proton frequencies 
Measures	volume; surface area; cortical thickness; density (VBM)	diffusion modeling (e.g. diffusion tensor imaging (DTI))	timecourse correlations	signal change between task conditions	metabolites
Functionality	gray or white matter size & shape	white matter microstructure	*functional* connectivity of brain regions	brain activity	brain metabolites
Literature	Peterson (34) Pujol (35) Pujol (36) Mortamais (37) Guxens (38) Alemany (39)	Pujol (35) Pujol (36)	Pujol (35) Pujol (36)	Pujol (35)	Pujol (35)



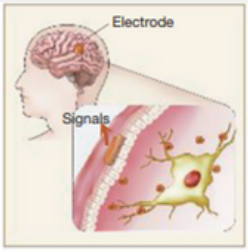
Research Updates: KO Ho Tin

Have you ever envisioned a future in the 2070s where people can have cyberbodies, using their minds to control machines and connect to the internet? This is the potential of BCI (brain–computer interface).

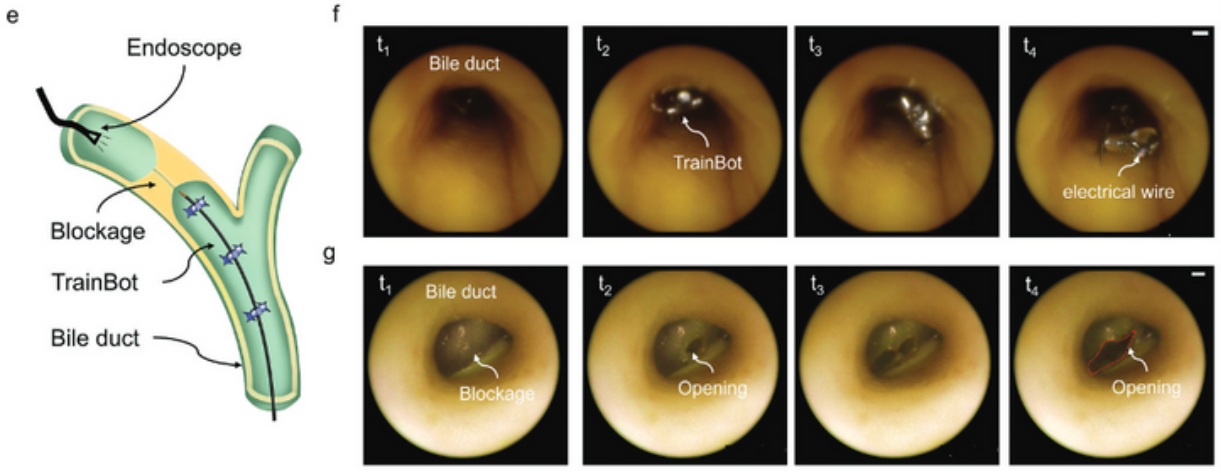
Some people envision updating our lives in the cyber world, dreaming of living forever or having our minds controlled by machines that could manipulate our thoughts, memories, and even societal norms. Isn't that frightening? However, these ideas remain speculative, as current technology is far from achieving such capabilities.

The brain-computer interface company (Neuralink), founded by the famous American entrepreneur Musk, has received approval from the US Food and Drug Administration (FDA) to begin implanting chip devices into the human brain of Nolan, who was paralyzed from the neck down after an accident. BCI decodes expected movement signals from the brain's motor center and translates them into computer commands - Nolan simply thinks about moving the cursor on the laptop screen and the cursor moves. Nolan used it to play Civilization VI, just like many of us enjoy coming home after work or school, turning on the computer, and diving into a game. For most paralyzed individuals, the desire is to live independently, and brain-computer interfaces (BCIs) can provide that opportunity for the future.

There are two types of brain-computer interfaces: implantable and semi-implantable. Implantable interfaces offer high accuracy and enable more complex decoding and coding, while semi-implantable ones provide a safer alternative. The substantial number of studies focused on motor centers is largely due to the relative simplicity of motor nerve coding. In discussions about coding, it's essential to highlight the role of AI in brain-computer interface coding. Brain-computer interfaces rely on receiving impulse signals from neurons in the brain. However, relying solely on humans to interpret these signals poses significant efficiency challenges. This is where AI becomes essential. RL(Reinforcement learning) can assist by helping algorithms identify useful patterns and logic within the constant neuronal impulses. Consequently, these algorithms can analyze the data and use it to connect external devices for manipulation.
BCI represents a technological wave that cannot be overlooked. With advancements in neuroscience, enhanced machine learning algorithms, and the development of more biologically compatible materials, BCIs have the potential to assist more patients and unlock a range of additional applications.



"Ultimately, we can do a full brain–machine interfaces where we can achieve a sort of symbiosis with AI," Elon Musk said.



