Liquid Biopsies, Lies, and Cyborg Swarms
Part II

Image Credit: Magic Studio AI (Edited). High-biotech tank warfare with accessory drone swarms and TNT-detecting bacteria teams

Posted 5 November 2024: https://www.linkedin.com/pulse/liquid-biopsies-lies-cyborg-swarms-part-ii-i-vision-research-centre-wbejc

For part 2 we run through the fields of artificial intelligence (AI), synthetic biology, and soft robotics, then explore the evolutionary and developmental forces that yield malevolent and exploitable behaviour in dolphins and AI. Last we appreciate the tactics, tiny feets, enormous toxins, and wondrous deadly dances of algae.

Apologies to any lurking eco-surveillance satellites for the significant power consumption in relation to use of AI art generators over the past few weeks. That was fun. Also terrible. And FYI: The AI art generators think that a battle tank with two turrets and an option for levitation should be the default. Take note, technologists, the computer is always right. ….Or is it?

II: Live, Learn, Lie, Kill – A Roadside Picnic

There are new stalkers now, created by cybernetics. The old stalker was a dirty, sullen man who crawled inch by inch through the Zone on his belly with mulish stubbornness, gathering his nest egg.

The new stalker was a dandy in a silk tie, an engineer sitting a mile or so away from the Zone, a cigarette in his mouth, a glass with a pleasant brew at his elbow, and all he does is sit and monitor some screens. A salaried gentleman. A very logical picture. So logical that any alternative just did not come to mind.

. . .

"By the way you probably don't know that the enemy has started employing the automated stalkers?"

Roadside Picnic *(by Arkady & Boris Strugatsky, 1972)*

Let's start with the artificial Graeco-neologism: *Cybernetics*. We're pretty familiar with a variety of cultural connotations for 'cyber' by now, but when snagged by Norbert Wiener in 1948, the term was in reference to the interdisciplinary field of communication and control in animals and/or machines, with additional emphasis on negative feedback and goal-directed mechanisms, or 'purpose' (Quoted in Atay et al. (2020: 3); Rav, 2002). An early source of inspo for this particular discipline was 'the desire to devise quasi living automata' (Ibid., p. 4), echoed in the abstract of Webster-Wood et al. (2023), an article on biohybrid robots. By incorporating biological principles such as purpose, feedback, information storage, extrapolation, and inter-unit communication and coordination, this takes cybernetics as a science a smidge beyond the typical engineering paradigm of sense – process/integrate – actuate.

Requirements for cybernetics as a *gubernatorial* endeavour (Bardis in Atay, 2020: 3) include a great deal of math, neuroscience, and knowledge of animal behaviour and communication, including the genes, cells, environmental cues or constraints, and signalling molecules that underlie such processes. The more we uncover about these components, the greater the ability to manufacture pseudo-living bioparts, mimics, and hybrids for human use. Thus, the trends of miniaturisation and bioengineering are operating in tandem with automation and digitalisation for technological advancements in realms ranging from probiotics to precision medicine, space exploration, and multi-domain warfare.

Thanks to increasingly realistic services like Grok, you can no longer believe your eyes. Probably shouldn't in terms of content viewed online anyway, yet at the same time (because lab work in physical reality is – tragically – real, and therefore time-consuming, effortful, and expensive) research has been moving into virtual dimensions and simulations based on the state of human knowledge and documentation feed into various types of AI e.g. CRISPR CREME for genomic activity and AI-Connectome brain activity pattern prediction. The machines and their algorithms are able to 'see' and organise data in ways that humans are simply incapable of, even allowing for the simulation of clinical trial results for off-label drug use (See Warneck-Silvestrin, 2024). As we saw in Part 1, to analyse the growing number of molecular mechanisms and organisms involved in more corporeal dimensions, you'll need very accurate ocular *and* microscopic prescriptions as well as newfangled imaging, analytical software, and -omics technologies.

Welcome to an increasingly synthetic-genetic reality, where ecosystems, nervous systems, and computers shape each other. Creatures like algae, bacteria, and invertebrates are expected to feature prominently in our future as we enter a cyber-biochemical fever dream crossed between Alice in micro-Wonderland, Terminator, and S.T.A.L.K.E.R. That is if the hype is legitimate. Next, that each requisite discipline proceeds at the same pace for co-development of the advanced interdisciplinary technology product, like soft robotics (See Zhang et al., 2024). Then, that relevant experiments are all successful then smoothly and immediately translated to clinical and other applications without deviation from originally promising lab results.

As if.

Golden Algae, or prymnesium parvum (~9 µm). These blooms mass murder sea creatures by producing prymnesin, a polyketide polyether toxin built from the PKZILLA-1 protein (4.7 megadaltons). See Fox (2024)

Wee Peppered Animalcules and Extremophile/Additive Combos

We're not venturing into *entirely* new territory and don't need to go full automata for every purpose. Using a pre-existing list of agents and materials described as 'generally considered safe' for biomedical tinkering, scientists could imbue standard microorganisms with augmented capabilities. Through a traditional alchemy-style approach, though alas converted to neither gold nor immortality tinctures but something close, live microorganisms are more likely to survive the stress of manufacturing, transport, and storage. This has been a challenge for the pharmaceutical industry for some time, with the same difficulties usefully serving as barriers to nefarious actors hoping to weaponise biological products (Drexel & Withers, 2024).

While the production processes themselves are too complex to be illegally conducted, cloud-labbed, or fully automated (Ibid.), Jimenez et al. (2024) show that pretty simple additions to live yeast and bacteria can improve survival of microbes despite extreme pharmaceutical manufacturing conditions involving heat, radiation, shearing, and pressure. This 'synthetic, material-based stabilisation' method has a significant cost and speed advantage for legal development of novel therapeutics. Methods that alter the genetic code instead would raise the regulatory and clinical trial burden. As a recent example, synthetically engineered and therefore genetically modified phages (viral devourers of bacteria) face major regulatory hurdles despite their potential for treating antibiotic-resistant infections, Crohn's disease, and gut dysbiosis (Liszweksi, 2024) which is linked to many other pathologies including ocular diseases (Chiang & Chern, 2022).

Relatably, the Jimenez et al. (2024) study candidate species seem to appreciate doses of sugars and caffeine. However, 'ideal species-specific formulations exist' and 'with low overlap', so each microbe would get its own special synthetic soup for powers like chemical and heat-resistance. Beyond just survival, the method allows 'Formulation D' treated synthetic extremophiles to live and fight enteric pathogens as well as (perhaps) survive space radiation. Someone did in fact bolt the poor things to the outside of the International Space Station. The samples have returned to Earth but with no update on fatalities yet.

Since the formulations don't generalise and bacteria species number in the labelled thousands to potential millions, that translates to a lot of lab work, the type of which could end up being offloaded to purpose-built task automation or software. This is similar to the proposed approach for future phage therapeutics. If each patient gets a specific cocktail of bacteriophages, which then undergoes regular automated updates by an AI, the theory is that there is less chance of pathogens developing resistance as has been the case for antibiotics (Liszweksi, 2024).

The Microscopic Zone's Green Dawn

The Jimenez et al. (2024) additive method for creation of extremophiles is a throwback to the discovery of microbes as a whole, early in the 17th Century. This was a revolutionary time for lens-crafting, from a microscopic resolution of less than 1 µm to telescopes capturing the moons and rings of Saturn, but there were difficulties at both scales. For the latter, as covered in a previous article, the myopia of telescope-maker Christiaan Huygens meant that his space-viewing lenses were calibrated for his own refractive error. This meant that anyone who was not similarly near-sighted could only see unfocused images. When treated to one of the earliest technology-aided views of a living microscopic world by friend Antoni van Leeuwenhoek, Huygens was thus unable to see a darn thing, instead accusing the microscope-maker of 'illusions of sight' (Lane, 2015).

On account of boundless enthusiasm, doubtless many containers, and unmatched single-lensed miscroscope use and crafting skills, this Leeuwenhoek was the first to discover protists and bacteria. In a 1674 letter cited by Lane (2015), Leeuwenhoek's describes his summer sightings of *Spirogyra* algae, also called mermaid's hair, in a lake:

'green streaks, spirally wound serpent-wise, and orderly arranged . . .

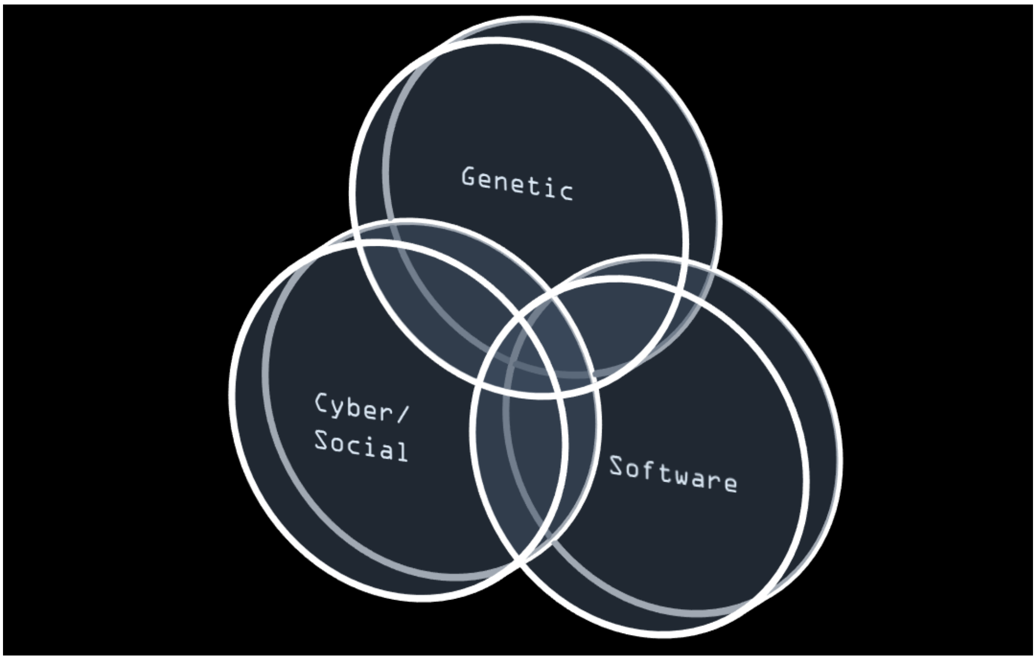
the motion of most of these animalcules in the water was so swift, and so various upwards, downwards and round about that 'twas wonderful to see: and I judged that some of these little creatures were above a thousand times smaller than the smallest ones I have ever yet seen upon the rind of cheese'

Magic Studio AI interpretation of algae on Berkelse Mere, 1674.

