SEPTEMBER 2021

BIOLOGY NEWSLETTER

Welcome, welcome!! For those of you joining the bio newsletter readership - prepare yourself, and for those of you who have returned dragging your feet - here's the latest edition of the newsletter to get you up and running ready to get right back into life at camp hill. If you have any questions, or would like to contribute an article, please feel free to drop me an email!

Enjoy!

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Now that I’ve lured you in with a cute robin - let's get into it: If chemistry is basically applied physics, and biology is applied chemistry… Why haven’t we done a newsletter on quantum biology yet???

This time I can't give you a 'quick summary', since although quantum theory describes the universe at a miniscule level, the amount of content it covers is certainly not. Essentially, we use quantum theory to describe things that classical physics like Newton's laws of motion just aren’t able to. Newton’s laws can be used in certain situations, as long as you know all of the things that have an effect on an object - for example air resistance and gravity etc on a skydiver). Only then are you able to predict the object’s subsequent motion.

In the quantum realm, things are slightly different. A quantum object’s position or speed exists as many different probabilities - that is until you measure it. The moment you measure its speed or location, those values become discrete. Evidently, this property means that our standard ways of thinking about biological processes are quite simplified and don’t really look at the whole picture. Electrons and chemical bonds and charges are generally best described by quantum theory, and since many of the biological processes around us rely on these, it’s a good idea to use these laws to more accurately describe what goes on.

I have tried to keep it brief, but as said above, so much of biology is underpinned by physics, and many things can currently only be explained using quantum theory. Aren’t we lucky!

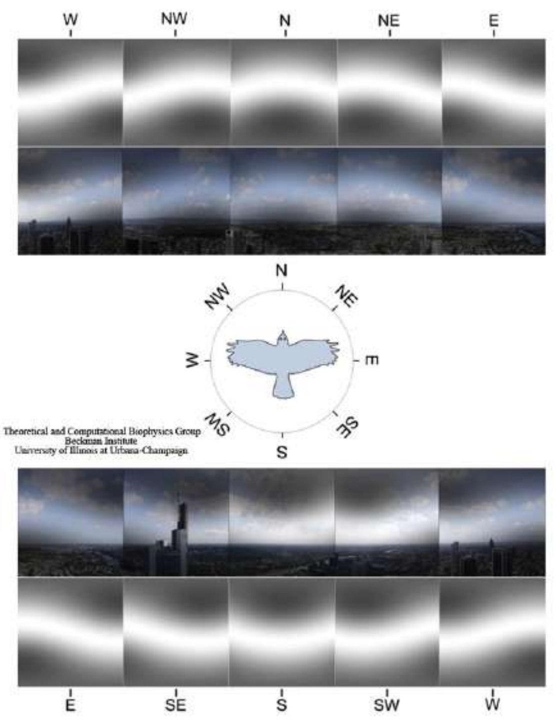
The travels of the robin

One of the perhaps most easily recognisable birds in the UK is the adult European robin. Each year these seasonal migrants can travel from the very north of Sweden down to the south of Spain, covering 200 miles in 1 day (Johnjoe Mcfadden and Al-Khalili, 2016). But without google maps, how do they not get lost?

One speculation is that they use a phenomenon called magnetoreception, which works kind of like a compass. The overall idea is that a magnetic field induces a chemical reaction in the bird, which then results in a biological response telling the robin which way is up and which is down. Many scientists had an issue with this line of thinking when it was first introduced, because individual molecules are only weakly magnetic, and so interact very minimally with a magnetic field as small as the Earth's. However, in certain situations, small energies can have large effects on a system. Imagine placing a book on a table. Would a fly landing on this be able to tip it over? Presumably not. If we were to then balance the book on its corner, being unstable, eventually it would wall over by itself. If a fly now lands on, say, the right side, the book might fall to the right. So even if the actual energy of the fly is tiny, as the system is not in equilibrium (aka not stable), it can still have a large effect.

To have a similar effect in a chemical sense, we need to first give molecules energy to revert them into a non-equilibrium state. This makes it possible for tiny quantities of magnetic energy to force these molecules into a chemical reaction (our tiny fly forcing the book to fall over). In our case, the book represents a molecule. When a molecule absorbs energy like a photon, the bond may break. Within the bond, an electron pair may split apart, creating 2 molecules with an odd number of electrons. These are called radicals, and are inherently unstable. The property of their electrons that we'll focus on is a little something called 'spin'. Spin is a quantum mechanical property of subatomic particles which makes them magnetic. They can exist in 2 states, or orientations, which have almost identical energy and so can be converted into each other with a little energy input, like one from the Earth's magnetic field. Each form of the radicals results in different reactions, so when a magnetic field interferes with their orientation, it can alter the probability of the radicals following one reaction pathway over another. In our example this refers to nudging the book to the left or the right - if you push it to the left you increase the probability of it falling to that side.