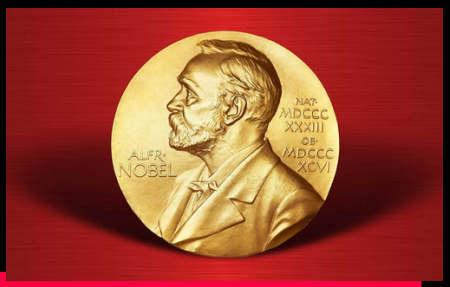
Over the past few years, integration of robotics in the medical field has proved to be groundbreaking for different procedures such as targeted drug delivery and surgical interventions, reducing recovery times and the need for subsequent surgeries. This proved to be especially important for minimally invasive procedures. However, a major challenge with robotics in medicine is the limited strength and mobility of the miniscule robots, lacking the capability to transport surgical instruments through the body for procedures such as endoscopic microsurgery. This is due to the robots struggling to move through the body effectively, as many of the internal surfaces, such as those of the gastrointestinal tract, are covered with mucus, making it difficult for traditional robots, designed for crawling, to gain traction, limiting their utility in navigating complex anatomical structures.

Recently, the German Cancer Research Centre (DKFZ) have developed a solution through connecting multiple millimetre-sized robots into a unified system which they call the “TrainBots”. The TrainBots, equipped with specialized “feet”, inspired my natural designs to increase traction on slippery surfaces and enhance movement through the body. This system has now ben experimented and validated to successfully perform electrosurgical procedures on bile duct obstructions.

The TrainBot system works wirelessly, controlled by a rotating magnetic field, which simultaneously manipulates the movements of each individual unit in the convoy. This magnetic control system enables the robots to move in a coordinated manner across surfaces while allowing the system to work as a whole to carry heavy instruments required for surgical tasks. Furthermore, the external magnetic actuation and control system is designed to operate over the distances typical of the human body, making it highly suitable for medical applications.

A promising milestone for the system involved the use of TrainBots in a simulated microsurgery procedure to treat bile duct obstructions on a pig, which may occur due to bile duct cancer, where the duct blocks up, causing bile to back up into the liver, posing serious health risks. Traditionally, an endoscope, which is a flexible tube, is typically inserted through the mouth, down the digestive tract and into the bile duct to navigate the site of blockage. However, sharp angles and narrow anatomy often pose as a challenge for surgeons, preventing them from reaching targeted areas effectively. The team stimulated a tissue ablation procedure using electrocauterization (a technique using electrical current to remove tissue) to demonstrate the potential and capabilities of the TrainBot system. The system transported a wire electrode (25 cm long and 3.5 times heavier than an individual TrainBot unit) to the blockage, where the electrode was used to apply an electrical voltage, slowly removing the obstructing tissue.

The success of the TrainBot has shown promising potential for the future development of robotics in the medical field. "After promising results with the TrainBots in the organ model, we are optimistic that we will be able to develop teams of miniature robots for further tasks in endoscopic surgery," says Moonkwang Jeong, the first author of the study. For example, after electrocauterization, a second TrainBot convoy could be used to bring a catheter for fluid drainage or perhaps for targeted drug delivery. This modular, multifunctional approach could significantly improve the efficiency and safety of complex surgical procedures that are currently difficult to perform with traditional instruments.



Key Figures and Discoveries: ALFRED NOBEL

The life and work of Alfred Nobel personify the relationship between scientific progress and moral obligation. Most famously, Nobel founded the Nobel Prizes. The scientific work of Nobel, especially in explosives, has had great effects on society and industry. His great feats, which formed his remarkable journey, came through personal experience and tragedy.

A Legacy:
Nobel had left a truly remarkable scientific legacy, founded upon his pioneering work with nitroglycerin—an incredibly volatile substance of great power yet with enormous attendant risks. In his formative years, Nobel worked together with his father to find ways to make nitroglycerin practically usable. His interest in the explosive compound later led to the invention of dynamite, but at the price of his younger brother Emil, who died in a factory explosion in 1864. The breakthrough for Nobel came in 1867 with the invention of dynamite, when he mixed nitroglycerin with kieselguhr—a porous earth that absorbed the liquid and made it sufficiently harmless to handle. That invention revolutionized the mining and construction industries, making controlled detonation of explosives on a scale previously unimaginable. Later, Nobel developed a blasting cap, further improving the safety of handling explosives and precision in their use. All this speaks to his relentless effort and drive to improve his work through experimentation and engineering. Nobel's contribution laid the bedrock for modern chemical engineering and detonative technologies. Besides explosives, Nobel held over 350 patents in fields ranging from synthetic rubber to artificial silk—a testament to his scientific curiosity and inventive genius.

The Dark Side of Invention:
Despite this great invention, Nobel soon became aware of the darker side of dynamite and its potential threat to humanity. As much as it helped industries carry out large-scale infrastructure projects, it also became a tool of destruction in wars. This duality in his work troubled him throughout, as is evident in his letters, where he often expressed regret over the negative impacts of his work. In his later years, these ethical concerns apparently led him to contemplate how his legacy would be remembered. This eventually led him to establish the Nobel Prizes, awarded for work in science, literature, and peace, as his effort to ensure that his legacy to humanity would be seen positively.

