Hi this is Steve Nerlich from Cheap Astronomy www.cheapastro.com and this is *Alien Biology. The case for carbon.*

This the second of two podcasts on the possibilities of extraterrestrial intelligence.

In the first part of this series we looked at the different biochemistries that might plausibly support life and more specifically, a complex ecosystem that might support intelligent aliens. We found that it's at least very likely that are you going to need a chemical solvent to get anything biochemical happening - and although it sounds like Earthly parochialism... as chemical solvents go - water is pretty darn ubiquitous and pretty darn versatile.

But a solvent is just the test tube in which things might happen. If you want biochemistry you need solutes as well. From what we know of Earth history – it's likely the early atmosphere was predominantly carbon dioxide and nitrogen and there was lots of liquid water on the surface as well as within the Earth's crust (remembering that life could have started underground).

We should also consider inputs from space – like the Murchison meteorite which crash-landed in Australia - and was found to have forms of amino acids - the basis of proteins and forms of nucleotides, the basis of DNA and RNA. In a laboratory setting we have also zapped a primitive Earth atmosphere with lightning – which is a useful way of getting nitrogen engaged in biochemistry, because nitrogen tends to need a lot of heat to form compounds. Anyway, within these laboratory experiments, including the Miller Urey experiment, it's possible to generate amino acids and nucleotides - as well as things like carboxylic acid - a key component of our metabolic energy production.

Now, all this means is that the chemical constituents of life on Earth could have either originated spontaneously on Earth or could have been delivered by meteors and comets – and really this distinction isn't that important when you remember that Earth formed out of the accretion disk that built the solar system – so any asteroids or comets are just left-overs that didn't accrete into planets earlier.

Anyhow, we tend to focus on DNA as the basis of life – via its ability to provide a code for building proteins – but what DNA mainly does is code for discrete RNA strands and it's those RNA strands that really code for proteins - and in the case of ribosomal RNA actually build those proteins.

So there is an idea called the RNA world hypothesis that proposes that the first biochemistry on Earth was composed of molecules that made copies of themselves. When you look at the fundemental building blocks of DNA and RNA - the nucleotides, you find the nucleotide cytosine will only bind with Guanine – and Guanine will only bind with cytosine - and adenine will only bind to uracil (or thymine in DNA). This means a random line of nucleotides in the order AGCU – create a template to bind together a partner chain of UCGA – and once formed that UCGA chain will bind another AGCU chain. So you end up with lots of AGCUs and UCGAs which steadily bind up any free As, Cs, Gs and Us from the remaining population of unchained components. So, this becomes a competitive environment favouring the survival of molecules which are the most efficient at binding free nucleotides - hence creating more copies of themselves.

While that makes a certain amount of sense – we do find these reactions in life today being mediated by enzymes – which make reactions happen much quicker, generally via the expenditure of chemical energy. So, it's possible that life might have begun passively and excruciatingly slowly - as very occasionally one molecule bumped into another molecule and if it happened to be the right type of molecule that was able to form a chemical bond then maybe sometimes they did and... well, it doesn't make for an altogether convincing story really. What's missing is that chemical energy that could really get things moving.

So there is another hypothesis – metabolism world, where the first biochemistry wasn't a replicating chemistry, but an energy-fixation chemistry. While it's true that the Sun provides a nett input of energy for life – there's has to be way to fix that solar energy into chemical energy if you are going to support a complex biochemistry.

Something fundamental to life on Earth today is that you can combine carbon dioxide and water - and get a carbohydrate. And forget about those free nucleotides, it's carbohydrates that life on Earth today really hungers for. Energy, it seems, is key. Carbohydrates are like little chemical batteries - stable in a chemical solvent like water, but if you have a way to break the carbohydrate back down into carbon dioxide and water, a bit of energy becomes available.

Metabolism world might have arisen from some random carbohydrate forming in liquid water – which then supported a community of metabolising prebiotic compounds that broke that carbohydrate back down to CO_2 and H_2O. And of course, in that situation any free carbohydrate becomes a limited resource - so you have a competitive environment favouring systems that could break down carbohydrate more efficiently - and at some point presumably an enterprising prebiotic stumbled upon a way to make its own carbohydrate. This might have been the first photosynthesising system - or it might have been a system that used geothermal energy. Either way, once you can create your own carbohydrate the competition is yours - at least until something learns that another rich source of carbohydrate is available by - well… eating you.

What's intriguing about life on Earth today is that the organisms that make their own cabohydrate, like plants, and the organisms that steal that carbohydrate, like animals, - all carry the same replication system based on RNA and DNA. And so this is the ultimate end of the question of what came first - the chicken or the egg?

It could have been an animal system feasting on rare but somehow spontaneously produced carbohydrate with a population of them later learning how to make the carbohydrate themselves - or the first thing could have been a system of plant-like chemicals which first encouraged the formation of carbohydrate without initially realising its potential as an energy source. And either way - the question remains as to whether either of these systems were already replicating, or is this a trick that they picked up later.

In any case, lots of clever folk have suggested a range of small scale biochemistries of this nature, that might persist with or without carbon. However, it's also the case that the structure of organisms that can reach any substantial size, complexity and hence presumably intelligence - will have to use polymers – which are large molecular structures, built up from the joining together of smaller units.

On Earth, we have proteins built from amino acids, DNA built from nucleotides and deoxyribose sugars – as well as various polysaccharides (for example cellulose or glycogen) which are built up from simple sugars. Armed only with a microscopic biochemical machinery capable of building these small units and then linking them together – you can make organisms on the scale of blue whales.

Carbon is extremely versatile at linking together other elements – indeed it's able to form more compounds than any other element we have ever observed. It is more universally abundant that the next best polymer maker, silicon – and it's worth considering that on Earth, silicon is unusually 900 times more abundant than carbon – but still ends up having minimal engagement in Earth biochemistry. Boron is also pretty good at building polymers, but is a relatively rare element in the universe.

So, in the absence of further data points - that is, the opportunity to study an alien life form, it does seem reasonable to assume that if we do meet a macroscopic alien life form – with a structural integrity sufficient to enable us to shake hands – that life form is at least, statistically likely, to have a primarily carbon-based structure.

But then we can probably be confident that aliens won't have hands. It might be more polite to offer to replenish their solvents via some Goldilocks zone heated water with an interesting carbon, nitrogen, oxygen alkaloid mixed – something we call coffee.

Thanks for listening. This is Steve Nerlich from Cheap Astronomy, www.cheapastro.com. Cheap Astronomy offers an educational website where the whole history of life on Earth can be readily extrapolated from a fairy cake and a glass of lemonade. No ads, no profit, just good science. Bye.