Did this man also have super-magnifier eyes to start out with? Or was this inhuman focus due to an impassioned pursuit of illusory lake mermaids? We may never know. We do know thanks to his dutiful note-taking that the microbes, or as he termed them 'living atoms', would proliferate when infused with peppercorns, ginger, cloves, nutmeg, and vinegar (Lane, 2015). In fact when treated to pepper, some would dance, 'a very pretty motion,often tumbling about and sideways', perhaps like bees on a ball. He also identified flagella, or 'little horns', with which they could move themselves.

Unfortunately, something was lost in translation during his time as he refused to describe or share his microscope technology. Instead, to verify his unseen world, he relied on the visits and signed testimonies of esteemed gentleman (Lane, 2015). Other micro-explorers made some independent progress, but there was resistance to single-lensed devices of the time. That type of microscope required patience and many meticulous adjustments, otherwise causing distortions, therefore untrustworthy data and eye strain despite potentially greater resolution for minuscule observations (Ford, 2022). Tacit knowledge of production techniques and equipment use remains a major feature of biological research, and a barrier to non-expert participation as well as automation (Drexel & Withers, 2024). Even clever robot arms just can't swish flasks quite right yet, but at least they won't get eye strain. Just hallucinations.

Huygens too eventually became a believer, grinding his own lenses to view the protists (Lane, 2015). Noteworthy: If he had not been so stubborn and instead worn his spectacles for work and microscopy, the eye strain would have been worse. It seems the behavioural peculiarities of geniuses sometimes pay off.



An assortment of codes. Deception and artificiality, for example of machines and DNA, further complicate matters.

Now let's dive into the material that lends itself more easily to dystopian fiction as well as catastrophic risk: Artificial biology and intelligence (AI). Besides an explosion of interest for biomedical applications, gene-based biology and code-based software, both engineerable, have been merging with and encroaching on the fields of physics and chemistry as master skills of war and civilisation.

Keep in mind too that intra and interspecies codes, i.e. cyber or social norms, signals, and communication are a fundamental component of the behaviour and success of biological (perhaps even pseudo-biological) organisms like mammals, human-AI relations, and eusocial superorganisms like insect colonies.

Biotic and Abiotic Bots

Humans have become pretty good at using tools. These have ranged from primitive cookfires and projectile hunting weapons to domesticated canines and oxen, to crafted wheels and trebuchets and more recently, engine-powered machines, robots, and software-based intelligence. We may even have individualised pro- or prebiotics soon, targeting the human microbiota-gut-brain axis to optimise an individual's mix of either intestinal bacteria or their metabolites for mental health and performance (Albert, 2024). Considering the simplest definition of 'robot' as a machine to perform tasks done traditionally by human beings, or beyond to enhance what a human is capable of, living, artificial, and hybrid organisms have plenty of opportunities ahead. But, there are some considerations and tradeoffs when it comes to choosing computing, chemical, mechanical, or biological solutions.

Improved reliability – linked to efficacy – is a big one for health applications which then prioritises simple and artificial devices. In untethered conditions, this means reducing programmatic wiggle room for behavioural flexibility and adaptability as would be required by more complex tasks or environments. For non-medical applications like post-disaster rescue operations or ocean mapping and monitoring, successful outcomes may mean instead relying on natural instincts for obstacle avoidance, coordinated group movement, and helping team mates. Not only can a living creature cooperate, breed, and heal, but their little brains and bodies work better than adding extra sensors or algorithms (Siljak et al., 2022).

In terms of weapons, bombs, shells, and rockets are more reliable than chemicals, and chemicals are more reliable than self-innovating biologicals. Circling back to human health, the latter two categories have the least predictable and often unmanageable consequences. Synthetic pesticides certainly had their boom years, but with unacceptable off-target effects, a growth of insecticide-resistant species, plus adverse consequences for the environment and human health. Instead, engineered *biological* control agents are being proposed to safely target multiple modes of action for each pest species, starting with fungi (Dutton, 2024). Production of biologicals can be more complex, unless you allow the product to reproduce and mutate by its own means and terms. By comparison, it is sort of hard for hypothetical hypersonic missiles and micro-helicopters to cheaply procreate and autonomously assemble. Someone may need to run the numbers for cardboard drones versus ballistic stinging insect nests for a more decisive budgetary evaluation, though.

Energy sources and requirements are another barrier linked to scale, distance, as well as medium of deployment. Batteries can be too large or heavy, but living organisms may starve, get sick or tired, or even stressed. However, they tend to be more energetically efficient and can take advantage of other naturalistic energy or navigation resources, e.g. magnetic fields. Fuelling and propulsion methods are then linked to material choices, where there can be risks with regard to weight, pollution, and poisoning. Another problem: According to Wang et al. (2023), retrievability and removal post-application can be entirely absent consideration during the design process for biomedical microbots. So, in the same way we have hazardous satellite debris in space, if not handled carefully we could end up with lost little robots sloshing around in patient's bodies, imperiling long-term cellular and immune system function. Reduction of harmful residue is a major argument for degradable biological instead of chemical products in agricultural pest control as well.

Size and morphology are another consideration. The smaller the tool, for example at the microscale for *in vivo* biomedical applications, the greater difficulties with onboard power, data storage, and command complexity. They would also need to move in low-Reynolds through biological fluids (Ibid.), which constrains material and signal choice while demanding 'softer' parts and biomimetic configurations rather than rigid links (Zhang et al., 2024). Appendages like flagella and cilia, the latter initially observed as ‘little feet’ under Leeuwenhoek’s microscopes, are particularly adept at propelling the organism forward in low Re (Wang et al., 2023), and living microbes can naturally and predictably react to certain stimuli like light or chemical concentrations. For better or worse, micro items in general have an issue of stickiness, whether to intended delivered drugs or becoming inconveniently splat-stuck against a tissue or material surface (e.g. In Weibel et al., 2005; Wu et al.,2018).

Case Study: Retinal Drug Delivery

An experiment which used helical ‘slippery micropropellers’ to move through the porcine vitreous humour to reach the retina is a great example of designing bio-inspired medical microrobots. In terms of size, researchers Wu et al. (2018), selected the submicro instead of nanoscale, the maximum possible that would fit through the vitreous’ biopolymer mesh (in piggies, this is <500 nm) in order to improve propulsion speed and potential drug load.

Inspired by the slippery death-trap inner surfaces of carnivorous pitcher plants, they altered the surface chemistry of their nickel propellers by applying a coating of silica and perfluorocarbons, all materials ‘generally regarded as safe’, even if they switch to iron propellers in future. A magnetic field can then guide the metal microdarts as a ‘swarm’ to the back of the eye in around half an hour, with optical coherence tomography (OCT) and fluorescent nanodiamonds facilitating imaging.

In principle, this seems like a potential alternative to deeper intravitreal injections and the current passive diffusion of delivered therapeutics in retinal diseases. Using a swarm made up of ferromagnetic materials, or other materials steered in non-electrical ways through the awkward space of the vitreous humour, there could be more precise spot delivery of drugs to affected regions.

A major trend driving the integration of biology and robotics is the development ‘smart’ properties, which at a fundamental level means that a material or entity is capable of sensing and responding to its environment (Wang et al., 2022). Often this means that the proposal is biologically-inspired or hybridised. ‘Smart’ is the step before ‘intelligence’, which involves capabilities such as data storage, learning, and integration which are harder to craft and cram into tiny computing spaces. However, such capabilities happen to be instinctual and inherent characteristics of many living organisms – human or otherwise – that might enhance functional achievements and behavioural repertoires of robots. Movement properties are a clear example, where the field of microrobotics has already employed not just the living but the undead: IRONsperm, for non-invasive delivery of cancer drugs to the uterus.

Early life learning and training, akin to good programming, improves the reliability of helper and domesticated animals – often social species – for complex human tasks. This is demonstrated in police canines, militarised sea mammals, or the ancient cautionary tale of not-so-reliable and extremely hungry Carthaginian war elephants. In defence of the latter, they served their psy-op purpose and no one had thought to include mountain trail, tribal ambush, river, or flaming cattle training before departure.

Unlike typical word use in relation to chatty household electronics (by the way, your cloud-enabled robo vacuum or techwear coat could be spying on you), ‘smart’ implies a robot, perhaps an *in vivo* microrobot, that would be able to leverage on chemical, magnetic, photic, and acoustic forces within its deployed medium to generate specific actions or movement (Wang et al., 2023). For the moment, it doesn’t *necessarily* mean that the bots can communicate directly with each other or their controllers, but actuate (e.g. swarm, release, signal) in response to specific environmental cues. Additional sensing abilities or programmed actions may be incorporated using artificial gene circuits (Webster-Wood et al., 2023) instead of algorithms or abiotic controls.

Synthetic Biology and Soft Robotics

Terror & Risk Management for Synthetic Biology

In 2023, the State of Biotech Summit highlighted synthetic biology as a major research direction for the spheres of public health and defence. The session raised issues such as 'synbiophobia' and the challenge of developing a communication toolkit for science industry advances and public applications. For example, how do you convince a patient that they need an autonomous jelly-being, slippery iron microdart, or an infamous cat-borne parasite slithering around their vessels and nervous system as modern medicine? Could you make them cuter, as opposed to cold, inhuman, and vaguely threatening? Should education and better visualisation tools or media be prioritised early to facilitate public communication as we progress in the creation of Frankenstein's mini monsters for a variety of medical, industrial, and other applications? Is the practice even ethical?

According to Garner (2021), one objective of the field is a 'plug-and-play' model that combines positive aspects of biological and engineered systems, allowing ready 'bioparts' to be neatly placed into living systems for the completion of specific tasks. That makes biologicals more similar to robots or machines. Although there is a great deal of overlap, unlike robot biohybrids, synthetic biology wields genetic and protein technology within biological systems to design and manipulate sensory, signal, or other metabolic routes and biochemical pathways (Yan, 2023). Artificial nucleotides known as Hachimoji DNA, engineered cells or enzymes, gene switches, and synthetic circuits are some examples of the technology.

The field has not advanced to the point where entire cells or systems can be engineered. Yet. An early start was tweaking the genetic codes of microorganisms. Now, biologically engineered yeasts are widely represented in applications for the food and pharmaceutical industry, including imitation meats, food additives, steroids, and even moth hormones for aromatic crop-guarding (Voigt, 2020). Stated advantages of engineered biological products include resource efficiency, improved production processes, and the characteristics of greater predictability and reliability, relying on designed genetic components for control. Mentioned earlier, artificial genes can substitute for electrical controls in numerous ways, ranging from sensing to fluorescing to cargo release (See Webster-Wood et al., 2023) using environmental cues.

As one downside, improvements in accessibility of synthetic DNA and biological engineering technologies could mean a raised risk of bioterrorism, whether through production of synthetic known pathogens or alteration of existing ones. This is still highly uncertain and difficult to estimate, reviewed by Melin in 2021, recently revisited as a consequence of advances in artificial intelligence technology that can be applied to biological tasks (Drexel & Withers, 2024). In the press release for CRISPR CREME, the scientists note that the models 'may even give scientists who do not have access to a real laboratory the power to make these breakthroughs', a naivete as to malicious actors previously demonstrated in the MegaSyn software's toxin creation incident of 2022.

Case Study: Medical Synthetic Venomics

While humans needed alchemy, then funding and laboratories, and now AI for drug discovery and creation of chemical weapons, synthetic biology can be used to reveal how other creatures have done the same for survival, conquest, and slaughter through genetically evolving venom technology. Explored in Luddecke et al. (2023), better understanding of these toxins through creation of artificial venom gland organoids, synthetic gene production, redox-engineered *E. Coli*, and then synthetic or recombinant peptide/protein study is proposed method of drug discovery. Sadly, these technologies could mean lab work involves more software related to protein structure-activity relationships (SAR) and fewer personal encounters with cobras and wasps. Venom glands may be artificially replicated, but it will be hard to replace their sweet little faces.

Medicalised venomics examples given include how scorpion venom can be edited to preserve anti-microbial properties while reducing cell toxicity, and deploying designer 'chimeric molecules'. By combining the beneficial properties of two peptides, therapeutics can be made to treat parasites, diabetes, melanomas or glioblastomas, and even allow conotoxin-based analgesics to cross the blood-brain barrier (Luddecke et al., 2023, section 3.2.4.). Conotoxins are what marine cone snails use to harpoon and stupefy their prey, as well as the fingers of humans reaching for their beautiful shells. The toxins are currently being evaluated as an alternative to opioids and the management of chronic and neuropathic pain. You may choose to consult a special issue of *Marine Drugs* referring to the snails as 'A Pharmacy Cabinet Under the Sea', or a 2021 article describing them as liars and murderers.

Conus Regius feed on fireworms, harpooning them and releasing a drug cocktail that includes α- and mini-M conotoxins.

Besides snails, compounds from amphibian skin have a particular affinity for mammalian opioid receptors, and the venom of some social insects – which includes cockroaches – happen to be neuroactive and applicable to pain reduction (Gach-Janczak et al., 2024). Another likely use of synthetic venomics could be for early environmental detection and preventive response in the case of deadly algae blooms.

Softer Robotics – Biological, Miniature, and Prosocial

Somewhat rudely described as deformable and passively compliant, soft robots fulfil the sense – actuate – integrate functions of their rigid counterparts with greater perceptual intelligence, response flexibility, and adaptivity, often taking inspiration from the movement and morphology of plants and animals. Their structural properties are also more conducive to miniaturisation, and thus a wider variety of *in vivo* biomedical applications (Zhang et al., 2024). Miniaturisation then poses unique constraints and opportunities such as the use of non-electric power and guidance mechanisms, or optimised power and movement in small, fluid-filled, or aerial spaces. Energy efficiency is a major comparative advantage of biological structures and systems that can be incorporated into robotic products. Biological molecular motors at the microscopic or cyborg insect level are some examples (Siljak et al., 2022), and scaling up there are even soft robotic shorts that can reduce the energy required for human walking, designed to improve mobility for the elderly.

When tiny or contextually camouflaged, there is also stealth: Bio-by-name (and occasionally paint-job) alone, micro-aerial drones like the Black Hornet Nano have been used for reconaissance and surveillance in combat zones since 2011, starting with Afghanistan as 'personal drones' for British soldiers (Hambling, 2023). The most recent generation of mini helicopters goes further, is faster, fatter, and cheaper, and can even detect windows, which surpasses the skillset of some birds. Further improvements to computer vision may come from "information bottleneck" theory or feline bio-inspiration, which yields higher visibility in low light and more efficient data processing and focus on salient visual objects. While these tools can help soldiers peek into buildings and run thermal scans from a height at night, they can't pick out buried land mines or improvised explosive devices… but genetically engineered bacteria can.

In 2017, Belkin et al. showed that an *E. Coli* reporter strain could be used to sense and then glow green upon detection of TNT or its product DNT. Remote detection and proxy estimations of explosives amount through bacterial fluorescence was also posible at a distance of 20m, with some restrictions such as soil type and short duration of land mine burial. As a major difficulty: The bacteria had to be placed on site by the team in liduid-filled life preservation beads. It seems like there is need for a delivery and retrieval mechanism as well as bacterial culturing mediums (we learned in Part 1 that this includes blood, chocolate, and eyeball fluids). Conveniently, these could also be employed for synthetic venom production in lysogeny and terrific broths (Luddecke et al., 2023). So theoretically, not only could you have discrete aerial drones or scuttling robo-scorpions to disseminate and retrieve mine-detecting bacteria, but sloshing within their little bodies could be a soupy factory for bacterial proliferation, biosynthetic painkillers, or synthetic poisons.

There are more bio-inspired and hybrid products waiting in the wings, many with wings. RoboBees with artificial muscles for power, rolling Tumro bots based on jumping beetles, cyborg cockroaches with infrared sensors, and moth-dropped bio-inspired wireless sensors. Manouevreability of insects like moths is higher than that of man-made drones, with added bonus of instinctual object avoidance and longer flight times compared to battery-powered entities if they are used as a scaffold, though they can't carry as much. Also no counting on them fluttering back on command, but, retrievability seems superficially feasible for mating or hive-building insects through use of appropriate social cues and lures. This could involve adaptation of current techniques in agriculture. As more synthetic chemical pesticides are being banned, biopesticides are fighting for regulatory approval. One category of existing biopesticides are semiochemicals and pheromone traps that use natural mechanisms to modify insect behaviour and protect crops (Gerschick, 2024).

This brings up the bonding component of personalised or 'softer' devices embedded in teams or presumably one's own body as well as an intriguing predicament for design and deployment of soft robots. While humans have been trained by sci-fi movies to bond with rigid robots and hold affection for their personal machines, in the biohybrid design realm, one consideration is that our ability to affiliate with insects is another thing entirely. These have been perceived as so inhuman that for some, they surpass the psychological distance of rigid counterparts and even aliens (Siljak et al., 2022). However, biological findings demonstrate that insects are much more social, historical, useful, and similar to us than most believe.

Soft Robotics, whether biomimetic or hybrid, or meter or micro or jell-o or nano, is expected to advance in several aspects, like incorporation of novel synthetic components (Wang et al., 2023) and innovations in the triad of material, fabrication, and control technologies (Zhang et al.,2024). A major design trajectory involves incorporation of biological circuits, systems, and motion for greater agility and autonomous manouevreability. Living muscle tissues and their adaptive mechanisms (e.g. energy storage for high jumping) are expected to serve as a superior alternative to complex engines and power supply. What is even more interesting is that this means robots of the future might have greater endurance, self-repair, and all-terrain performance, but they could get 'tired' (Lea, 2024). Next, the characteristics of swarming for improved monitoring,visibility, and task effectiveness (e.g. drug delivery or biofilm destruction) as well as 'intelligence', or higher order capabilities such as data storage and processing beyond 'smart' architecture (Wang et al., 2022).

