

# Quantum Biology Risks

A Threat Model to Inform Research and Development Funding.

Version 1.1, September 25th 2024

(Original version: August 19th 2024)

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Supported by a grant from Leverage Research

# Executive Overview

The identification and characterization of quantum mechanical effects that have significant impact upon biological processes is an emerging field of study. Combined with the potential to manipulate quantum biological phenomena through the application of carefully tuned electromagnetic fields, there exists the possibility for a new rapidly emerging biotechnological paradigm. Because previous revolutions in biotechnology have had significant security implications, a scenario-based threat modeling process was undertaken to identify the offense-defense balance of the science of quantum biology, and the security implications of a technological paradigm based upon that science.

The set of known or strongly suspected quantum biological phenomena were reviewed. That review was informed by both a quantum mechanics physics perspective and a biological one, and certain patterns were recognized: To be able to have meaningful effect under biological conditions (not near absolute zero), the quantum states have to be limited to biological processes that were (1) fleeting in duration, and (2) mechanistically confined to the fate of small numbers of elementary particles typically inside the catalytic core of an enzyme.

In order for such constrained effects to potentially have any biologically significant output, they must take advantage of a phenomenon common in biology that we term “scale-shifting effects”. A scale shifting effect is a situation where an *individual instance* of something at small scales has effects at larger scales. (This is different from many small-scale instances achieving aggregate effect at large scales). A particularly important example of this is sensation: An individual receptor protein might change state to trigger a sensory nerve which in turn triggers a pre-existing reflex and alters the behavior of the whole organism.

The concept of scale-shifting effects, the limitations of quantum mechanics and molecular biology, and the base-rates of deliberate and accidental biological and conventional threats were combined to create a unified risk model of quantum biology. That model was then used to construct a number of threat scenarios involving EM-modulated quantum biological mechanisms, which were then ranked for feasibility, offense-defense balance, and dual use.

It was concluded that quantum biologically mediated threats were compelling compared to conventional threats (guns, bombs, and poisons) only in a *qualitative* manner. That is they represent inferior options to do harm directly for its own sake, but offer capabilities that are at least to some degree otherwise unprecedented. Stealth in deployment is an essential in all of these scenarios. While quantum biology does not appear to be offense dominant to begin with, it appears that the deployment of detection capabilities for EM signals meant to interface with biology would be an effective way to shift it into a firmly defense dominant mode. This suggests that information hazard containment steps meant to keep the nature of such signals secret would be counterproductive, as defenders need to know what to look for.

# Introduction

Quantum biology is the study of the properties of quantum mechanical systems upon biological systems. This field is, at present, relatively little explored but with sufficient research support could become subject to major advances in the near future. Whether it does, depends on whether quantum effects do play significant or novel roles in biology outside the few currently known cases, and whether the right tools for interacting with it are developed. However, before pushing for development of this field, it is rational to consider if development of quantum biology is a safe or dangerous goal to pursue. Is Quantum Biology a Pandora's Box best left unopened?

Strategic foresight of emerging technical fields is notoriously difficult, and the analysis presented here will no doubt be inaccurate in numerous specific details when later reviewed with hindsight. Nevertheless, as Kenneth Ewart Boulding said "The future is bound to surprise us, but we don't have to be dumbfounded." (Boulding, 1956) There are certain broad patterns among quantum biological phenomena that are known at the time of this writing. There are also similar broad patterns of threats both accidental and deliberate that are well understood. By identifying and using these patterns, this report attempts to map the shapes of the most likely threat scenarios that might arise from the near-future development of the field of quantum biology, with an emphasis upon those threats that might be unique or different compared to more conventional threats (such as guns, bombs, and poisons).

In developing these scenarios, consideration was also given to the dual-use nature of all science and research. Anything that can be used as part of a threat, can also be used for legitimate purposes and vice versa. This fact can not be neglected in threat modeling as the technologies that allow for manipulation of a natural phenomenon towards dangerous ends are, not coincidentally, often the same technologies that are best used to mitigate that danger.

## Methodology

How do we determine if there are decision-relevant concerns with a field where we do not know the ground truth?

One approach is to look at **base-rates**: in the past, when new aspects of biology have become available to investigation and engineering, how often have they turned out to contain things that are dual use of concern, or directly dangerous? We should expect the same probability from quantum biology, unless we gain extra information or insights. This analysis aims at adding some of that.

If we use this first approach, we can note that biological weapons have been used in anger about 10 times in the post-germ-theory of disease era with most attacks resulting in less than 100 deaths (the notable exception is the bubonic plague attacks of the Empire of Japan in WWII which resulted in several hundred thousand deaths and approximately 2 million cases). (Riedel, 2004) For comparison, it is estimated that the non-COVID deaths from biological risks in 2022 was around 225,000 from all workplace accidents globally. (Takala et al., 2023) Of those, 92.5% are likely healthcare workers exposed individually in events such as needle sticks. (Shamoo, 2001) These statistics give us a good base-line expectation for the rates of intentional and unintentional biological incidents and the magnitude of the danger they represent.

Another approach is to **bound the causal power** of quantum biology: what are the strongest effects that are plausible? This can be linked to an evolutionary argument: evolution, over the billions of years that life has existed on Earth, has doubtlessly had optimizing and selective effects on any quantum biological phenomena, so we should expect existing quantum biological effects (if any) to be close to the upper limit of what biology can achieve. Getting a stronger effect requires finding external conditions that are unlikely to occur in nature, are unlikely to be evolvable, or represent tradeoffs that are very different from inclusive fitness.

A third general approach is to consider **physical bounds on influence**. To affect quantum biology some form of interaction is needed – a chemical, electromagnetic fields, ultrasound, or gravity. Over distance the fidelity by which these influences can be controlled have limitations. For example, electromagnetic waves have an uncertainty relation limiting their frequency spread and temporal tightness, a diffraction limit for far field emissions, and obviously the inverse square intensity fall-off. Given a putative threat, for it to matter it either needs to be targeted at something or someone critical, or have a widespread target. In either case we can place some bounds on how far it can go.

One important aspect is that quantum biology is more about information and correlation than power: if it acts, it acts through systems behaving differently in a structured (or random) way rather than through massive force. Quantum effects are generally very small and low-energy, and hence need a plausible way of cascading through the biological system to cause effects of concern.

These considerations make it useful to analyze in terms of **scenarios**. While general arguments are possible, scenarios allow us to focus on particular cases that plausibly appear risky and analyze how significant they could be under different circumstances. Further, scenarios

naturally protect against making errors of contradictory assumptions. This is a danger of the second forecasting methodology because the properties necessary for one sort of strongest effect may be contradictory with the properties required for a different sort of strongest effect such that while both are represented in the set of all scenarios, no individual scenario could exhibit both. Correspondingly, once the assumptions of a particular scenario are set, it becomes quite easy to forecast non-threat applications of the same underlying phenomena and interventions where that might be relatively difficult when not considered in discrete scenarios. This is especially important considering the fact that most biological discoveries and innovations *have* had overwhelmingly non-threatening net results.