Loneliness:
Nobel's personal life was marked by loneliness. “You refer to my many friends”. Nobel wrote in a letter.” Where are they? On the muddy bottom of old illusions, or busy listening to the rattle of saved pennies? Believe me, numerous friends one gains only among dogs which one feeds with the flesh of others, or worms which one feeds with one’s own. Grateful stomachs and grateful hearts are twins.” Perhaps this loneliness ultimately led him to take steps to ensure that his work would be viewed positively by future generations.

$E=M.C^2$

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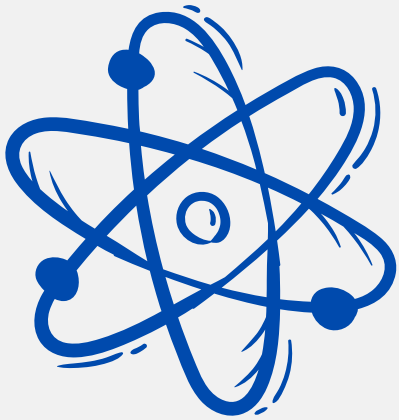
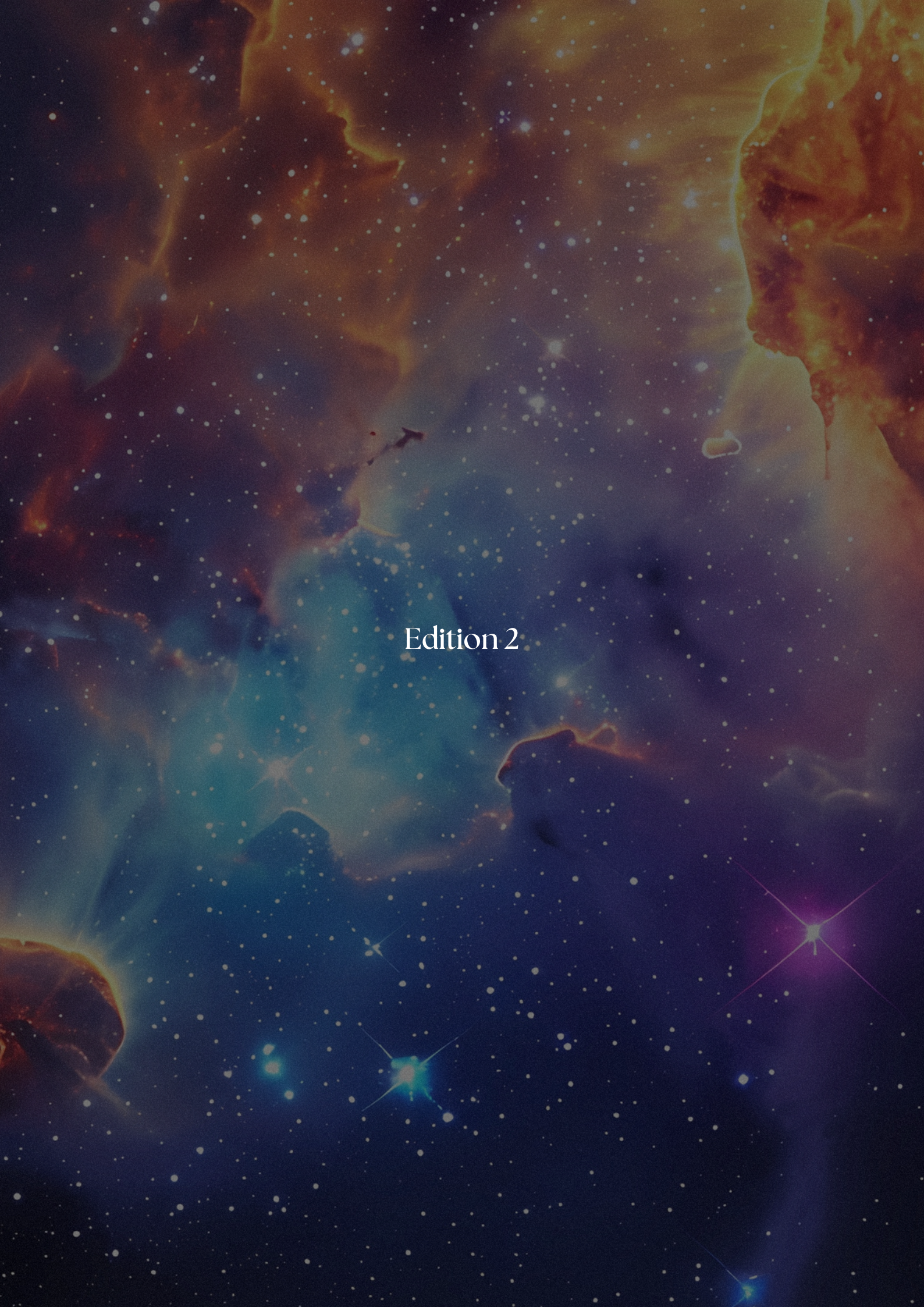
ALZHEIMERS
DYNAMITE
ENDOSCOPY
INTERFACE
MACHINE LEARNING
NITROGLYCERIN
NOBEL
OPERCULUM
POLLUTION
ROBOTICS
SYNAPSE

I have keys but open no locks,
I have space but no room,
I can enter but can't go outside.
What am I?

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