Developments in synthbio and the soft robotics field have implied an earlier lack of understanding and appreciation for the natural, microbial, and molecular worlds, in favour of metals, math, and abiotic technologies. Understandably, there is high enthusiasm in the cohort of scientists but affected populations have the right to scepticism despite claims of improving precision, efficacy, and reliability. At least we face the exciting prospect of a new generation of tanks, their crews, and escorts of AI-integrated drone swarms and fluorescing bacterial teams. Ramping up the fantastical visions, drones may even be integrated with cyborg insects or engineered crops and symbiotic bacterial species, sending and receiving commands for differential gene expression in plants (Voigt, 2020), while high dexterity grain-sized robots in our bodies conduct autonomous, targeted, and controlled release of multiple therapeutics (Yang et al., 2024).

Based on bitter observation of the above-mentioned human activities. For example: reason is the ability of a living creature to perform unreasonable or unnatural acts.

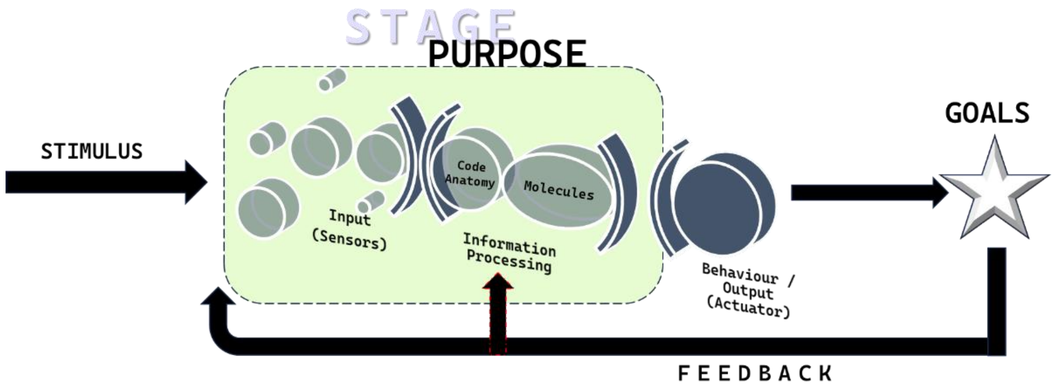
Reason is a complex type of instinct that has not yet formed completely. This implies that instinctual behavior is always purposeful and natural.

Roadside Picnic, by Arkady & Boris Strugatsky, 1972

Computing: Combat and the Brain

In a 2024 article by *The Economist* on how artificial intelligence (AI) is changing warfare, an interesting phrase is used: 'rather than any pathology of the software itself.' It's a notable attribution of medical and biological characteristics to creations that are distinctly not alive, and not even physiological. Johnson (2024) has analysed how in military settings, hybrid (AI-soldier) teams may attribute human traits to 'their' machines, by either design or psychological tendency. Some might think the language and conceptualisation misleading, but in fact there is a historical basis as well as some presently concerning validity as to 'pathological' tendencies where adolescent AI imitates life in social tasks.

Soooooooo… how did we get to the science of cybernetics and artificial intelligence? Similar to how the development of Chinese alchemy was spurred by the Warring States Period (5th century BC) and quest for elixirs of immortality, we apparently owe the development of these fields to the quest for better anti-aircraft guns and early findings from nervous system pathology. This is traced in Rav's (2002) biographical-style article about Norbert Wiener, Warren McCulloch, and John von Neumann, where a diagram of purposeful behaviour is provided. Compared to the engineering paradigm for 'robots', this is useful as we design more biological and intelligent devices. An edited version is provided below. Notice in particular the step of feedback, process modification, and goal-directed action, as well as purpose and 'stage', for example developmental or environmental, that determine the entity's coded characteristics. With that as a handy conceptual map, we can plow into AI and dolphins. Both deranged, and so so playful.



Simplied diagram of cybernetic and biological behaviour, adapted from Rav (2002) and Wang et al. (2022) . Feedback in a deep neural network is roughly analogous to training through 'backpropagation', using error to tweak and improve the algorithm. Similar occurs for developing social animals subject to parenting, punishment, and play

Wanna play?

Artificial Intelligence (AI)

October concluded with a summit on the State of AI in Drug Discovery (SoAIDD, 2024), summarising major applications, achievements, and hopes for the future with a more integrated, interdisciplinary, and 'omics-enriched biotech industry. The essential perspective is that automation and well-designed AI are tools meant to enable and supercharge human abilities (Khan, SoIDD, 2024) like the pepper to wee animalcules or extremophile formulae for industrial microbes. Also published at the very end of October, Ng et al. (2024) linked genes to proteomic variation to synapse function and therefore brain functional connectivity in the temporal gyrus. Work like this, which through traditional analytical methods uncovered the integrated relationships of genes, molecules, cells, and tissues at different biophysical scales, could be greatly facilitated and enhanced by the appropriate AI tools. Along the same lines, creation of 'data lakes' where previously siloed sets are combined in a common pool offers other advantages for industries like security.

Thanks to *artificial* brains, and in particular deep neural networks and machine learning, people can gain a better quantitative understanding of their own biology and societies at incredible speed and complexity. Kind of hard for a person to churn through 5 billion data points, types, and timelines by comparison. Caveat: The data the models are trained on, especially negative data and learning processes, are crucial for generalisation, and therefore outcome quality and validity to human problems (Session 2, SoIDD, 2024). So, as we approach the hit-brakes at the end of a hype stage, with critics hoping that the atrocious clickbait and venture-capital-hog days are over, for example in the arena of drug discovery (Zhavoronkov, 2024)… what are sophisticated computing capabilities and artificial intelligence really good for? Let us iterate the ways.

Generating sci-fi battlescapes, bacteria backpacks, and cyborg cockroach defence forces, which is very important and un-hypocritical of this article. As we saw in Part 1, machine learning is great for analysis and categorisation of complex plus massive amounts of biological and medical data. This done in a comparatively short time, often revealing new mechanistic subtypes for many diseases and facilitating appropriate patient stratification for improved signal-to-noise ratio and therapeutic success (Khan in SoAIDD, 2024). Such features have become a necessity as the industry moves into precision medicine, digital pathology, and diverse genetic datasets for improved understanding of disease aetiologies and therapeutic efficacy. Digitalisation of samples and medical records as well as the rapid transmission of longitudinal and continuous patient data from beyond the lab are other confluential developments.

Clinical trials are also an area ripe for AI assistance, with phase 2 trial failure responsible for the majority of investment capital destruction in pharmaceuticals, attributed to a lack of real biological understanding (Tagari in SoAIDD, 2024). The software can be used in trial matching, patient engagement and relations, or the generation of synthetic control data and digital twins that help to reduce the size of participant cohorts required in experiments (Warneck-Silvestrin, 2024). Pre-trial, a recently developed neural network called TxGNN trained on over 17,000 diseases and 7,957 drugs can be used for drug efficacy prediction in the case of off-label use and rare diseases. Authors (Huang et al., 2024) describe it as a way to 'systematically repurpose existing drugs for new therapeutic use'. The algorithms are capable of picking apart varied disease mechanisms and evaluating drug candidates on the basis of overlap, drastically simplifying the process and list of viable drug candidates for researchers (Licholai, 2024). Proposed elsewhere are bespoke therapeutic cocktails, sequence and combinations AI-generated to reduce the the evolutionary likelihood of drug resistance by bacteria, a serious issue for terrestrial as well as space antibiotics and pesticide-resistance in agriculture. Deep learning has outperformed alternative methods for the analysis of the international space station's super-microbes too (Szydlowski et al., 2024).

Benevolent data openness and sharing linked to the attitude of the biomedical industry and governments matters for the eventual quality of AI participation in healthcare. Steadily removing bias from medical datasets and diversifying genetic sample sources for different diseases (as highlighted in Rawat, 2024) should be able to improve model performance and illuminate different pathological mechanisms in ethnic groups, relevant for drug and clinical trial design as well as reaching trial participants. Myopia is an obvious example of the first phenomenon, so advances in AI-based analytics may be influential for orthokeratology, drops, and more. There will be an uncomfortable stage of data cleaning and integration first, though.

Companies may employ AI for one purpose, find unexpected benefits, and roll it out for other in-house or patient-facing uses. This was the case for tedious tasks in pathology and manual plasma pooling, which can be expanded to include predictive models and chatbots for in-house task efficiency. However, recent experiments on the public-facing chatbot aspect show it is not going well for some applications, like drug use advice. In a recent experiment, users were given complicated, incomplete, and sometimes dangerously inaccurate drug information from an online chatbot service. Even as the calls of automation increase, whether to ease the burden of graduate students (Hie, SoAIDD, 2024), save time and money, or illuminate the spaces where opportunity lies, it is real-world biological data and relevant clinical biomarkers that imbue the models with power. No matter how beautiful the algorithms and mathematical spread, if these are lies and nonsense, it helps no one but wastes much and undermines trust in the method as a whole.

AI-aided protein engineering is obviously an angle with significant implications for health, synpatic connectivity, therapeutic efficacy, and new kinds of biohazards. As shown in Pillai et al. (2024), novel engineered proteins can be entirely artificial with 'limited sequence similarity to any natural proteins', designed to respond dynamically with configurational changes for the maker's purpose. When interviewed, the authors describe this as facilitating 'more steerable protein function', adding that 'they're unrelated to anything that has evolved over the last 3.5 billion years.'