In this way, if the bird were able to measure changes in the yield of a biochemical reaction, it could generate a signal that would allow it to interpret the inclination of the magnetic field lines in space. The magnetic field lines emerge vertically from the magnetic South pole, and re enter vertically in the magnetic Northpole. They encircle the Earth, and lie completely parallel to the earth's surface near the geographical equator. Thus, by identifying how vertical or horizontal these lines are, the birds are able to tell apart the equator and the poles, making it easier to know in which direction to fly come seasonal changes.



Cryptochrome, a pigment in the bird’s retina, has been found to produce the radicals needed. Due to the location it was found in, we can infer that magnetoreception is reliant on certain wavelengths of light entering the eye - blue and green seem to be the best for birds. Radicals are formed via a series of electron transport proteins, and depending on the influence of the magnetic field, a reaction takes place. One theory is that these products affect the sensitivity of light receptors, resulting in lighter or darker regions in the bird's point of view that correspond to the direction of the field lines (Wiltschko, Nießner and Wiltschko, 2021).

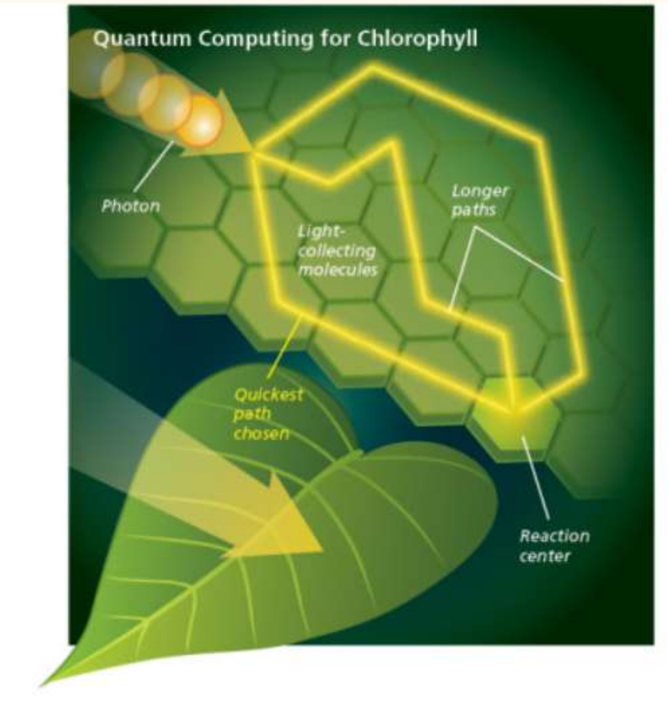
On top of this, there is also the possibility that quantum entanglement plays a role. This is the idea that groups of particles can be connected, even across far distances, and can also “communicate” with each other. This means that we can’t describe one of these particles without also talking about the state of the other. When using this to talk about avian magnetoreception, we can say that as these 2 particles are linked, we can view both at the same time. This may mean that birds are able to see their surroundings and the magnetic field at the same time, and use both simultaneously as a navigation aid (Vitascientific.com, 2016).

There are a couple of other ideas, such as birds having magnetite particles within their head that measure the intensity of the magnetic field, since this varies depending on distance from the poles, but we won’t go too far into that. Even if you did feel tempted to migrate away from this article, I think I’ve provided you with ample methods to safely do so. Worst case scenario - just whip out your phone!

Extra reading (if you really want to get into the nitty gritty of triplet and singlet electron spin states!): http://hore.chem.ox.ac.uk/PDFs/The_Quantum_Robin.pdf

Photosynthesis

Although the overall efficiency of photosynthesis is only a few percent (not all sunlight is absorbed and not all energy is used to synthesise biomass) the actual process of collecting the light is nearly totally efficient, at around 95%. This has been thought to be due to a quantum property called superposition - basically the ability of particles to be in multiple places at once (well, technically they are nowhere at all until you measure their position, at which point they randomly settle into a spot). While you probably couldn't use this to be in school and in bed at the same time, for photosynthetic organisms it could be incredibly useful. Many plants, because of their pigments, tend to absorb blue and red light, and reflect the green - which is why so much of England used to be this colour. Therefore, since the wavelengths of light varies over the day, collecting light this way should be quite hit and miss. Previously, biologists had assumed that the collected light energy was guided via antenna pigments along one of many possible pathways to locations where synthesis reactions took place (Merali, 2014). As this wouldn't always be the fastest route, the efficacy should drop. However, in a superposition state, the energy can travel along all of the different molecular pathways simultaneously to find the optimal energy transfer pathway. Once it has, the energy would stop being in this multifaceted state and just go down the fastest route.



If only I could apply this quantum property to my maths revision - maybe then the transfer of information into my brain would be slightly more efficient…

Photo time!

And as a little bonus to give our frazzled brains a break: here are the Astronomy Photographer of the Year Awards, courtesy of NewScientist - and to use their pun: aren't they out of this world ;). And if you're needing ideas for an article - astrobiology anyone??

Reference list

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Wiltschko, R., Nießner, C. and Wiltschko, W. (2021). The Magnetic Compass of Birds: The Role of Cryptochrome. *Frontiers in Physiology*, 12. doi:10.3389/fphys.2021.667000.