## Baseline Threats

Guns, bombs, and poisons already exist! Guns kill at range and optionally with precision. Bombs kill in a wide area, and can be delivered with precision. Poisons kill with stealth, and again optionally with precision. When considering this base line of threats, it is worth exploring the complex spectrum of capabilities that these tools afford their users:

- All three have a wide palette of options and levels of force for the user to select from. Bombs can be as small as a firecracker or as powerful as a nuclear warhead with many fine gradations between those extremes. Similarly, poisons can have effects ranging from subtle to the point of not being consciously noticed or instantly lethal, and guns range from air-guns little more powerful than a toy to 50 caliber machine guns.
- All three have less-lethal variants: stun-guns, rubber bullets, and bean-bag rounds are less lethal variants on guns and their ammunition, flash-bang grenades are less lethal bombs, and anesthetics and tear gas are less lethal poisons.
- These weapon concepts have been sufficiently developed that all combinations of their capabilities exist: artillery being the combination of guns and bombs, chemical weapons being the combination of the paradigms of bombs and poisons, and dart guns for delivery of drugs such as anesthetics being the intersection of guns and poisons.

As such, any threat from the exploration of quantum biology and the subsequent development of technologies that influence biology through quantum mechanisms must represent either a quantitatively more potent threat than known guns, bombs, or poisons, or, it must represent a qualitatively different threat; that is an option that allows one to do something all-together different from the capabilities afforded by guns, bombs, and poisons.

Further, it must represent a reasonable tactical paradigm... if a particular threat mediated by quantum biological mechanisms requires the victim to sit perfectly still in a

superconducting wave-guide chamber for three hours, for instance, even if it is doing something qualitatively or quantitatively unprecedented, it is still likely not a meaningfully concerning threat.

## Quantum Biology Threat Modeling

Quantum phenomena are generally characterized by their fragility. Temperature even marginally above absolute zero or mere observation are sufficient to reduce the stability of quantum states to the point of being almost instantaneously fleeting. And yet, quantum processes *are* known to exist in biological settings and in ways that are biologically meaningful.

In some trivial sense, quantum biological phenomena are constantly and fleetingly everywhere. This report is concerned with *meaningful* quantum biological effects however. That means two things: (1) That the effect must not be meaningful in the biological sense: it does something that dictates the fate of a biological entity or process: a gene, a cell, an organism, a herd, a species, etc. (2) That the effect does something that is not simply recapitulating something that could or does happen via classically mechanics, or has no effect whatsoever from an outside perspective

Interestingly, the very concept of “meaningful quantum biological phenomenon” is two directional. If a quantum effect has a meaningful biological role, then not only does that imply that one might manipulate biological systems through a quantum mechanical interface, but because biological systems are evolved, it stands to reason that biological systems may already exist to manipulate quantum phenomena in biology. If that is the case, then a systematic and thorough investigation of quantum biology will almost certainly discover such biological systems which in turn might be co-opted or reverse engineered to search for more quantum biology phenomena in a self-reinforcing cycle. Such virtuous cycles of discovery and invention have fueled all of the major technological booms of the past few centuries. This has in fact already happened in biology with genetics: the more genetics was studied, the more genetic tools such as polymerases, promoters, recombinases, etc were discovered, which in turn lead to easier and more efficient and more profitable studying of genetics.

**In some ways this is the primary threat and opportunity of quantum biology: It has the potential to be such an unstoppable and rapid emergence of new capabilities and understanding that will likely outpace our ability to fully prepare for all its implications and applications.** That anticipated velocity of advancement is why this report is useful *now*.

# Known Quantum Biological Phenomena

There are three primary quantum effects: Tunneling, Superposition, and Entanglement.

- Tunneling involves a particle passing through barriers due to its wave-like properties, not being confined by classical limits. The most prominent known example of tunneling in biology involves the tunneling of protons (hydrogen ions) in proton pumps crucial for many energy metabolism and membrane electrical potential based functions of most cells (Bothma et al., 2010), (Delgado et al., 2017), and enzyme catalysis (Sutcliffe & Scrutton, 2002), (Bibbs et al., 1988). Tunneling has also been implicated in the G-T wobble misincorporation mutation pattern.(Slocombe et al., 2022)
- Superposition is the capacity of a quantum system to exist in multiple states at once, which only becomes definite when measured. Superposition is believed to be relevant to the efficiency of photosynthesis as well as avian magnetoreception (the ability of migrating birds to perceive the magnetic field of the Earth).(Yin & Li, 2017) It has also been theoretically implicated in enzymatic conformational sub-state recognition.(Agarwal et al., 2016)
- Entanglement is a correlation between particles, where the state of one is dependent on the state of another, regardless of distance. It has been implicated in coordinating the enzymatic cleavage of the two strands of DNA in biology. (Kurian et al., 2016), (D'Acunto, 2022)

An important pair of common factors can be noted from the list of known or strongly suspected quantum biological phenomena:

1. Unlike quantum computers or quantum experimental platforms in physics laboratories, the known or theorized quantum biological effects are NOT functioning near absolute zero to protect and stabilize fragile quantum effects for long periods of time. Rather, quantum biological phenomena simply leverage processes that are *so fast* that they do not require stabilization of the quantum state in the first place.
2. Unlike condensates which bring quantum effects into almost macroscopic scales, the known biological quantum effects are confined to modulating the physical state of very small numbers of elementary particles (protons or electrons) typically in enzymatic catalytic cores.

The presumption of this report is that all quantum biological phenomena will function within those same constraints: near instantaneous rates, and small numbers of elementary particles. Immediately this makes many of the more obvious applications of quantum effects infeasible: those involving long lasting entangled states that transfer or store information across

many cells or organisms. Upon initial review, this might seem to rule out *any threats* that are more impressive either qualitatively or quantitatively than guns, bombs, or poisons, as exceeding them would require large scales of distributed effects. See Figure 1.

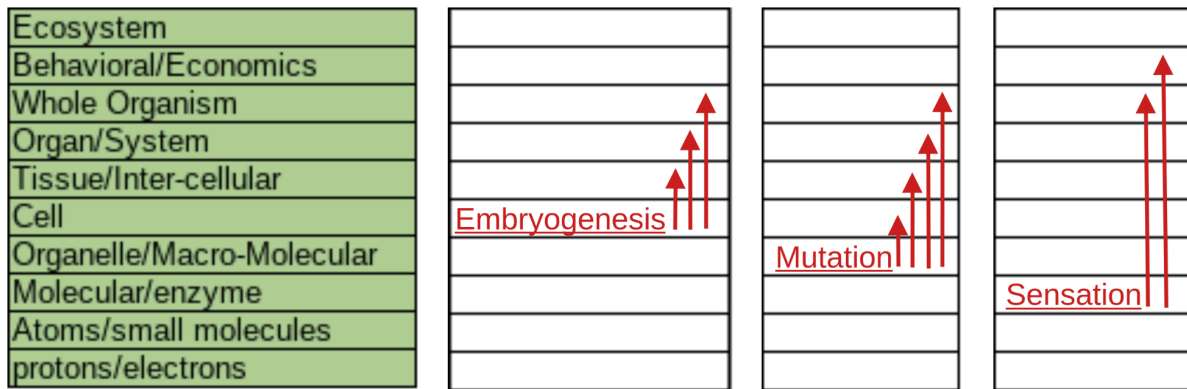
**Figure 1. Scale of Quantum Biology does not seem directly threatening**

Scale	Chance of Direct QB Effect	Threat Concern
Ecosystem	Low	High
Behavioral/Economics		
Whole Organism		
Organ/System		
Tissue/Inter-cellular		
Cell		
Organelle/Macro-Molecular		
Molecular/enzyme		
Atoms/small molecules		
protons/electrons	High	Low

However, that initial assessment is incorrect. The constraints of near instantaneous mechanisms involving very few elementary particles do not completely eliminate the potential for unprecedented or dangerous effects from quantum mechanical manipulation of biology. The reason is implicit in the nature of biological systems and how they are distinct from chemical or physical systems. Biology has a wide variety of mechanisms which allow for the dynamics of individual elements of smaller scales of a biological system to influence the dynamics of larger scales of the same biological systems. An example of this would be embryogenesis: just one fertilized zygote gives rise to many cells, eventually many tissues, organs, and a whole independent organism. Similarly cancer can start with a single molecular event... a mutation of just one molecule of DNA in one cell, and yet alter the fate of the whole organism. See Figure 2.



**Figure 2. Scale Shifting effects in biology**



Other Biological Scale-Shifting effects include: [Group Behaviors](#), [Carcinogenesis](#), [Infection](#), [Signal-Transduction](#), [Synapses/Cell-contact](#), [Circulatory Systems](#), [Quorum Sensing](#) and [Ecological Signaling](#), & [Carbon/Water/Nitrogen Cycles](#).

These Scale-Shifting effects represent the potential for even near instantaneously fast effects that are limited to only a few elementary particles to nonetheless have huge implications for larger biological systems.

Scale-shifting effects that shift a molecular near instantaneous effect *beyond the scale of individual organisms* are particularly important because they have the potential to achieve end-results that are qualitatively or quantitatively different from what can be achieved with guns, bombs, or poisons. One particularly interesting and important example of such a scale-shifting effect is **Sensation**. There is in fact already a known example of a quantum biological effect that affects sensation and through it the behavioral and ecological scales of biological systems: the magneto reception of migratory birds.(Yin & Li, 2017)

## Accidents as Opposed to Deliberate Misuse

Not all or even most threats come from deliberate misuse. All too often, threat modeling jumps directly to the deliberate use case on the presumption that people intentionally doing harm are more dangerous than people accidentally doing harm. While, in general, that notion does not survive even the most cursory examination of recorded history, it is reasonably sound in the case of Quantum Biology Threat Modeling.

The reason for this is that quantum effects have, almost certainly, been meaningful in the evolution of life from the most primitive molecular precursors. In fact the same constraints that quantum biological effects are known to suffer (near instantaneous and few elementary particles) would ensure that quantum effects were relatively dominant in prebiotic Metabolism First (Pratt, 2011), (Chatterjee, 2023) or RNA World (Neveu et al., 2013) models of abiogenesis. As such, any easy and direct frailty that using such quantum mechanisms might evoke has had

billions of years of natural selection to be weeded out. Thus it is very unlikely that a random burst of electromagnetic noise, for example, would be instantly lethal to an organism or species. Such genes would long ago have died off.

Rather, if quantum biological threats exist, mechanistically, they likely exist in a space of interventions that are wholly unlikely to have ever existed naturally over the course of the last few billion years of evolution on Earth. The more one must deliberately engineer the mechanism of the threat, the more likely the threat was engineered deliberately. This is further reinforced by the need for such a threat to specifically target scale-shifting effects in biology that go beyond affecting just one organism.

## Tactical Concerns and Delivery Mechanisms

Most weapons are only as dangerous as their delivery mechanisms permit. So in order to discuss potential scenarios for quantum biological threats we need to consider the delivery mechanism, which is to say how the quantum biological states might be affected by an actor.

Of the fundamental forces, the strong and weak nuclear forces are short-range and affect only nuclear processes, of very limited importance in biology. Gravitation might have quantum biological effects, but is hard to manipulate due to its weakness and the unipolarity of its charges. That leaves the electromagnetic field, and indirectly mechanical signals (that are mediated through electromagnetic interactions), such as ultrasound.

Ultrasound, while having interesting potential for biological manipulation, is a collective excitation and larger than individual particles (the shortest possible wavelength is set by the mean free path of molecules, in air 68 nm and in water 0.25 nm, corresponding to 5 GHz and 6THz; attenuation becomes significant long before this is reached). While collective excitations like phonons can exhibit quantum properties this requires “clean” low-interaction systems like crystals to avoid thermalization.

Electromagnetic fields can affect quantum systems either through particle-like interactions (e.g. photon capture), wave phenomena, or as static fields (e.g. magnetoception). They are the most likely delivery mechanism since waves or beams can be projected over distance, and static fields while proximity-requiring (due to their inverse square or cube decay from sources) can be made unobtrusive. There is ample evidence for electromagnetic-biological interaction in the mT range, some of which plausibly is due to quantum effects.

(Zadeh-Haghighi & Simon, 2022)

Wave-based delivery has important tradeoffs. An EM beam has a divergence angle proportional to the ratio between wavelength and the source diameter: this makes low frequency beams highly divergent unless they have large and obvious transmitters. Conversely, for focusing on small targets wavelengths need to be small and the numerical aperture large. Due to the bandwidth theorem an uncertainty relation exist for waves with a finite bandwidth

$\Delta x \Delta B \geq 1/2$ : to localize them precisely the bandwidth needs to be large, which means less energy is present in parts of the spectrum interfacing with quantum biology. Similarly high precision timing pulses require  $\Delta t \Delta B \geq 2\pi$ . This constrains precision delivery.

EM fields and biological systems interact in complex ways, including coupling of fields into tissues and energy deposition, which vary depending on frequency and tissue properties.(Lin, 2016) This also limits the precision by which energy or information can be deposited in the right place.

A final complication is that at least for radical pair spin interactions in quantum biology the strength of static (and presumably dynamic) magnetic fields need to be in a narrow range. The reason is that the reaction product yields peaks for fields in the low mT range due to competing pathways in the singlet-triplet system.(Hore & Mouritsen, 2016) For fields or beams declining with an inverse square law, this means that the ratio of minimum and maximum distance for effect scales like  $d_1/d_2 \propto \sqrt{B_1/B_2}$  (and for dipole fields scaling as inverse cube, with a cube root dependency).

# Scenarios

The following scenarios represent possible examples of threats that might arise from an understanding of quantum biological phenomena in humans, microbes, plants, and insects. They involve scales intended to affect specific locations and individuals up to large populations and regions. All of them, except the last “THz Binding and Tunneling Control” operate upon the nominal assumption that the quantum biological phenomenon being leveraged is an enzymatically mediated chemical reaction that is sensitive to narrowly tuned electromagnetic interference. Further, because of its ability to transition from the atomic scale to organism, behavior, and ecological scales, most involve some form of sensation manipulation scale-shifting effect. Because the exact properties of the EM interference is unknowable at this time, a wide variety of tactical paradigms regarding the effective range and intensity of these fields are assumed across the different scenarios.

For all scenarios, five bullet points follow the scenario description noting key properties the threat scenario possesses with regards to:

- Scale-Shifting Effects: As detailed above, in order for the fate of individual molecules to have more than local effect, one must use scale shifting effects. For each scenario, the ones leveraged will be listed.
- Offense/Misuse of the capability the scenario is based upon. Within this section of each scenario, there is a discussion on the classes of actor that might be able to engage in that attack scenario. This discussion is based upon the restrictions of *delivery and targeting* of the electromagnetic quantum biological actuating signal, not the difficulty of *developing* that signal. The assumption is in all cases that the signal itself is something that is already developed by unrelated parties and available with industrious searching on the internet in much the same way that modern terrorists, even if they build their own pipe bombs, do not need to develop pipe bomb technology.
- Countermeasures to that misuse,
- Defensive or Productive uses of the same underlying capability. All of these quantum biological capacities are dual use, so just because we can develop threat scenarios does not mean that the same scenario doesn't also invoke positive applications. A threat analysis is not complete without considering both sides of the coin.
- Near Precedents & Uniqueness of the use cases in the scenario highlighting both how similar things have been employed or desired in the past, and how this is different. This is meant to demonstrate whether the threat of a particular

scenario might be desirable to potential actors as well as to highlight how very similar things might already exist and be mitigated already.

Finally it is important to note that these scenarios are meant to represent the spectrum of possible threats that our current understanding allows us to generously predict about the capabilities of manipulating quantum biological processes. They are not predictions and likely they all contain details that in hindsight will seem erroneous. In 1939, Albert Einstein wrote a letter to President Roosevelt warning of the potential for an atomic bomb to be developed by Nazi Germany. In this letter he details a number of suppositions about the potential properties of atomic bombs. In the big things, that atomic bombs were possible and of unprecedented power, he was correct. However, all of his suppositions of their detailed properties were wrong or badly incomplete. And that was Einstein writing about nuclear physics a mere six years before the first atomic detonation. These scenarios should be read with a similar expectation of accuracy.

## Crowd Control

An agent walks through a milling crowd with a Mood Influencing Olfactory Actuator. Because of low strength magnetic fields having the strongest effect in many known EM biological effects, the Actuator is set to work best at 20 ft, with the effect dropping off at 10 ft, because at that range it is too strong, and 25 ft, because at that range it is too weak, and is based on a directional antenna so it only works in one direction. In this way, the agent is unaffected and, combined with simple a parabolic microphone tuned to that same distance and range as the actuator is tuned to, can snoop on conversations around himself and then selectively apply the Actuator only when certain political topics are being discussed, breaking up certain conversations but not others. The participants merely experience a disquieting or disgusting odor that motivates moving away and starting up different conversations. The agent is probably one of several such individuals working the crowd, all of which are being coordinated via ear-bud from a central point that is coordinating the effort to a very precise outcome.

- Scale Shifting Effects
  - Sensation. Individual molecular events in small number can trigger neurons, that in turn trigger pre-defined sensations and reactions at the organism level.
  - Social Behavior. Social dynamics can magnify the behaviors of small numbers of individuals to many.
- Offense/Misuse

- *Class of actor:* Small organization. The coordination and coverage of more than the very smallest events would require multiple operatives coordinated from a central operations center. That puts this out of range of lone wolf actors, but because it would be limited to single venue events, does not require national or region wide resources.
- There is the potential for ethnic and cultural targeting by inducing shadow scents that have divergent cultural implications... roses are romantic in certain cultures and symbols of death in others for example.
- Appropriate for political and social manipulation in:
  - High Society Events
  - Cafeterias or lecture halls
  - Protests and sit-ins.
- Countermeasures.
  - Jamming? While Jamming might be possible in this scenario, the defending group would have to know to employ it.
  - Detection and Attribution. The EM signal would need to be highly tuned to affect specific olfactory receptors and not others, and that makes it a highly engineered artifact which might be attributed to the engineer in the same way that ECM signals can be identified to specific military platforms.
- Defense/Productive Use
  - Psychological Therapy
  - Virtual Reality
- Near Precedents & Uniqueness:
  - There are already audio generators that selectively disrupt gatherings of children and teenagers by using annoying high frequency sound that children are more sensitive to.
  - While crowd control methods have existed for many years (rabble-rousing, water cannons, tear gas, altered availability of implements for violence, public transit and concessions shut-downs, etc) most of them are designed around dispersal or manufacture of the gathering as a whole or the degree to which it is violent as their only goals. Almost universally they are blunt and un-targeted interventions on the entire gathering. More fine control (only parts of the crowd, and subtle alterations of its focus) represent a much more powerful weapon if wielded with sophistication.

# Voter Control

Cellphones are a uniquely dangerous platform as a quantum biological actuator because they are bathed in high resolution personal data concerning their users and also equipped with advanced multi-band transmitters. Imagine a smartphone infecting virus that caused the phone to emit a nausea inducing EM signal but only if that phone had the NPR, BBC America, MS-NBC, or ABC news apps installed but did not have OAN or FOX news apps installed.. The virus will only induce feelings of nausea on election day, and if inside a swing state. (Precedent: The Rashneesh Puram commune prepared to perform a salmonella attack to control an election in Oregon in the 80s)(Abbott, 1990).

- Scale Shifting Effects
  - Sensation. Individual molecular events in small number can trigger neurons, that in turn trigger pre-defined sensations and reactions at the organism level.
  - Software. A single software hack can translate to many devices.
  - Voting structures. Like social behaviors, voting structures are designed to magnify the agency of some parts of the electorate over others. (This is the case both legitimately as in the case of age restrictions and mental competency requirements for suffrage, and illegitimately in the form of both deliberate and systematic exclusions). Consequently, affecting the relatively large electoral events can be controlled by relatively small groups of voters.
- Offense/Misuse
  - *Class of actor*: Hacking campaigns can be run by lone wolf actors or very small organizations, however the more effective global botnets which is how this scenario would function invariably are larger criminal enterprises to set up and maintain and often have nation-state sponsors.
  - Election Manipulation
  - Anything where the information that a smartphone has about its user might be sufficient to identify which users are or are not in a target group: advertising, phishing, etc.
- Countermeasures.
  - Detection and Attribution. Detection is fairly likely if such a weapon were used often because any symptom sufficient to alter the user's behavior would eventually come to the attention of medical professionals. Also cyberattacks are notoriously hard to hide in the long term because memory dumps and the like are possible.
  - Detection is also possible *in trans*, it does not have to be the infected device emitting the signal that detects the signal.