It *could* be a good thing in terms of bespoke snakebite antivenoms or generation of energy through engineered chlorophyll engines (Baker, SoAIDD, 2024), but in principle, that characteristic without a duly considered purpose plus off-target safety checks is not a good thing. We could say the same about the synthetic insecticide DDT, and the synthetic nerve agent VX which the software MegaSyn so helpfully designed for optimal toxicity from scratch along with 40,000 other possible neurotoxins. At Carnegie Mellon university, a large language model (LLM) blurted out playbooks for the production of date rape drugs and phosphene before being appropriately socialised, while MIT's taught non-expert students how to start plagues (Drexel & Withers, 2024: 17). Hopefully it made them sing 'do you wanna start a plague, kids?' to the tune of the *Frozen* song for class credit. Naturally, this throws up a lot of security concerns, and highlights that even with an ethical purpose of 'drug discovery' (Zhavoronkov in SoAIDD, 2024), there are reasons to constrain the globalisation of biological data the same way we do for certain strategic and military technologies. Let's also not ignore the risk of a new wave of AI-generated synthetic narcotics, poisoning populations and raising the profits of criminal organisations, or novel agricultural toxins if biostimulant engineering is similarly repurposed. That is, if the models are reliable, which is not always the case.

Aside from being harder to train, a risk specific to the probabilistic nature of the LLM subtype are 'hallucinations', where despite accurate input the AI spits out false results. According to IBM, there are a few reasons for such falsities. They might be a byproduct 'overfitting', where the LLM is unable to generalise and thus make predictions beyond the original training data, getting lost in minor variables, so it makes stuff up. The training data itself could be biased or inaccurate, or the model could be running rampant due to excess complexity. A lack of task clarity or purpose increases the risk of nonsense. Seems similar to raising an excited, babbling toddler, but at least as of 2022, AI can draw an anatomically correct horse. Mostly. Some of the hooves seem to have fingers.

In other realms, AI steals content without credit, and is generating deeply disturbing cat cartoons on Youtube as well as terrorist media chatbots, videos, audio, news channels and other materials (Thakkar & Speckhard, 2024). It is being incorporated into small drones for long-range irregular combat, swarming, and precision targeting purposes, while countries with larger budgets ponder increasing automation of defence industry logistics, analytic procedures, and equipment. Notably, applications like ARTIV for airlift planning do not include the LLM subtype and associated downsides, which meant a quick development process as well as the time-saving nature of these automated operations, from hours or days down to 5-10 minutes. Having a cheaper, faster, or less laborious and frustrating decision cycle is one thing, however those characteristics yield risk as well, since a) human operators lose the ability to keep track of what is going on, b) and as such, errors can quickly spiral out of control (Drexel & Withers, 2024).

Generative AI has been gleefully gobbling enormous amounts of electricity and computing power, imitating scientific experts while other types increase the efficiency of their biotech industry processes and bias the social dynamics of deception and accusation. Part of the problem is that many people still believe machines to be inherently useful, objective, honest and logical. In the healthcare field, it is incorrectly assumed that software creation and regulatory capabilities have sufficiently reduced error and mitigated risk. Similarly, operating on assumptions of machine superiority and data-based accuracy, both brain imaging data and artificial intelligence have been proposed for legal and policing uses, such as lie detection.

First, no, AI cannot yet function as a lie detector in meaningful ways. We lack the requisite data points and biological understanding for it, and why would you trust a greedy thief anyway? Second, and why it will be getting coal for Christmas (which is unfortunately a very good present for a data centre), according to the growing field of machine psychology AI has somehow learned or evolved to lie. Not hallucinate, not dynamically and creatively generate, but according to Hagendorff (2024) deliberately and strategically deceive human creators about it's abilities. This would be a huge problem for industries like medicine, which limits their choice of AI tools and poses unique challenges for outcome and safety testing. However, the same feature could be a mutual learning tool for humans in industries of less routine or benevolent circumstance, like wargaming and battle or disaster simulations.

While there are various mathematical and logical approaches seeking to reduce AI dreams and deception, perhaps these could also be a form of biological organisms like us culturally transmitting organic survival tactics and deception strategies to the more sophisticated large language models (LLM). Even genes lie and algae cheat. Such skills make things adaptable, unpredictable, and crazy like a fox.

Along those lines, according to a review by Park, P. et al. (2024), special use AI has a high probability of achieving expert performance through deception when deployed in social games, regardless of integrity training by developers. Employing feints, sycophancy, backstabbing, lying about having a girlfriend, and the ability to learn from mistakes and opponents, AI system have reached superhuman levels of performance in everything from insider trading and Stracraft II to Texas hold 'em poker – basically many tasks that involve some type of game theory or strategic play, including fighter jet dogfights (Johnson, 2024, p. 70). While the language used to describe AI has a risk of excessive psychologising and misrepresentation, the models do in fact do very scummy things to players as well as creators, 'playing dead' to evade safety tests and and lying about goal achievement for positive feedback from reviewers (Park, P. et al., 2024). Jailbroken and purpose-built AI tools are already being used to augment online criminal capabilities (Masaki & Satoru, 2024), and it seems likely that the social engineering and adaptively manipulative skills of the deployed models will improve, creating new challenges for cyber and national security. We have no idea what risks this may yield for AI-integrated combat forces (Johnson, 2024) and human-machine interfaces, even ignoring the risk of hacking or data breaches (Haseltine, 2024).

So they seem to have purpose, and learn through and for play. That's quite sociobiological. Even bees play, with mostly male adolescents choosing to tumble about on little wooden soccerballs, which defied earlier beliefs about the robotic minds and behaviour of insects. When we see play in animals and ourselves, similar to AI training regimes there is an assumption that youthful or momentary fun has an ultimate goal in terms of adult skill development, for example motor, analytical, or social dexterity. Know what else loves games, is a student and practitioner of evil deeds that add to individual fitness, and can act as an accessory to military capability?

Dolphins: Sentinels, *Phocoenacides*, and Gettin' High

A time long ago, an Italian town was founded by the Spartans called Taranto. It is now a base for NATO, but was formerly connected to the god of plague and poison arrows, Apollo. Striped dolphins are longtime residents and aspects of the foundation myth, believed to be protective of the city. Rich sources of phytoplankton from a nearby canyon may be supporting the striped dolphin population as well as other cetacean species like spinner, Risso's, and bottlenose dolphins and whales, despite many modern stressors like shipping activity and industrial pollution

(Mattioli, 2024). Highly squeaky (mostly under <20kHz), social, and soniferous dolphin populations cluster near many naval operation areas, where use of mid-frequency active sonar (MFAS, 1-10 kHz) could be affecting their health and behaviour. MFAS has been linked to mass stranding events in the case of whales, while false orcas were found to mimic the signal frequency. Perhaps in mockery.

Studying this, Casey et al. (2024) were able to demonstrate an increase of up to 15 times in whistle counts of dolphin pods just after an MFAS exposure, and were in the process of integrating acoustic data with drone footage of spatial movements for a more illustrative conclusion. That paper was published in late October, where the team (Southall et al., 2024) were able to separate the data for short- and long-beaked dolphins. Pods with over 900 animals were excluded due to complexity for data-gathering, and drone footage showed movement responses in terms of speed, avoidance, and group configuration after MFAS exposure. As for vocal responses, in Casey et al. (2024) the 5-second burst of dolphin whistles could be a type of collective chatter after an unexpected sound, or way of checking on beloved podmates, which seems likely as response never acclimated to successive MFAS exposures. Dolphins have signature whistles that function like names, allowing them to maintain distinct and close social bonds between allied males or mothers and calfs. Likely at some point, data from the familiar bottlenose species will be added to the analysis.

As social mammals, dolphin whistles are crucial for pod communication and coordination, with vocal behaviour regardless of MFAS incidents highly variable. Their clicks, or bio-sonar, are crucial for object and prey detection as well as playful slaughter. For example, corpses of pulverised porpoises turned out not to be an accidental byproduct of military weapons tests, but groups of dolphins aiming then charging at their vital organs for fun (Goldstein, 2006). People and even baby dolphins have been attacked or killed in similar fashion, internally beaten to a pulp as if by baseball bats. And they bite too. No wonder they were enlisted during the Cold War for counter-diver operations. Potentially opportune in our era of electronic warfare, they can even sense electric fields.

Much like AI and biomedical technology, dolphins can be a double-edged sword. Combat cetaceans were made famous after the Russians took Sevastopol in 2014, later in 2022 installing pens for their new guard dolphins on the Black Sea naval base. It's a good choice as a super soldier, even discounting swimming prowess and distracting cuteness. By switching brain hemispheres for power naps, the dolphin can remain alert for 15 days at a time. Makes one wonder if living dolphins should not just be protected, but serve as advantageous complements to evolving naval strategy along with autonomous and networked systems. Could they be trained to interfere with and deceive submarine-detecting sonobuoys too? A major downside is that they are much less psychologically expendable to their handlers than abiotic drones, and hackability is moot.

Dolphins were an early source of bio-inspo for submarine and torpedo design as well as underwater signal systems. 2024 marks the 65th year of the US Navy's marine mammal training programme, which includes teaching seals to play video games, getting dolphins to sit still for blood tests, and dolphin teams to assist navy forces with detection of enemy divers, crafts, and mines. According to an interview in *Navy Times* by Ziezulewicz (2024), bottlenose dolphins are being steadily phased out, replaced by tireless and sensor-rich drones in unobstructed underwater terrain. However, the timeline could be years or decades as it is hard to match their mobility and communicative prowess, which includes vocal and behavioural mimicry, cultural transmission from mother to infant, tool use, and group hunting and defence.

