

# **STELLAR FIRMA**

## **TIM AND BEN DO SCIENCE**

### **A THIRD TIME**

#### **(PART ONE)**

#### **Content Warnings**

- **Innuendo**
- **Discussions of: graphic death & injury in space, exercise**
- **Mentions of: knives, fascism, violence & injury (inc. eye trauma), food, alcohol**
- **SFX: occasional beeping**

**BRYN:** Hello, and welcome to “Tim and Ben Do Science, part three.” I am your host today, the special Stellar Firma guest Bryn Monroe. Those of you who have listened to “Tim and Ben Do Science, part one,” and “Tim and Ben Do Science, part two,” will know what we’re about today, but uh, just to put any doubts to rest in your mind, I am of course joined by...

**BEN:** Tim Meredith.

**TIM:** A-and Ben Meredith. Oooh, we’re having fun. Because people can’t tell us apart already. Ohh, cos we have the same voice.

**[Bryn begins to laugh]**

**BEN:** Yes.

**TIM:** We’ve got the same Meredith larynx. I’m Tim. Come on. Let’s be sensible.

**BEN:** I’m Ben, you silly billies.

**TIM:** You silly goose. And Bryn, if you’re the most special host, can I be just, the most specialist boy?

**BRYN:** I mean, I think that’s yet to be established. That’ll depend on how well you do.

**TIM:** I feel like I’m a special little boy, and Ben’s this guy over here.

**[BEN:** Well, we’ll see.] Like, and that’s how you tell us apart.

**BEN:** We shall see who gets given the certificate.

**TIM:** Okay.

**BRYN:** Yeah, well, this is our third [**TIM:** And final!] Tim and Ben Do Science. Third and final. [**TIM:** It's for all the beans.] The series is over. [**TIM:** Yeah.] I'm very sad.

**TIM:** It's done. If you've heard it now—

**BRYN:** I've not. I'm pretending to be sad because I have yet to hear the final couple of episodes.

**BEN:** I thought it was rubbish.

**TIM:** Yeah, Ben didn't care for it.

**BEN:** I didn't like it at all.

**TIM:** And weirdly, you can tell that in his performance. [**BEN:** Yeah yeah yeah, real lackluster.] Like, he's delivering his lines like, 'Oh, what a denouement this is.'

**[Ben makes some buzzy David 7 lip sounds]**

**BRYN:** So we are in fact recording this episodes before the final two or three episodes of the series air. So I haven't found them, and that means you are from my interrogation of any science crimes that may occur in those final couple of episodes.

**TIM:** It's just time tables and people being fine in black holes. You'd hate it, Bryn.

**BEN:** I think there were some specific bits of the script that Tim did write thinking, "Bryn's gonna hate this."

**TIM:** Yeah, most of it.

**BEN:** Cos it's bad, not cos it's scientifically inaccurate. It's just rubbish.

**TIM:** No, yeah, it's really scientifically accurate, but it's very bad narrative.

**BEN:** