

FROM QUARKS TO CONSCIOUSNESS

27 Big Questions

A first journey through the Universe, Earth, life, and how we find things out

For curious readers aged 9 to 12

Educational adaptation v1.0. English edition of a bilingual companion volume. DOI: 10.5281/zenodo.22337865.

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Welcome. The world is full of clues. Light from a star, a rock from a mountain, a tiny cell, and a pattern in a fossil can all help us discover something. You do not need to know every difficult word before you begin. You need to notice, ask, compare, and keep a good question when the answer is not ready yet.

Twenty-seven doors

This book has twenty-seven chapters. Some begin in the sky, some in the ground beneath our feet, and some inside living things. Together they tell one long story: how the Universe changed, how Earth changed, how life changed, and how people learned to look for evidence.

You do not have to read everything in one go. Open a chapter that catches your attention. Then use the index to find the next question that connects with it.

Clues are better than guesses

A good answer is not just a clever idea. It needs clues that can be checked. Scientists use instruments, careful measurements, comparisons, and sometimes more than one kind of evidence. A single clue can fool us. Several clues that agree can make an explanation much stronger.

You will see four useful kinds of sentence: things we know well; explanations that fit the evidence so far; questions scientists are still working on; and ideas that need more testing. Learning which is which is part of learning science.

Your job as a reader

Ask: What is the clue? How did someone find it? What does it show directly? What part is a careful conclusion? You can draw a picture, make a list of new words, or explain an idea to someone else. If a chapter leaves you with a new question, it has done something important.

Suggested routes

Signals and cosmic scale

QTC-001 to QTC-006: light, darkness, matter in stars, and measurement across distance.

Earth, life, and change

QTC-007 to QTC-010: deep time, gradients, the meaning of life, variation and selection.

The early Universe and a forming planet

QTC-011 to QTC-020: ancient light, the Big Bang, early matter, unseen stars, planets, dating, climate, and prebiotic chemistry.

Living systems and inheritance

QTC-021 to QTC-027: evolving chemistry, first cells, LUCA, microbial worlds, rock records, cellular mergers, and information across generations.

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The 27 questions

QTC-001 What Are We Seeing When We Look into Space?

Source article: QTC-001 — Everything You See Is the Past

The big question: When we look at the Moon, a star, or a faraway galaxy, are we seeing it exactly as it is right now?

A short answer: No. Light needs time to travel. Moonlight takes a little more than one second to reach us. Light from the Andromeda Galaxy takes about two and a half million years. Looking far into space is like opening a book whose pages were written at different times.

The clue: In 1676, Ole Rømer noticed that eclipses of one of Jupiter's moons did not arrive at the same time all year. The change made sense if light had a travel time. Today, scientists use clocks, distances and telescopes to work out what a received signal can tell them.

Think like a scientist: Imagine that every photograph from a friend arrives late. What would you need to know before deciding what your friend is doing now? How is a telescope like receiving a late photograph?

Remember: A telescope receives light, not the object itself. At the greatest distances, even correcting travel time does not give everyone in the Universe one shared "now."

QTC-002 Why Is the Night Sky Dark?

Source article: QTC-002 — Why Is the Night Sky Dark?

The big question: If there are so many stars, why is most of the night sky black instead of bright?

A short answer: The stars have not been shining forever. The Universe has a history, and there has not been enough time for starlight to fill every direction. Expansion also stretches and dims some old light, but time is the main clue.

The clue: Imagine an endless forest with a glowing tree in every direction. In a universe that had always been full of shining stars, your eyes should eventually meet a star wherever you looked. Our dark sky tells us that this picture cannot be right.

Think like a scientist: Cover a page with small bright dots. Then leave some empty space between them. Which page is more like the night sky? What would change if stars had been shining forever?

Remember: Darkness is not empty. It is evidence that stars and galaxies have a finite history.

QTC-003 Why Does a Table Feel Solid?

Source article: QTC-003 — Why Are Solid Things Solid?

The big question: Why does your hand stop when you press it against a table, even though atoms are extremely small?

A short answer: Atoms do not work like tiny hard balls bumping together. The electrons in your hand and the table interact. Pushing them closer takes energy, so the table pushes back. Many tiny interactions together make a solid feel firm.

The clue: Try pressing a sponge and then a wooden table. Both are made of atoms, but their atoms are arranged differently and can move by different amounts. Scientists use electricity and quantum rules to explain why matter can resist squeezing, bending and sliding.

Think like a scientist: Press gently on a sponge, a book and a cushion. Which changes shape most? What does that tell you about how their materials respond to a push?

Remember: Solidity is a shared effect of huge numbers of particles and their interactions. It is not a hidden hard shell inside each atom.

QTC-004 How Did Star Stuff Get into Your Body?

Source article: QTC-004 — Where Were the Atoms in Your Body Made?

The big question: Where did the atoms in your body come from before they became part of you?

A short answer: They have more than one story. Much of the hydrogen began soon after the Big Bang. Carbon and oxygen were made later in stars. Other elements came from different kinds of stellar events and were mixed together before the Solar System formed.

The clue: Counting gives different answers. By number, hydrogen is the most common atom in a typical body. By mass, oxygen and carbon matter more. This is why scientists use careful measurements before saying what the body is mostly made of.

Think like a scientist: Make two lists: things that are common by number and things that are heavy. Why might the winner change when you count objects instead of weighing them?

Remember: We can trace broad cosmic routes for the elements, but we usually cannot point to one exact ancient star and say that one atom in you came from it. Some element histories are still being worked out.

QTC-005 How Can Starlight Tell Us What Is Inside a Star?

Source article: QTC-005 — How Do We Know What Stars Are Made Of?

The big question: How can scientists learn about a star when they cannot take a piece of it into a laboratory?

A short answer: They study its light. Atoms can absorb or give off particular colours of light. A spectrum spreads starlight into its colours, and the pattern gives clues about which chemical elements may be there.

The clue: A line in a spectrum is not a simple label that says exactly how much of an element a star contains. Temperature, pressure and the state of the atoms can change the line too. Scientists compare observations, laboratory results and models before drawing a conclusion.

Think like a scientist: Imagine that two drinks look the same colour but one is hot and one is cold. Would colour alone tell you everything about them? How is that like reading a line in starlight?

Remember: Starlight gives strong evidence, not a physical sample. Even the Sun still gives scientists some measurements that do not yet fit together perfectly.

QTC-006 How Do We Know How Far Away a Star Is?

Source article: QTC-006 — How Far Away Is the Universe? The Cosmic Distance Ladder

The big question: How can we measure the distance to a star or galaxy when we cannot travel there?

A short answer: Astronomers use several measuring methods that support one another. A nearby star seems to shift a tiny bit as Earth goes around the Sun. Farther away, special stars and exploding stars become carefully checked distance markers. It is not one huge ruler. It is a chain of measurements.

The clue: Look at a nearby finger with one eye, then the other. It seems to move against the background. A nearby star does something similar as Earth moves around the Sun. This is called parallax. It gives a first distance scale. Scientists use that scale to check other methods that reach farther into space.

Think like a scientist: Hold up one finger and look at it first with one eye and then the other. Why does it seem to move? Why would a very distant star appear to move less than a nearby star?

Remember: These distance methods are good enough to reveal a real puzzle: two ways of estimating how fast the Universe expands still give different answers, and scientists do not yet know why.

QTC-007 How Do Rocks Tell Us How Old Earth Is?

Source article: QTC-007 — Deep Time

The big question: How can scientists learn about events that happened billions of years before people existed?

A short answer: Rocks keep clues about what happened first and what happened later. Some also contain atoms that change at known rates, like very slow clocks. Earth's age does not come from one special rock. It comes from many clues that agree, including meteorites and measurements of lead atoms.

The clue: A crack of melted rock that cuts through another rock must be younger than the rock it cuts. Fossils also appear in a meaningful order. These clues give an order before they give a date. Radioactive clocks add numbers, but scientists must check for contamination and for changes that could spoil a clock.

Think like a scientist: Put three books on a table. Slide a pencil through the top two. Which books were already there when the pencil was added? How is this like a younger rock cutting an older one?

Remember: Deep time is a reconstruction from several kinds of evidence. Carbon-14 can date recent things, but it cannot date the age of Earth.

QTC-008 How Do Cells Use Tiny Differences as Power?

Source article: QTC-008 — Life Runs on Gradients

The big question: How can a cell make useful energy from a difference across a very thin membrane?

A short answer: Cells move tiny charged particles, called ions, to one side of a membrane. This makes a difference, like water held behind a dam. When the particles return through a molecular machine, the cell can make ATP, a molecule it uses to connect energy to many jobs.

The clue: Scientists found that a cell's energy machines use membranes, differences in particles and voltage together. Later experiments and images showed parts of ATP synthase turning as ions passed through. Some organisms use sodium ions instead of protons.

Think like a scientist: Make a line of marbles at the top of a ramp. What happens when they roll down? What has to be present before the marbles can move?

Remember: A gradient is a useful difference that can power work. It is an energy source, not by itself a living system.

QTC-009 What Makes Something Alive?

Source article: QTC-009 — What Do We Actually Mean by Life?

The big question: Why can we recognise many living things but still disagree about some cases at the edges?

A short answer: Scientists agree that people, trees and cells are alive. But no single definition solves every difficult case. A definition can help us sort known things, explain how life is organised, or decide what to look for when searching somewhere new.

The clue: A mule can be unable to have babies and still be alive. A dry spore can seem inactive and later grow. A virus can change and evolve, but it needs a cell to make more viruses. One checklist does not settle every case.

Think like a scientist: Draw three circles labelled 'uses energy', 'has cells' and 'makes copies'. Where would you place a cat, a seed and a virus? Why does the diagram not give every answer by itself?

Remember: Water, organic molecules or an unusual signal are not proof of life on their own. First ask what question you are testing, then choose the evidence that could separate life from a convincing look-alike.

QTC-010 Do Living Things Change Because They Need To?

Source article: QTC-010 — Random Variation and a Filter

The big question: If an animal faces a problem, does its body make the change it needs?

A short answer: No. New inherited differences do not appear because they would solve a current problem. They arise through ordinary chemistry, which has patterns and biases. Over generations, some differences can become more common when they help descendants leave more offspring in that setting.

The clue: 'Random mutation' does not mean that every change is equally likely or that nothing has a cause. It means the change is not made because the organism knows what it needs. Natural selection is also not a plan, and it is not the only process that changes a population.

Think like a scientist: Imagine many paper airplanes with slightly different wing shapes. Test them in one breeze. Which shapes fly farther? Would the same shape always win in a different room?

Remember: Evolution can make useful adaptations without foresight or a goal. What works depends on the place and time, and evolution does not always mean progress.

QTC-011 Why Can't We See the Beginning With a Telescope?

Source article: QTC-011 — The Oldest Light We Can See

The big question: Why is the oldest light we can see not a picture of the very beginning of the Universe?

A short answer: Early in the Universe, free electrons kept bouncing light around, like a thick fog. About 380,000 years later, atoms formed and light could travel much more freely. That old light is still arriving from every direction today.

The clue: The cosmic microwave background is the oldest electromagnetic light we can observe across the whole sky. Scientists predicted that it should exist before it was detected. The first famous detection was one extra signal at one frequency; later measurements checked its full pattern much more carefully.

Think like a scientist: Shine a torch through clear water, then through cloudy water. When can you see farther? What would you need to know before calling a sky map a direct photograph?

Remember: The cosmic microwave background is strong evidence about an early stage of the Universe. It does not directly show the beginning, and scientists still use models to infer what came before it.

QTC-012 What Does the Big Bang Really Describe?

Source article: QTC-012 — What Do We Really Mean by the Big Bang?

The big question: Was the Big Bang an explosion from one point into empty space?

A short answer: No. The Big Bang describes a history in which the observable Universe was much hotter and denser and has been expanding. On very large scales, galaxies move apart because space changes; planets, atoms and people are still held together by their own forces.

The clue: Scientists do not rely on one picture or one word. They compare several clues: how distant galaxies are moving, old light across the sky, the amounts of light elements, and the pattern of matter on large scales. Together these clues support a hot, expanding past.

Think like a scientist: Put dots on a balloon and slowly inflate it. Do the dots need a special dot in the middle to move apart? What is different between the balloon model and the real Universe?

Remember: The Big Bang is strong science because its well-tested claim is careful: the early observable Universe was hot, dense and expanding. Ideas about an exact beginning, inflation or a bounce are separate questions.

QTC-013 How Can We Learn About a Time Before Atoms?

Source article: QTC-013 — Before Atoms

The big question: How can scientists learn about an early time when light could not travel freely through the Universe?

A short answer: The oldest light we can see began travelling freely after atoms formed. For earlier times, scientists build a careful reconstruction from later clues, such as expansion, light elements and experiments that test tiny particles.

The clue: Not having a photograph does not mean having no evidence. Different measurements must agree: physics measured in laboratories, the amounts of hydrogen and helium, and features in the oldest light. Each clue has limits, so scientists test whether one explanation fits all of them.

Think like a scientist: Imagine you arrive after snow has stopped falling. Which clues could tell you about the earlier storm: footprints, snow depth, a weather station or a photograph? Which clue could be misleading by itself?

Remember: Scientists can infer important parts of the early Universe without seeing them directly. Giving a time a grand name, such as a Planck era, does not prove that every proposed detail has been observed.

QTC-014 Why Is There More Matter Than Antimatter?

Source article: QTC-014 — Matter, Antimatter and an Unsolved Imbalance

The big question: If matter and antimatter can cancel each other, why is there any ordinary matter left?

A short answer: Matter and antimatter can meet and turn into other forms of energy, such as light. In the early Universe there seem to have been nearly matching amounts. A tiny extra amount of matter was left, and that is what later made stars, planets and us. Scientists do not yet know exactly why the extra amount remained.

The clue: Antimatter is real: scientists make and measure it in laboratories, and it also appears in some natural processes. The puzzle is narrower than it first sounds. Measurements point to a very small leftover, about one extra matter particle for every 1.6 billion photons, not to a universe with no antimatter at all.

Think like a scientist: Put equal pairs of two colours of counters on a table. Remove one counter of each colour from every pair. Then leave one extra counter in one colour. What is different about the final set? What would you need to measure before saying where the extra counter came from?

Remember: We have good evidence that matter and antimatter can behave differently in particular tests. We do not yet have one confirmed explanation for the cosmic leftover. A possible idea is not the same as a solved answer.

QTC-015 Where Are the Very First Stars?

Source article: QTC-015 — The Stars We Have Never Seen

The big question: How can scientists look for the first stars if no one has identified one with certainty?

A short answer: The first stars formed from hydrogen and helium, before later stars made many heavier elements. Scientists have found very distant galaxies and unusual gas, but no individual star has yet been confirmed as a metal-free first star. These objects are difficult to study because their light is faint and has travelled for a very long time.

The clue: A strong candidate needs more than one exciting picture. Scientists compare its distance, the kind of light it gives out, how little heavy material it contains, and whether another source could produce the same signs. Each clue can rule ideas out as well as support them.

Think like a scientist: Imagine you are choosing a missing item from a mystery box. One clue says it is far away. Another says it gives a special kind of light. A third says it contains almost no heavy elements. Which clue would be weakest by itself? Why is a group of clues stronger?