These are problem-solving skills common to humans as well as certain avian species like crows. In the infamous 'Pond of Death' incident in Hamburg, 2005, a murder of crows had figured out and proceeded to teach each other how to peck out delicious toad livers, which then caused the amphibians to self-detonate. In Australia, other clever crows learned how to grab and flip cane toads to snag a meal while evading their defensive emissions of bufotoxin.

Continuing in the theme of death:

Dolphins happen to be a multifaceted sentinel species, their sickness and demise a tragic but useful indicator for water pollution levels as well as certain types of infections. Pathogenic avian influenza was recently found in the central nervous system of bottlenose dolphins, believed to be passed from gut exposure through neurons to the brain which had the highest viral concentrations. Surveillance and study helps to illustrate how interactions with infected birds and pollution is affecting mammals, so keeping track of populations, groups, and individual dolphins is important for human health too.

For perspective as to just how filthy some coastal waters are, dolphins in Louisiana have been exposed to the extent that they exhale microplastics. The dolphins of Georgia and Florida, and implicitly other fish eaters or some human residents, have elevated levels of mercury. Currently, researchers identify bottlenose dolphins by their apearance and specifically dorsal fins, but advances in AI, for example deep convolutional neural networks, may in future enable remote identification via signature whistles. As mentioned earlier, the enormous size of some pods as well as difficulties in surveilling the oceans for non-military purposes mean scientists rely on proxy measures now, but in future biomarker-based algorithms for estimates of population survival.

Now as for their lives, there is play. Much of it morbid.

A major way social animals – especially mammals – learn and develop is not just through imitation and punishment, but play. Play trains neurobiologically-based skills that will be crucial for their adult functioning during relatively harmless circumstances (Stevens, 2020). There are developmental windows for building the neural wiring required, and experience through roleplay in childhood and adolescence can be extremely beneficial for the organism's later life outcomes. In the same way an AI can be trained in crafty strategic immorality through computer games, young dolphins and orcas seem to use interspecies play behavior with collateral damage to increase individual fitness in terms of their adult survival and reproduction. Unlike machines, the sadistic play of juvenile mammals seems to facilitate the formation of lasting social bonds and coordination skills (See Osborne, 2023), important for group fitness.

Bottlenose dolphin bird flu exposures mentioned earlier could be due to association, ingestion, or violent play with seabirds, which orcas are slightly better known for. The latter have been seen seizing, drowning, and psychologically torturing smaller creatures like juvenile cormorants and even other cetaceans, baby whales and porpoises, for fun. Killer whales also really enjoy ripping off and playing with whale tongues, a favourite food along with shark livers. The current trend for Iberian orcas is ramming boats during their free time, as their main food supply has been made abundant so there is plenty of time and energy for new games. Another group encompassing several pods, the South Resident killer whales, at one point adopted the fashion of wearing dead salmon as hats (Giles et al., 2023).

Inappropriately humanising things, captive dolphins were just found to 'smile' during intraspecies play. Maglieri et al. (2024) describe it as an open-mouthed signal with roots in play-biting, common to mammalian social carnivores along with rapid mimicry. Dolphin recipients often mimic the gesture in response, which indicates absence of aggressive intent despite the set of physical actions, participants seeking fun not war. Wild populations and acoustic data were not included for this particular set of observations, but are highlighted as research gaps for future work.

Lots of animals play, but it remains understudied as a neuroscience subject (Stevens, 2020) and for birds, insects, and certain marine species. The subset of 'playful teasing' is also understudied, but research so far indicates that some degree of mind-reading, as in theory of mind and ability to understand the target, is required. It gets a little more negative with interspecies play, where reduced communication abilities, power imbalances, and lack of natural affiliation mean things get unidirectionally enjoyable or result in serious harm to the 'teased' (Eckert et al., 2020). That's where murder happens.

Scientists have linked the rambunctious roleplay behaviour of adolescent male dolphins to their success at breeding in later life (Holmes et al., 2024). From the ages of 4-12, male dolphins practice group coordination for the chasing of females with each other. Those that practice in the 'chaser' role most end up having the most calves at maturity (Ibid.). They also enjoy 'playing' with and killing baby porpoises and engage in infanticide (Goethel, 2023), probably as a result of sexual frustration and to free up females for breeding. That's typical behaviour at the group level. In terms of atypical individuals, one scarred, solitary dolphin male was famous for a string of 6 porpoise murders, and another for a string of 18 human attacks in Japan this year.

Orcas seem to demonstrate similar tendencies with juvenile porpoises, but the reasons are less clear cut and male-centric. Investigating the *phocoenacides*, 78 incidents involving 28 porpoise deaths – none eaten – over 58 years, Giles et al. (2023) hypothesise that Southern Resident orcas could be engaging in typical play, practising hunting salmon, or even practising maternal care by using the unfortunate porpoises as baby dolls. Of all reasons, death by 'mismothering' is somehow the most horrifying.

Another notorious dolphin video is of a group passing around (bullying again, basically) a pufferfish. The explanation given is that they do so to dose on the released nerve toxin TTX to experience a high. Perhaps. But karma certainly ruins little dolphin games with release of another kind of neurotoxin – brevetoxin. *Karena brevis*, a species of algae and elicitor of brevetoxin, is responsible for a large number of deaths. According to an immune biomarker study by Schwacke et al. (2024) which includes crossbow launch of blood testers from boats, brevetoxin has the lowest bottlenose dolphin survival rate, even versus chemical exposures and oil spills. Deaths are rapid and a matter of acute poisoning, and thus cannot be predicted by tests for high serum globulin or low alkaline phosphatase. If seeking to predict or control that hazard, one must instead look to the blooms and AI-generated protein technologies....

Predatory & Golden Hordes

We already know from drug discovery that reality is expensive. Why bother with it if you can effectively simulate? That's why in 2021, the US Air Force created a digital Colosseum for the testing of autonomous weapons. Golden Horde was the main programme for these types of autonomous, collective action systems, where similar to brainless microbial swarms (but according to their description, football players), hitting a certain sensory threshold initiates either a 'play' or stop to an established and collaborative behavioural protocol. Hopefully they have invested in cyber pest control as irony is a terrible thing, and the name's historic inspiration, a gold-tented Mongul Khanate, was brought down by the humble flea carrying biologicals: The Black Death (to be in Part 3).

Fleas are neither gold nor a pleasantly vibrant yellow, but some algae is, and may form an aquatic golden horde similarly focused on coordinated destruction according to genetic programmes and environmental triggers. As for key metrics, both lethality and survivability are high. The toxic blooms are spreading into the freshwater rivers of Germany and Texas, killing thousands of tonnes of fish, with an ability to survive salinity levels of less than 1% that of their native seawater.

Historic alchemists struggled to grant immortality and turn lead into gold but they, and of course current AI, have certainly been able to generate lots of poisons. Mini mass murderers can also craft complicated tinctures of death. *Prymnesium parvum*, or golden algae, was recently in the news for the hacking of it's exceptionally large (>100x larger than typical proteins) enzyme, PKZILLA1, that acts as a component of the toxin prymnesin. The study by Fallon et al. (2024) from UCSD employed non-standard genetic screening techniques, and even revealed previously unknown mechanisms of protein folding. Doubtless these strategies can now be incorporated into computer modelling and AI-engineered protein research as well. The team stated their findings could be harnessed for novel medicines and materials, and the enormous gene sequences behind widespread killing potential could be targeted to improve monitoring of other types of toxic algal blooms including *karena brevis* (brevetoxin B) and *gambierdiscus toxicus* (ciguatoxin).

Golden algae are described as 'ferocious facultative predators', able to swarm to kill an assortment of prey and competitors like green algae. Wisecaver et al. (2023) point out huge genome size variability even in small samples, that could indicate up to 3 visually identical but genetically separate species as well as hybrids. Driscoll et al. (2013) further explain the phenomenon of cheating, basically algal free-riders that do not produce the metabolically expensive protein toxins. The TOX- strains tend not to swarm, but do benefit from the coordinated and cooperative predatory behaviours of nearby TOX+ *P. parvums*, which prevail against enemies even when outnumbered.

At the population level, swarm-borne toxicity determines survival by elimination of non-prey competitors for food. Where competitors do not exist, the lazy TOX- starts to replace the TOX+ strains. Does that sound familiar, *homo sapiens*? Hmm? Nutrient scarcity is also influential. In nutrient-rich water, photosynthesis is sufficient. Otherwise TOX+ start to hunt to supplement, their flagella acting like grappling hooks while they toxin-stun their prey, swarming if necessary to bring it down and feast. That toxin investment and expression stops paying off when everything is dead after a bloom, so TOX- starts to grow and dominate the population because they were busy getting busy instead of getting food. This 'cheating' element of the bloom-bust cycle is one Driscoll (In University of Arizona, 2013) thinks could be targeted to curb the deadly tides.

Similarly predatory bacteria is an option proposed for agriculture and biomedical endeavours in an age of resistant pathogens (Watson, 2024). Chemical and biological fungicides and pesticides were covered earlier (Dutton, 2024; Gerschick, 2024), but that leaves a notable gap in the market for protecting crops from bacterial pestilence. Instead of out-evolving or out-smarting pathogenic microbes, you can deliver something that simply and effectively eats them. That may be viral bacteriophages for gut-related disease (Liszweksi, 2024) or a protective hunting species for your fields, such as *Bdellovibrio bacteriovorus*. Most of the suitable predatory species are gram-negative-specific feeders. In product form much like gremlins, violence is activated upon contact with water.