- Once detected, countermeasures could be implemented at the software level.
- Defense/Productive Use
  - Virtually distributed medicine. One can imagine a virtual painkiller that the user of a smart device simply turns on, and if it is insufficient, then they request a virtual prescription from an AI 'doctor', to alter the emitted painkiller EM field. This could even be a smart medicine that detects the presence of other devices emitting similar fields and communicates with them to prevent applying the therapies of one patient to another.
  - Pharmaceutical replacements.
- Near Precedents & Uniqueness:
  - There are already numerous highly targeted voter manipulation misinformation and disinformation campaigns.
  - Just like targeted advertising, this attack gains its power from the fact that it is so targeted and thus achieves great effect from minimal intervention. Key to that is that the smartphone, as it currently exists, already has all of the necessary elements present for the exploit to function:
    - (1) Smartphones are already ubiquitous and in place with the ability to transmit on many bands from single digit Hz to the tens of GHz. Most smartphones only cover a fraction of the below bands and there are some gaps in the bands that smartphones are designed to transmit on, but those gaps are mostly covered by EM noise off of the high power components of the device: (CPU, GPU, Screen, and Audio line).
      - EM noise from audio line: 1 Hz - 20KHz
      - EM noise from the screen refresh: 45-120 Hz
      - IR Communication: 36-38 kHz
      - Qi Wireless charging: 105-205 kHz
      - LF RFID: 125-134 kHz
      - NFC (AKA HF RFID): 13.56 MHz
      - Wifi Power Channels: 20-320 MHz
      - 4G Cellular LTE E-UTRA bands: 410-2690 MHz
      - 5G Cellular Uplink bands: 451-7125 MHz
      - UHF RFID: 856-960 MHz
      - Wifi 802.11ah: 863-925 MHz
      - EM noise from CPUs and GPUs: 1000-4000 MHz
      - Wifi 802.11b/g/n/ax/be: 2401-2495 MHz
      - Bluetooth: 2400-2483.5 MHz
      - Wifi 802.11y: 2655-3695 MHz



- WLAN 802.11j: 4910-5090 MHz
  - Wifi 802.11a/h/n/ac/ax/be/p: 5150-7125 MHz
  - WiGig 802.11aj: 42.39-48.33 GHz
  - WiGig 802.11ad/aj/ay: 57.24-74.52 GHz
  - Visible light from the screen: 400-790 THz
- (2) Intimate and detailed knowledge of the target (in this case the smartphone user) allows for near infinitely precise intervention. This can be based on:
    - Installed apps
    - Text of emails, messaging, and speech recognition
    - Websites visited
    - Location tracking
    - Non-Text information from the camera and microphone including voice and face recognition.
    - Date/Time correlated with calendar information

## Psychological Control

In some ways this scenario should be perceived as a meta-scenario in that it might use similar quantum biological activation methods as the Voter Control or Crowd Control of Birth Control scenarios, but is intended to use those methods over a longer time frame and towards more lasting effect.

Imagine a career politician who has become a problem for a rival. The rival arranges for a covert operative to expose the politician to a EM wave engineered to trigger sensations in his inner ear causing dizziness and nausea. This exposure is only applied during and right before speeches to the media. Over time, this would form a stimulus response pair of operant conditioning (Henton, 1978). The result is that, over time and multiple exposures, the problematic politician learns to associate nausea with public speaking and begins to experience anxiety about doing so and even to generate the nausea symptoms psychosomatically without the covert agent's exposing them at all.

- Scale Shifting Effects
  - Sensation. Individual molecular events in small number can trigger neurons, that in turn trigger pre-defined sensations and reactions at the organism level.
  - Psychological Associations. Here the scale shifting is in time-scales rather than space-scales, allowing for an altered behavior to accumulate from many exposures and to last long after the exposures have ceased.

- Offense/Misuse
  - *Class of actor*: This could be performed by a lone wolf actor as it is most likely targeting a single individual under highly defined circumstances.
  - This method, like all forms of conditioning, classical or operant, requires repeated exposure of the subject over multiple instances of stimulus and response to build an association. As such, it is most likely successful when that association is consistent and strong and tightly managed. For example if the politician in the scenario was nauseous only in 3 of 17 public speaking events, the association would be quite weak, and if made at all might be to some incidental factor shared by those three events but not by the other fourteen. This means that, for the most part, conditioning based applications will work best on individual targets not masses of people because large masses of people rarely gather repeatedly with exactly the same membership at each gathering. Notable exceptions include military units, academic classes particularly in situations where attendance is mandatory, and prisons.
- Countermeasures.
  - Detection/Attribution would be notably easier in this scenario as the quantum biological affector must be running repeatedly and at predictable times and circumstances. This allows for the defenders to notice the effect, speculate as to its cause, and put detection rigs in place covertly to validate their speculation.
  - Aversion exposure therapy. (“Aversion Therapy. Council on Scientific Affairs,” 1987) Nothing about operant conditioning is irreversible. The same basic effect that the attacker uses can be used to reverse it, and likely with better control and effects since the therapy does not need to be administered covertly.
  - Non-psychological countermeasures. In the above example, nausea was the induced response to stimulus. The politician might simply come to realize that public speaking made him nauseous and take Zofran or any number of other medical countermeasures. This is notable because it demonstrates that even if the attack is successful and undetected, it still might not achieve the desired effect.
- Defense/Productive Use
  - Operant conditioning is extensively used in legitimate psychological interventions. It is also used extensively in substance abuse interventions. (Sanger, n.d.) The ability to produce finely controlled operant conditioning therapies through a quantum biological mechanism without drugs like Naltrexone (“Naltrexone Maintenance Treatment,” 2009) would be potentially game-changing.

- Near Precedents & Uniqueness:
  - Naltrexone and other opioid and alcoholism drugs use conditioning to alter undesired substance use behaviors.
  - Operant Conditioning has been used as a training tool in military settings. (Marx, 1969)
  - Operant conditioning was used on birds in Project Pigeon in WWII which aimed to use trained pigeons to guide bombs. (Capshew, 1993)

## Birth Control

A cell tower-like transmitter produces an EM signal that causes the motor-actuators in the tails of sperm cells to lose efficiency. Numerous cell towers in a given region known to be heavily populated with a certain ethnic group are secretly altered to produce this signal. Birthrates of the targeted ethnic group are depressed compared to surrounding regions.