Remember: Very distant objects can teach us about the early Universe. But a promising candidate is not yet a confirmed first star, and scientists keep testing other explanations.

QTC-016 How Does a Planet Begin?

Source article: QTC-016 — How to Build a Planet

The big question: How can dust around a young star become a planet?

A short answer: Young stars are surrounded by disks of gas and dust. Tiny grains can stick, drift and sometimes gather into larger bodies. This is part of planet building, but it is not a single recipe. A ring or a gap in a disk can have more than one cause, and a growing planet changes its surroundings too.

The clue: Scientists put together different kinds of evidence: disks around young stars, meteorites, the motions of small bodies, the ages of ancient minerals and the inside of Earth. The oldest solid pieces in our Solar System help mark an early time, but they are not the birthday of a finished Earth.

Think like a scientist: Make a line of small paper circles and gently slide the paper. Which circles stay together? Which spread apart? Now imagine that gravity, collisions and gas are also acting. Why would a picture of one ring not tell the whole story of how a planet formed?

Remember: No single rock, disk picture or computer model keeps the whole history. Planet formation is reconstructed by checking whether several kinds of evidence can fit together.

QTC-017 How Do Rocks Tell Us Their Ages?

Source article: QTC-017 — How We Learned to Date the Past

The big question: How can a rock help scientists work out when something happened?

A short answer: Some atoms change into other atoms in a regular, measurable way. This can act like a clock, but a rock does not simply come with an age written on it. Scientists must work out which mineral they measured and what event set its clock, such as cooling, crystallising or changing during heat and pressure.

The clue: A useful date combines several careful steps. Scientists measure tiny amounts of different atoms, check for contamination, and compare the result with the rock's history. A date can describe when a mineral cooled, not necessarily when Earth or even the whole rock was made.

Think like a scientist: Put three books in a stack. Slide a pencil between the top two books. Which book looks younger: the one above the pencil or the one below? Now ask: what other clues would you need before deciding the exact age of either book?

Remember: A good scientific date names the sample, the event, the kind of atomic clock, the method and how uncertain the answer is.

QTC-018 How Do We Know Continents Move?

Source article: QTC-018 — The Planet That Moves

The big question: How did an idea about moving continents become strong science?

A short answer: Alfred Wegener noticed that some continents seem to fit together. He also compared fossils, rocks, mountain belts and signs of ancient ice. These clues made a stronger case together, but his explanation for what could move continents was not good enough.

The clue: Science moved on when new measurements of the ocean floor and Earth's movements could be tested. Today GPS can measure slow motion in millimetres or centimetres each year. Even so, plate boundaries are wide, complicated zones, not perfectly sharp cracks everywhere.

Think like a scientist: Tear a map-shaped piece of paper into several parts. Can you make the edges fit in more than one way? What other clues besides shape would help you decide whether the pieces once belonged together?

Remember: A familiar outline can start a question, not finish it. A strong explanation must fit many kinds of evidence and also explain how the movement happens.

QTC-019 Can Earth Keep Its Climate Steady?

Source article: QTC-019 — Earth's Thermostat

The big question: How can rocks, water and air affect Earth's climate over a very long time?

A short answer: Over long periods, carbon dioxide can move from volcanoes and other geological sources into rocks and sea-floor sediments. Rainwater and soil water react with some rocks, and rivers carry the products to the ocean. There, carbon can become part of carbonate rock. This process can help change the amount of carbon dioxide in the air.

The clue: When a planet is warmer, its water cycle can become stronger and some rock reactions can happen faster. When it is cooler, those reactions can slow down. This is why scientists describe part of the carbon cycle as a thermostat, but it is a useful model with limits, not a perfect machine.

Think like a scientist: Think of a huge bath with one very slow tap and one very slow drain. If the water level changes, why might you need to watch for a long time before saying which part caused it? What other changes could affect the level?