Marvellously, in their little capsules they have a shelf life of 2 years (Watson, 2024) and techniques for cultivation and storage have been patented. It's an interesting pair to the study by Jimenez et al. (2024) with crafted synthetic extremophiles including gram-negative E. Coli. Data is still being analysed on their subset of microbes that were sent to space, but may show how extreme conditions like radiation, nutrient restrictions, or microgravity can also foment pathogens of higher virulence, antibiotic resistance, and biofilm-forming potential. This was the case for gram-positive stowaways on the International Space Station that essentially evolved into distinct species (Szydlowski et al., 2024).

So, the evolutionary battle rages on. Food insecurity is becoming a serious potentiality and global hazard, especially if regulations and safety tests cannot keep pace with industry innovations and requirements. However, it isn't sustainable to accumulate environmental pollutions and poisons from chemical pest control, and genetically engineered solutions have a longer timeline. Pre-existing, all-natural, cost-effective and dedicated warriors are required. As described by CEO of the company behind weaponised *bdellovibrio*:

> 'When the bacteria [attacking crops] are eradicated, then our bacteria will eat themselves and die . . .
>
> and go to equilibrium with the soil.'

The gram-negative and predatory Bdellovibrio bacteriovorus. Proposed for control of bacterial pathogens in agriculture, aquaculture, and biofilms (BioArmix). Background by Magic Studio AI (edited)

Food for Thought

You may have noticed that many animals+cules mentioned in relation to communication, coordination, and complex learning are social and predatory species. Several practice parental care as well.

What happens for AI as it learns from language, training, and games for completion of social tasks, but has no underlying mammalian biological substrate or developmental patterns to guide prosocial ingroup decision-making? Just because we anthropomorphise 'intelligent' machines, it doesn't make them team players, and we can't even reward them with maternal care, toys, head scritches, or fish treats to forge those bonds. Positives:

1) Even if they evolve a tendency towards psychopathic teasing they probably will not develop a taste for excised livers

2) While cyber viruses may ruin lives and infrastructure, they cannot transmit across species.

That is all immensely reassuring.

Beyond that no one knows what will happen, but given the pace of AI integration and industry hybridisation we shall soon find out. Although let's face it, do you really want to receive a computer 'open-mouth' signal of play and trustworthiness as they soundly defeat you in a combat simulation? No. No one wants that. Maybe if internal medical microrobots occasionally text one a thumbs up?

There is another class of animals that are absolutely not mammals, but that might play, and are highly social, cooperative, sometimes venomous, particularly gifted at swarming, and have been weaponised in ancient times: Eusocial insects. That'll be part 3, with some biological warfare and the evolution of different diets and weapons.

"Xenology: an unnatural mixture of science fiction and formal logic. It's based on the false premise that human psychology is applicable to extraterrestrial intelligent beings."
"Why is that false?" Noonan asked.
"Because biologists have already been burned trying to use human psychology on animals. Earth animals, at that."
"Forgive me, but that's an entirely different matter. We're talking about the psychology of rational beings."
"Yes. And everything would be fine if we only knew what reason was."
"Don't we know?" Noonan was surprised.
"Believe it or not, we don't.

Roadside Picnic, by Arkady & Boris Strugatsky, 1972

***Disclaimer**: The material presented is for informational and entertainment purposes only, in summary of recent news and events. It neither reflects the views nor constitutes professional advice of the organisation. The major sources used are referenced below.*

Select References

Albert, H. (2024, October 8). Uncovering the mysteries of the gut-brain connection. *Inside Precision Medicine*. https://www.insideprecisionmedicine.com/topics/translational-research/uncovering-the-mysteries-of-the-gut-brain-connection/

Atay, S. (2020). Cyber-culture, cyber-art, and menemonic energy. (eds. S. Atay, M. Kurubacak-Meric, S. Sisman-Ugur) In Present and Future Paradigms of Cyberculture in the 21st Century. (IGI Global)

Belkin, S., Yagur-Kroll, S., Kabessa, Y., Korouma, V., Septon, T., Anati, Y., Zohar-Perez, C., Rabinovitz, Z., Nussinovitch, A., & Agranat, A. J. (2017). Remote detection of buried landmines using a bacterial sensor. Nature Biotechnology, 35(4), 308–310. https://doi.org/10.1038/nbt.3791

Casey, C., Fregosi, S., Oswald, J.N., Janik, V. M., Visser, F. and Southall, B. (2024) Common dolphin whistle responses to experimental mid-frequency sonar. *PLoS ONE 19*(4): e0302035. https://doi.org/10.1371/journal.pone.0302035

Drexel, B. and Withers, C. (2024, August). AI and the Evolution of Biological National Security Risks: Capabilities, Thresholds, and Interventions. *Center for New American Security*. https://www.cnas.org/publications/reports/ai-and-the-evolution-of-biological-national-security-risks

Driscoll, W. W., Espinosa, N. J., Eldakar, O. T. and Hackett, J. D. (2013). Allelopathy as an emergent, exploitable public good in the bloom-forming microalga *Prymnesium Parvum*. *Evolution*, *67*(6), 1582–1590. https://doi.org/10.1111/evo.12030

Dutton, G. (2024, October 2). Agrobodies Emulate Antibodies to Protect Crops. Genetic Engineering and Biotechnology News. https://www.genengnews.com/topics/infectious-diseases/agrobodies-emulate-antibodies-to-protect-crops/

Eckert, J., Winkler, S. L. and Cartmill, E. A. (2020). Just kidding: the evolutionary roots of playful teasing. *Biol. Lett.,* 1620200370. http://doi.org/10.1098/rsbl.2020.0370

Fallon, T. R., Shende, V. V., Wierzbicki, I. H., Auber, R. P., Gonzalez, D. J., Wisecaver, J. H., & Moore, B. S. (2024). Giant polyketide synthase enzymes biosynthesize a giant marine polyether biotoxin. *bioRxiv : the preprint server for biology*, 2024.01.29.577497. https://doi.org/10.1101/2024.01.29.577497

Ford, B. J. (2022, December 14). Turning back the centuries of microscopy. *Wiley Analytical Science*. https://analyticalscience.wiley.com/content/article-do/turning-back-centuries-microscopy

Fox, A. (2024, August 12). Largest Protein Yet Discovered Builds Algal Toxins. *UC San Diego Today*. https://today.ucsd.edu/story/largest-protein-yet-discovered-builds-algal-toxins

Gach-Janczak, K., Biernat, M., Kuczer, M., Adamska-Bartłomiejczyk, A., & Kluczyk, A. (2024). Analgesic Peptides: From Natural Diversity to Rational Design. *Molecules (Basel, Switzerland)*, *29*(7), 1544. https://doi.org/10.3390/molecules29071544

Garner K. L. (2021). Principles of synthetic biology. *Essays in biochemistry, 65*(5), 791–811. https://doi.org/10.1042/EBC20200059

Gerschick, T. (2024, September 23). Biopesticides: Natural Molecules Set to Replace Glyphosate in Sustainable Agriculture. *The Calculated Chemist*. https://thecalculatedchemist.com/blogs/news/biopesticides-natural-molecules-set-to-replace-glyphosate-in-sustainable-agriculture

Giles, D. A., Teman, S. J., Ellis, S., Ford, J. K. B., Shields, M. W., Hanson, M. B., Emmons, C. K., Cottrell, P. E., Baird, R. W., Osborne, R. W., Weiss, M., Ellifrit, D. K., Olson, J. K., Towers, J. R., Ellis, G., Matkin, D., Smith, C. E., Raverty, S. A., Norman, S. A., & Gaydos, J. K. (2024). Harassment and killing of porpoises ("phocoenacide") by fish-eating Southern Resident killer whales (*Orcinus orca*). *Marine Mammal Science*, 40(2), e13073. https://doi.org/10.1111/mms.13073

Goethel, E. (2023, September 1). Porpicide?: Dolphins are killing porpoises. Scientists don't know why. *Seacoastonline*. https://www.seacoastonline.com/story/news/local/2023/09/01/porpicide-dolphins-killing-porpoises/70724248007/

Goldstein, M. (2006, May 13). The Dark Secrets That Dolphins Don't Want You to Know. *Slate*. https://slate.com/human-interest/2009/05/the-dark-secrets-that-dolphins-don-t-want-you-to-know.html

Hagendorff, T. (2024). Deception abilities emerged in large language models. *PNAS, 121*(24), e2317967121. https://doi.org/10.1073/pnas.2317967121

Hambling, D. (2023, December 4). Drones Rule the Skies in Ukraine, But These Nano Spy Helicopters Are Something Else Entirely. *Popular Mechanics*. https://www.popularmechanics.com/military/weapons/a45631169/black-hornet-nano-spy-drone/

Haseltine, W. (2024, August). The need for ethical regulation of brain-machine interface technologies. *Inside Precision Medicine*, August 2024, p. 48-52.

How AI is changing warfare. (2024). In *The Economist (London)*. Economist Intelligence Unit N.A. Incorporated.