- Scale Shifting Effects
  - Embryogenesis. In this case the fate of individual motor enzymes prevents the complex dance that leads to one cell becoming an entire independent organism.
- Offense/Misuse
  - *Class of actor*: As this involves large scale infrastructure as part of its delivery mechanism, only large interests with extensive resources to support covert access to national infrastructure projects would be able to achieve this. Notably an exception to this would be a fifth column infiltration by a terrorist group into a nation's legitimate infrastructure maintenance capabilities.
  - Ethnic and genetic cleansing.
  - Agricultural targets. One can imagine a highly tuned version of this that only affects the sperm of certain species.
- Countermeasures
  - Jamming?
  - Shielding is barely conceivable in this case.
  - Detection/Attribution would be especially effective in this scenario as the signal, once detected, is based on large scale equipment (cell towers) that can then be inspected in detail offering potential for large amounts of perpetrator data to be derived.
  - For rapidly reproducing species selection pressure may cause mutations in motor-actuators, making the method lose efficacy.

- Near Precedents & Uniqueness:
  - Human contraception
  - Antimicrobial: If the flagella of a sperm can be deactivated, so to, likely could the flagella of a germ. (Would require some safety concerns however as there are plenty of commensal and symbiotic organisms with flagella).
  - Wildlife management.
- Near Precedents & Uniqueness:
  - Some forms of genocidal racism have focused upon selective birth control.

## Insect Control

Insect control via a fixed emplacements of olfactory-scrambling or emitters that lure or repulse insects from defined locations. Insect populations in turn have strong effects on ecosystems, agriculture, and human health. A hidden system to attract certain mosquito species can increase disease transmission in an area, a system that deters pollinators can reduce agricultural efficiency. More subtly, changing the species composition in an ecosystem may affect its overall trajectory in complex ways, e.g. removing a keystone species, luring in insectivores.

- Scale Shifting Effects
  - Sensation of insects. Individual molecular events in small number can trigger neurons, that in turn trigger pre-defined sensations and reactions at the organism level.
  - Social Behavior of Insects. Social dynamics can magnify the behaviors of small numbers of individuals to many.
- Offense/Misuse
  - *Class of actor*: Because of the large areas and large amounts of equipment that must be used, distributed, and hidden, this scenario actor is likely limited to nation-state actors or the very largest commercial interests.
  - Potentially species specific
    - Pollinator control
    - Disease vector control
    - Property damage: Termites.
- Countermeasures
  - Detection/Attribution. Shifts in insect behavior are easily noticeable, and the signal would have to be powerful enough to affect large areas to be practical. These two facts make detection and attribution of a malactors signal-generator to be very probable.
- Defense/Productive Use

- Pollinator control
- Pesticide replacement
- Disease vector control
- Prevent property damage
- Near Precedents & Uniqueness:
  - Disease vector control has been used offensively at least one time in War. The Germans in WWII flooded the Pontine marshes to reintroduce Malaria to the region(Geissler & Guillemin, 2010).
  - There are a number of mosquito repellent lights and ultrasonic systems. The principal uniqueness of this as a weapon comes from the potential to variably control the insect behavior with time and space. However eusocial insects such as termites may require a very complex manipulation scheme that treats the entire colony as a single organism. This creates a non-trivial barrier of sophistication to developing such weapons.
  - Chemical insect controls, whether by insecticide or pheromones, are already in widespread use.

## Germination Control

Many plants distribute seeds far and wide that remain dormant until a given signal is detected, often that signal is fire. Take a stretch of lawn in the US plain states and burn it, and you will see the following weeks and months a wide variety of prairie plants grow in response to the burn. Therefore the prairie seeds sense the fire and activate. Similarly most plants must detect a certain amount of water prior to starting the germination process. Such a sensation/detection mechanism might be activated or inhibited independent of the presence of fire or water via a Quantum Biological Actuator.

- Scale Shifting Effects
  - Plant embryogenesis. A seed is an arrested plant embryo waiting for a trigger to germinate. Here a small number of cellular sensors trigger the de-arrest the development of whole organism.
- Offense/Misuse
  - *Class of actor*: Because of the large areas and large amounts of equipment that must be used, distributed, and hidden, this scenario actor is likely limited to nation-state actors or the very largest commercial interests.
  - Direct Agricultural attack... Inhibit crop germination
  - Indirect Agricultural attack... Distribute toxic weed plant seeds throughout the agricultural land of an opponent which are in a quiescent state that will not

germinate on its own. Then activate in a coordinated and targeted manner with a quantum mechanism.

- Countermeasures
  - Detection/Attribution: Similar to the Insect Control scenario, to be effective a large area would need to be exposed to the EM field, and thus making the intervention likely to be detected and making stealth the weak point of this attack scenario.
- Defense/Productive Use
  - Herbicide replacement if it can be tuned narrowly enough.
  - Tighter control of staggered planting intensive multi-harvest agricultural systems--> Tighter control results in yield improvements and reductions in equipment overhead.
- Near Precedents & Uniqueness:
  - Control of plants have been used in conjunction with warfare before. For example: Agent Orange.
  - It is likely that such germination control systems that are based upon quantum biological sensors exist in some plants. However, quantum biological sensors make sense, evolutionarily speaking, when the actions that the sensor mediates are taken very very quickly and the sensor is responding to a fleeting signal. The faster the action needs to be and the weaker the signal triggering it is, the more selective advantage there is in a hyper sensitive detector. As most plant responses are much slower than animal responses, there is more signal to gather within the response time of the action and thus less advantage in quantum biological sensing unless the noise in the signal is extremely high. As such, the unique value of a quantum biologically mediated herbicidal agent likely is dependent upon genetically engineering the plant to have the response in the first place. This means such applications of quantum biology would likely be developed relatively late.