Remember: This natural response works over hundreds of thousands of years. It cannot be treated as a quick answer to changes caused by people over years or decades.

QTC-020 Could Chemistry Make Some of Life's Ingredients?

Source article: QTC-020 — Before Life: A Planet Full of Chemistry

The big question: Before anything was alive, could Earth already make some ingredients that life uses?

A short answer: Yes. Water, rocks, gases, sunlight, lightning, heat and meteorites can help make some organic molecules. An amino acid is a small chemical building block used to make proteins. Making an amino acid, however, is not the same as making a cell or a living thing.

The clue: Scientists test possible early-Earth chemistry in experiments. In selected gases, lightning can make amino acids. Meteorites can carry amino acids and sugars. Light, heat, rocks and water can also help reactions happen. These are clues about what chemistry can do, not a film of the one path that happened on early Earth.

Think like a scientist: Imagine a box of building blocks. If you find three kinds of blocks in the box, have you found a finished house? What extra steps, arrangements or evidence would be needed before you could say a living system had formed?

Remember: Experiments have made some ingredients used by life. Nobody has watched those ingredients become the first living thing, and no experiment has shown one exact historical path.

QTC-021 When Can Chemistry Start to Evolve?

Source article: QTC-021 — When Chemistry Began to Evolve

The big question: What must happen before chemistry can change in ways that build on earlier changes?

A short answer: Change by itself is not evolution. For evolution, something must last long enough or make copies, its copies must sometimes differ, and some differences must be passed on because they help the copies continue. A copying system also has to be accurate enough that useful information is not lost at every generation.

The clue: A chemical reaction can make more of itself without evolving. A droplet can grow and split without passing on a helpful difference. Scientists therefore ask not only, 'Does it copy?' but also, 'Can differences last, be inherited and change what happens next?'

Think like a scientist: Draw a simple pattern of coloured squares. Ask a friend to copy it several times, allowing one small mistake each time. Which differences remain after several copies? What would happen if every copy had too many mistakes?

Remember: Scientists can test pieces of this problem in laboratories, but nobody has watched ordinary early-Earth chemistry become a fully independent, open-ended evolving lineage.

QTC-022 Why Have We Never Seen the First Cell?

Source article: QTC-022 — The First Cells We Never Saw

The big question: Why can scientists not point to a fossil and say, 'This was the first cell'?

A short answer: The rocks that keep signs of ancient life formed after the most important early steps had already happened. Old structures and chemical signs can show that communities lived, but they do not show the very first membrane around the very first system that could pass on information.

The clue: Laboratories explore the missing time from another direction. Tiny fatty bubbles can grow and divide. Droplets can bring helpful molecules together. Other experiments put copying molecules inside small compartments. These are useful pieces, but they do not prove that all the pieces first appeared together in one place.

Think like a scientist: Imagine trying to reconstruct the first bicycle from a bell, a wheel, a handlebar and a photograph of a modern bike. Which parts could you show existed? Which part would still be a careful guess about the order?

Remember: No fossil preserves the first cell. The evidence does not tell us one certain route, or that life could only have begun once.

QTC-023 Who Was LUCA?

Source article: QTC-023 — LUCA: The Ancestor We Reconstructed

The big question: What does LUCA mean, and why was LUCA not one fossil or one named creature?

A short answer: LUCA means the last universal common ancestor. It is the last ancestral population shared by all the kinds of cells alive today. 'Last' matters because earlier life may have existed, swapped genes or disappeared. 'Common ancestor' means an ancestor worked out from living descendants, not a single old organism found in a rock.

The clue: Scientists compare molecular information in many living cells. Bacteria and Archaea are two great groups of living things made of single cells without a nucleus. The cells in plants, animals and fungi keep their genes inside a nucleus instead, and are called eukaryotes. Some shared features reach deep into both Bacteria and Archaea, which helps them reconstruct part of an ancient family history. Different methods can recover different details, so the picture is still being tested.