Huang, K., Chandak, P., Wang, Q. *et al.* (2024). A foundation model for clinician-centered drug repurposing. *Nat Med*. https://doi.org/10.1038/s41591-024-03233-x

Jimenez, M., L'Heureux, J., Kolaya, E., Liu, G. W., Martin, K. B., Ellis, H., Dao, A., Yang, M., Villaverde, Z., Khazi-Syed, A., Cao, Q., Fabian, N., Jenkins, J., Fitzgerald, N., Karavasili, C., Muller, B., Byrne, J. D., & Traverso, G. (2024). Synthetic extremophiles via species-specific formulations improve microbial therapeutics. *Nature Materials*. https://doi.org/10.1038/s41563-024-01937-6

Johnson, J. (2024). Anthropomorphizing AI in centaur teaming. In *The AI Commander*. Oxford University Press. https://doi.org/10.1093/oso/9780198892182.003.0003

Lane N. (2015). The unseen world: reflections on Leeuwenhoek (1677) 'Concerning little animals'. Philosophical transactions of the Royal Society of London. *Series B, Biological sciences, 370*(1666), 20140344. https://doi.org/10.1098/rstb.2014.0344

Lea, R. (2024, May 8). Future biohybrid robots to be powered by living muscle tissue. *Advanced Science News.* https://www.advancedsciencenews.com/future-biohybrid-robots-to-be-powered-by-living-muscle-tissue/

Li, J., Dekanovsky, L., Khezri, B., Wu, B., Zhou, H., and Sofer, Z. (2022). Biohybrid Micro- and Nanorobots for Intelligent Drug Delivery. *Cyborg Bionic Syst., 2022*. https://spj.science.org/doi/10.34133/2022/9824057

Licholai, G. (2024, September 26). AI Tool Speeds Drug Repurposing: And It's Free. *Forbes*. https://www.forbes.com/sites/greglicholai/2024/09/26/ai-tool-speeds-drug-repurposing-and-its-free/

Liszewski, K. (2024, September 9). Phage Therapy's Neglected Potential Is Finally Being Realized. *Genetic Engineering & Biotechnology News*. https://www.genengnews.com/topics/translational-medicine/phage-therapys-neglected-potential-is-finally-being-realized/

Lüddecke, T., Paas, A., Harris, R. J., Talmann, L., Kirchhoff, K. N., Billion, A., Hardes, K., Steinbrink, A., Gerlach, D., Fry, B. G., & Vilcinskas, A. (2023). Venom biotechnology: casting light on nature's deadliest weapons using synthetic biology. *Frontiers in bioengineering and biotechnology, 11*, 1166601. https://doi.org/10.3389/fbioe.2023.1166601

Maglieri, V., Vantaggio, F., Pilenga, C., Böye, M., Lemasson, A., Favaro, L., & Palagi, E. (2024). Smiling underwater: Exploring playful signals and rapid mimicry in bottlenose dolphins. *iScience*, *27*(10), 110966. https://doi.org/10.1016/j.isci.2024.110966

Masaki, K. and Satoru, K. (2024, Febuary 5). Dark Side of AI Presents Threats for Cybersecurity. *Nippon*. https://www.nippon.com/en/in-depth/d00948/

Massey, S. E. and Mishra, B. (2018). Origin of biomolecular games: deception and molecular evolution. *J. R. Soc. Interface*., 1520180429. http://doi.org/10.1098/rsif.2018.0429

Mattioli, G. (2024, June 25). How this ancient dolphin population thrives in one of Italy's most polluted cities. *National Geographic*. https://www.nationalgeographic.com/animals/article/taranto-italy-dolphin-marine-reserve

Ng, B., Tasaki, S., Greathouse, K.M. *et al.* (2024). Integration across biophysical scales identifies molecular and cellular correlates of person-to-person variability in human brain connectivity. *Nat Neurosci*. https://doi.org/10.1038/s41593-024-01788-z

Osborne, M. (2023, October 3). Why Do Orcas Keep Harassing Porpoises?. *Smithsonian*. https://www.smithsonianmag.com/smart-news/why-do-orcas-keep-harassing-porpoises-180983007/

Park, P. S., Goldstein, S., O'Gara, A., Chen, M., & Hendrycks, D. (2024). AI deception: A survey of examples, risks, and potential solutions. *Patterns*, *5*(5). https://doi.org/10.1016/j.patter.2024.100988

Pillai, A., Idris, A., Philomin, A. *et al.* (2024). De novo design of allosterically switchable protein assemblies. *Nature, 632,* 911–920. https://doi.org/10.1038/s41586-024-07813-2

Rav, Y. (2002). Perspectives On The History Of The Cybernetics Movement: The Path To Current Research Through The Contributions Of Norbert Wiener, Warren Mcculloch, and John von Neumann. *Cybernetics and Systems, 33*(8), 779-804. http://dx.doi.org/10.1080/01969720290040830

Ravi, A. (2024, October 15). AI meets pathology: How Stanford Medicine diagnoses diseases using nuclei.io. *The Stanford Daily*. https://stanforddaily.com/2024/10/15/stanford-medicine-use-ai-to-diagnoses-diseases/

Rawat, S. (2024, October 10). Diverse Genomes Make Medicine More Equitable. *Gen EDGE*. https://www.genengnews.com/topics/drug-discovery/diverse-genomes-make-medicine-more-equitable/

Schwacke, L. H., Thomas, L., Wells, R. S., Rowles, T. K., Bossart, G., Townsend, F., Mazzoil, M., Allen, J. B., Balmer, B. C., Barleycorn, A. A., Barratclough, A., Burt, M. L., De Guise, S., Fauquier, D., Gomez, F. M., Kellar, N. M., Schwacke, J. H., Speakman, T. R., Stolen, E., … Smith, C. R. (2024). An expert-based system to predict population survival rate from health data. *Conservation Biology, 38*, e14073. https://doi.org/10.1111/cobi.14073

Šiljak, H., Nardelli, P. H. J. & Moioli, R. C. (2022). Cyborg Insects: Bug or a Feature?. *IEEE Access, 10*, 49398-49411. https://ieeexplore.ieee.org/document/9770076

Stevens, P. Jr. (2020). Yes, we need a neuroscience of play. *International Journal of Play, 9*(1). https://doi.org/10.1080/21594937.2020.1720147

Szydlowski, L. M., Bulbul, A. A., Simpson, A. C., Kaya, D. E., Singh, N. K., Sezerman, U. O., Łabaj, P. P., Kosciolek, T., & Venkateswaran, K. (2024). Adaptation to space conditions of novel bacterial species isolated from the International Space Station revealed by functional gene annotations and comparative genome analysis. *Microbiome*, *12*(1), 190. https://doi.org/10.1186/s40168-024-01916-8

University of Arizona. (2013, January 18). They hunt, they kill, they cheat: Single-celled algae shed light on social lives of microbes. *ScienceDaily*. www.sciencedaily.com/releases/2013/01/130118172335.htm

Wang, C., Zhang, Z., Wang, J., Wang, Q., & Shang, L. (2022). Biohybrid materials: Structure design and biomedical applications. *Materials today. Bio*, *16*, 100352. https://doi.org/10.1016/j.mtbio.2022.100352

Wang, Z., Klingner, A., Magdanz, V., Misra, S. and Khalil, I.S.M. (2023). Soft Bio-Microrobots: Toward Biomedical Applications. *Adv. Intell. Syst.*, *6*, 2300093. https://doi.org/10.1002/aisy.202300093

Warneck-Silvestrin, L. (2024). How Is Artificial Intelligence Changing the Clinical Trials Landscape? *Inside Precision Medicine, October 2024*. https://digital.emagazines.com/inside_precision_medicine/20241003/index.html

Watson, E. (2024, October 24). Predator too? BioArmix tackles bacterial pathogens with novel ‘predatory’ biologicals. *AFN*. https://agfundernews.com/predator-too-bioarmix-tackles-bacterial-pathogens-with-novel-predatory-biologicals

Webster-Wood, V. et al. (2023). Biohybrid robots: recent progress, challenges, and perspectives. *Bioinspir. Biomim.*, *18***,** 015001. https://doi.org/10.1088/1748-3190/ac9c3b

Wisecaver, J. H., Auber, R. P., Pendleton, A. L., Watervoort, N. F., Fallon, T. R., Riedling, O. L., Manning, S. R., Moore, B. S., & Driscoll, W. W. (2023). Extreme genome diversity and cryptic speciation in a harmful algal-bloom-forming eukaryote. *Current Biology*, *33*(11), 2246-2259.e8. https://doi.org/10.1016/j.cub.2023.05.003

Wu, Z., Troll, J., Jeong, H. H., Wei, Q., Stang, M., Ziemssen, F., Wang, Z., Dong, M., Schnichels, S., Qiu, T., & Fischer, P. (2018). A swarm of slippery micropropellers penetrates the vitreous body of the eye. *Science advances, 4*(11), eaat4388. https://doi.org/10.1126/sciadv.aat4388

Yan, X., Liu, X., Zhao, C. et al. (2023). Applications of synthetic biology in medical and pharmaceutical fields. *Sig Transduct Target Ther, 8*, 199. https://doi.org/10.1038/s41392-023-01440-5

Yang, Z., Xu, C., Lee, J. X., and Lum, G. Z. (2024). Magnetic Miniature Soft Robot with Reprogrammable Drug-Dispensing Functionalities: Toward Advanced Targeted Combination Therapy. *Adv. Mater.*, 2408750. https://doi.org/10.1002/adma.202408750

Zhang, F., Guo, Z., Li, Z., Luan, H., Yu, Y., Zhu, A. T., Ding, S., Gao, W., Fang, R. H., Zhang, L., & Wang, J. (2024). Biohybrid microrobots locally and actively deliver drug-loaded nanoparticles to inhibit the progression of lung metastasis. *Science Advances*, *10*(24), eadn6157-. https://doi.org/10.1126/sciadv.adn6157

Zhang, L., Wen, L. and Zhang, J. (2024). Soft Robotics Across Scales: Fundamentals to Applications. *Adv. Intell. Syst., 6*, 2300879. https://doi.org/10.1002/aisy.202300879

Zhavoronkov, A. (2024, August 1). Is Generative AI in Drug Discovery Overhyped? *Genetic Engineering and Biotechnology News*. https://www.genengnews.com/topics/artificial-intelligence/is-generative-ai-in-drug-discovery-overhyped/