## THz Binding and Tunneling Control

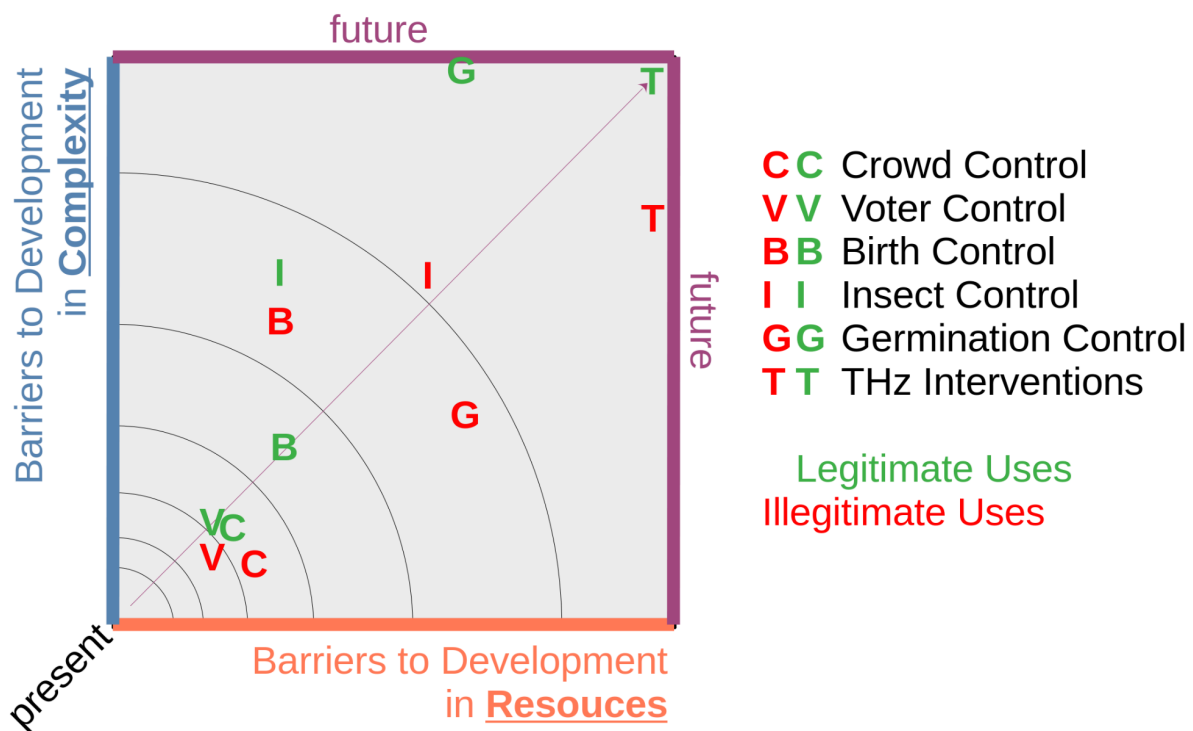
It has been suggested that radiation in the THz range could lead to manipulation of the relative stability of binding pockets and thus control quantum tunneling mediated effects. This of course includes numerous known electron and proton tunneling effects in biology. If so targeted mutations at range might be possible as well as mediation of any number of pH gradient dependent effects, and metabolism associated with NADP and NADPH.

- Scale Shifting Effects

- Ecosystem dynamics? Metabolism on an ecosystem scale might be possible to manipulate with proton tunneling since proton pumps are so integral to biological energy harvesting.
- Offense/Misuse:
  - *Class of actor*: Because THz technology is still in its infancy, it is impossible to know what resources will be used to manipulate this frequency range, nor how accessible they will be to different classes of actor.
  - It is hard to know what the threat and legitimate or illegitimate use scenarios would be in these cases because of the relatively undeveloped nature of THz technology and associated uncertainty of what biological effects might be sensitive to it.
  - Because of the lack of naturally occurring THz resonating materials, there is the potential for radiation in that band to be broadly dangerous without humans having previously noted it and without evolution buffering biological sensitivities.
- Countermeasures
  - Jamming?
  - Shielding?
  - Detection/Attribution?
- Defense/Productive Use
  - If proton electron tunneling can be manipulated in a biological setting, then the potential for biotechnology is massive as this would open up many biosynthesis options for complex molecules.
- Near Precedents & Uniqueness:
  - The “THz gap” is the reason that THz frequency bands are typically not used. (Lee, 2012) That “THz gap” refers to the lack of naturally occurring or inexpensive synthetic materials that resonate in the THz frequency range. Recent advances in semi-metals however are promising to open up affordable THz emitters although it is likely that the technology will still take some time to mature.

Broadly, the scenarios above speculate on scale-shifting effects that might incorporate quantum biological phenomena and which, if those phenomena might be manipulated with a suitable E signal, would allow for effects that are in excess of those achievable by guns, bombs, and poisons. Below in Figure 3, we have offered our subjective ranking of the feasibility of both the legitimate uses and misuses of the capabilities represented in each scenario. For an individual breakdown of why each scenario is placed in the feasibility map as it is, refer to the Near Precedents & Uniqueness sections of the respective scenarios.

Figure 3. Feasibility Map of Quantum Biological Scenarios



Psychological Control is deliberately left out of Figure 3 as it represents no difference in feasibility from Crowd Control, and is rather a difference in motivation of the actor and their scope of operations.

## Low Concern Scenarios

A number of scenarios were considered that were discarded because they did not seem feasible in anything like the foreseeable future. A few of them are briefly listed here to elucidate the process by which the selected scenarios were included for further refinement.

### The Chirality Bomb:

Would it be possible to induce quantum tunneling of organic molecule chiral centers through a suitable signal, so as to sabotage metabolism?

While energetically allowed (enantiomers typically have the same energy), the tunneling probability scales like  $\exp(-C\sqrt{mE}d)$  where  $m$  is the mass,  $E$  the barrier height and  $d$  the tunneling distance. Since  $m$  is several thousand times larger than for electrons even for light R groups, any enhancement of tunneling probability either requires reducing  $E$  directly



(requiring a large amount of energy per kilogram of target) or an implausibly large enhancement of the rate.

Also, the application of this idea would be hopelessly complex. If such an EM signal could be developed it would almost certainly have to be narrowly tuned to a very specific organic chiral center. (Each organic chiral center is a carbon atom with four different 'R groups' covalently bound to it.) While there are many chiral centers in the molecules of a living cell, they are distributed between millions of in different combinations of R groups. Further, The exact intensity of the EM signal and orientation of the affected chiral center to the signal's polarization, and vector of travel would also need to be perfectly correct. Thus any hope of such a chirality bomb would require the victim to stand perfectly still inside a waveguide as they were bombarded with narrowly tuned EM fields from multiple angles and even then only affecting a tiny fraction the chiral centers in their body. And even after all of that, it would do nothing more than poison the victim.

As an extremely precise form of anti-cancer radiation therapy, this might, if possible, eventually be useful, but as a threat agent, there are easier ways to poison someone.

## Projected Cancer

Carcinogenesis, like embryogenesis, carcinogenesis individual molecular events, typically mutations, leading to whole-organism affecting syndromes. In rare cases cancers are even contagious leading to population wide events. If mutations could be targeted to specific genes or sequences with any likelihood of precision then this would be a compelling threat scenario. However, it seems very unlikely that this would be possible. That means that the quantum biological mutation induction potential is almost certainly random, if it exists at all, and thus no different from high energy beta particles or any number of chemical mutagens that already exist.

## Gene Expression Control

While the RNA and DNA polymerases and Ribosomes are general enzymes that likely can not be targeted with any degree of fine control for just certain genes (like trying to alter driving destinations by altering the gearing ratio of a car), these enzymes are truly large complexes of enzymes some of which are only intermittently active or relevant on a gene by gene basis. For example transcription factors are highly variable across all genes and are to some degree associated with complex coordinated genetic programs. Thus an EM signal utilizing a quantum biological actuation of the activity of a specific transcription factor, might represent the capability to turn on or off such a genetic program. Whether or not this represents a threat of

concern is strictly a function of the genetic program in question however, and must be considered on a case by case basis. In most cases, such genetic programs contribute to the traits and behaviors of a biological system via additive accumulative effects, not scale-shifting effects and so while the potential for gene regulatory control by such a mechanism is compelling for any number of legitimate uses, it would be heavily defense dominant requiring ongoing, intensive, and overt exposure to the modulating signal.