Think like a scientist: Draw a family tree that begins with cousins you know. Could you find the same great-grandparent from several branches? What would be different if some old family records were missing?

Remember: LUCA was not the first life and not a solitary organism. It is a reconstruction of shared ancestry, and some parts of that reconstruction remain uncertain.

QTC-024 Why Is Earth a Microbial Planet?

Source article: QTC-024 — The Microbial Planet

The big question: Why do scientists say most of Earth's history has been a microbial story?

A short answer: Microbes are tiny living things that include Bacteria, Archaea and many microscopic eukaryotes. Forests and animals are easy to notice, but microbes have lived in many more places for far longer and carry out important chemical work in soils, oceans and rocks.

The clue: Scientists use microscopes, drilling, genetic clues and studies of cell molecules to find life where eyes alone cannot. These methods revealed huge microbial communities in the ocean, below the sea floor and underground. Exact totals change as measurements improve, but the big picture is strong.

Think like a scientist: Make a list of places where you can see large living things. Then add places where tiny living things might be working even when you cannot see them: soil, a pond, inside rocks or deep below the sea. What evidence could help you check each place?

Remember: 'Microbe' is a useful everyday group, not one branch on a single family tree. The importance of microbes is clear, while exact global numbers and ancient changes are still revised.

QTC-025 How Can a Rock Tell Us About Old Air?

Source article: QTC-025 — How to Read an Atmosphere from a Rock

The big question: Can a rock hold a simple sample of the air from long ago?

A short answer: No. A rock is not old air in a jar. Different minerals and chemical clues can record parts of weathering, water or sunlight reactions. Scientists must work out what each clue can mean and how old it is.

The clue: Ancient rocks have been buried and changed. One clue may describe local water, another a reaction with light, and another a wider part of the atmosphere. Strong reconstructions compare several clues instead of forcing them into one simple story.

Think like a scientist: Imagine three witnesses describing yesterday's weather from a wet coat, a puddle and a photograph. What could each witness show? What could none of them show alone?

Remember: Scientists reconstruct ancient atmospheres by linking measurements, reactions and environments. The answer improves when independent clues agree.

QTC-026 How Did One Cell End Up Inside Another?

Source article: QTC-026 — The Cell Within the Cell

The big question: Why do mitochondria and plastids look like tiny descendants of bacteria?

A short answer: Long ago, some bacteria began living inside other cells. Mitochondria are the small parts that help a cell release energy, and plastids are the parts that let plants and algae use sunlight. Both still carry several signs of that history, including their own small sets of genes, their membranes and their ways of dividing.

The clue: Archaea are a great group of single-celled living things, alongside bacteria. Cyanobacteria are bacteria that use sunlight to make sugars. Scientists compare genes, cell parts and the machines that move proteins. Together they show that mitochondria have bacterial ancestry inside a host related to Archaea. Plastids record a later partnership with cyanobacteria.

Think like a scientist: Imagine two different teams building one new machine. Which parts might keep the style of the first team, and which the second? What evidence would show that both teams really contributed?

Remember: The merger is well supported, but scientists still test several possible details of the pathway that led to complex cells.

QTC-027 How Can Information Become Inheritance?

Source article: QTC-027 — From Information to Inheritance: Tree, Web and Viruses

The big question: Why must copying be both careful and not perfectly identical?

A short answer: In cells, DNA is copied, checked and repaired. Most copies are very similar, but a few differences can remain. If copying were perfect, nothing new could be inherited. If it were far too inaccurate, useful information would quickly disappear.

The clue: Family histories can look like trees when information passes from parents to descendants. But genes can also be copied, lost, rearranged or sometimes move between lineages. That is why scientists compare many clues before drawing one simple family tree.

Think like a scientist: Copy a short pattern of letters several times. Keep most letters the same but change one occasionally. Which changes can be followed through later copies? When would the pattern become too mixed to read?

Remember: Inheritance works because continuity and change work together. Neither one alone explains the history of life.