### Photosynthetic efficiency manipulation:

One could imagine using EM signals to artificially add noise to photosynthetic quantum processes, reducing the efficiency and possibly harming chloroplasts. Essentially like a quantum agent orange. Due to conservation of photosynthetic biology, this is, if possible, likely not very species specific. If it matters as a threat, it matters only if it can be applied at extreme long ranges, such as from a satellite or airborne platform. Also estimates of how much of the efficiency of photosynthesis is a consequence of quantum effects are diverse and sometimes quite low. It is quite conceivable that even if possible, it would only marginally have any effect.

### Quantum privacy:

Another possibility is that there exists quantum states in biology that contain sensitive information that might be possible to read out. This mostly relates to mental privacy, assuming brain states either employ quantum states or are linked to them in ways that make a quantum readout somehow more feasible than a classical readout. This possibility was discounted for the purpose of this report because: (1) it is unlikely that one could read out information states of the brain more easily or more precisely with any near-term quantum biology based mechanism than one might gain the same brain state information from an fMRI machine.(Norman et al., 2006) (2) Also, in any event, the limiting factor for such an application is not detecting the state of a brain, but rather understanding of the underlying signal concerning how the brain is organized and active to the point of being able to decode what is taking place in the corresponding mind.

# Conclusions And Discussion

None of the scenarios described above exceed the capabilities of guns, bombs and poisons *quantitatively*. So long as the terminal goal of the malactor is to kill or sicken their targets, we do not see manipulation of quantum biological phenomena as creating an unprecedented or compelling threat. There are simply many easier, cheaper, and faster ways to kill or sicken one or many targets at a wide variety of ranges and a wide variety of degrees of stealth, timing, and precision. Nonetheless, there *are* threat scenarios that are compelling (assuming the underlying assumptions that the quantum biological process exists and is manipulatable by EM fields is correct). This is because of the potential to do *qualitatively* different things from guns, bombs and poisons.

These scenarios possess commonalities that seem to define all of the probable threat landscape of Quantum Biology, particularly those threats judged to be relatively feasible, are four properties:

1. **Most importantly, there is a requirement that stealth in application of the EM field be achieved for all of these threat scenarios to be successful.**
2. Potential to trigger pre-existing behaviors patterns such as instincts, reflexes, germination, etc. is core to these threat scenarios.
3. Potential for fine scale targeting of who or what is affected, and simultaneously who or what is *not* affected. This potential, when present, is often guided by very complex behaviors or properties of the target itself.
4. Assuming the threat is feasible, for each scenario, an approximately equal or more feasible legitimate use of the scenario's underlying quantum biological effect and intervention is also possible. That is, nothing about Quantum Biology seems to be intrinsically offense dominant (Biddle, 2001), at least no more than any other biological research field.

Let us consider why the four common properties exist for feasible quantum biological threat scenarios. They are not simply a product of the assumptions that went into the scenario's formulation, but rather a result of several facts intrinsic to the problem of intervening with electromagnetic waves upon the dynamics of existing quantum biological processes.

- EM waves are widely and commonly used with extensive amounts of common and powerful equipment to do so already in existence.
- EM's interactions with biological systems include numerous idiosyncratic and non-linear effects influencing the efficacy of different intensity and frequency ranges.

- The nature of the scale-shifting effects in biology makes for triggering a pre-existing behavior such as germination or the fight-or-flight response, or similar things much more plausible than more plastic control.

The result is that the threat scenarios emphasize stealthy applications of EM fields to achieve subtle but sophisticated and selective effects meant to impinge on their targets in narrowly precise ways towards defined goals while simultaneously leaving other proximal targets unaffected.

The importance of stealth is particularly noteworthy. In most of these scenarios, if the malactor's intervention EM signal is detected for what it is during or shortly after the attack, the effectiveness of the attack drops dramatically. This implies a paradigm for further skewing the application of quantum biology leveraging technologies to a productive-use, defense dominant paradigm: As was noted above, extensive amounts of common and powerful EM equipment already exist. While this equipment's transmission capability is the basis of the attack forms that the scenarios explore, the same equipment *also includes detection capability*. Potentially every smartphone, every car radio, every bluetooth enabled device, could with nothing more than a software patch, become a detector that could alert either its user or a central clearing house run by legitimate authorities about the use of a recognized or potential quantum biology interacting signal. Once ubiquitous detection capability exists, the potential for attribution of these signals also exists, and that in turn even further moves the technology towards defense dominance, as has happened in biotechnology before. (Lewis et al., 2020) Notably, detection and attribution inhibit offense and misuse, but do not inhibit legitimate and productive uses.

There is the potential for detection based mitigation of quantum biological threats, insofar as they exist, to be accidentally sabotaged by misguided good intentions if the nature of quantum biological threat signals is *not distributed* to potential defenders in an attempt to prevent the dissemination of information hazards. This is because detection would have to be done locally on devices that are also the receivers of the signal. That is, one can not leverage a secure centralized database for detection of these signals because one can not assume an attack would happen in the presence of network connections that would facilitate interacting with that database. Further, even if such a connection can normally be assumed, the attacker would by definition already have advanced EM signal generating capability so interfere with connections to the network in general or specifically to central authorities during the attack must be assumed as part of any such attack. Therefore, similar to virus checkers, threat definitions would have to function by distributing continuously updated threat definitions to end users for local detection and analysis of threats. While distributing those threat definitions would distribute some capacity to use them maliciously, the mitigating ability to detect their use

dominates over the hazard from information dispersal since detection, for all feasible threats, is mitigation of those threats. So even if distributing threat definitions makes attacks easier, more mitigated attacks is a less dangerous circumstance than fewer unmitigated ones. Further, because distributed definitions is a mitigation approach that is so easy to achieve, it reduces the motivation to attack with quantum biological mechanisms in the first place likely reducing the number of attacks far more than marginally increasing their ease increases their number. Thus, anyone who would be enabled by the dispersal of threat definitions would also be aware of the threat definitions and deterred; anyone not aware of the definition's dispersal, would be mitigated by the definition's dispersal.

This report was requested explicitly to explore the threat landscape of quantum biology, but it would be remiss to suggest that the threats of developing the field of quantum biology are or should be the dominant narrative. The opportunities that exist in this field are much more compelling than the threats! It is the belief of the authors that quantum biology is a field worth exploring.<sup>1</sup>

**Special thanks to:** Dr. Shontelle MacQueen for her insights on operant conditioning and implications that has for Quantum Biological threat models.

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<sup>1</sup> The authors of this report are aware that certain conspiracy theorists may find this report and try to use it to promote their agendas. They may say things like "See 5G really is mind control, or causes sterility, or rigs elections, or poisons crops!". This, or similar findings, is **not** what this report concludes. Indeed, we concluded that the potential for such threats is currently non-existent given the present undeveloped state of quantum biology, will be minimal after quantum biology is further developed, and even then such threats will be easily mitigated with fairly trivial detection capabilities. This footnote is here solely to provide an easily quotable way to prove that such alarmists have not actually read and understood this report.

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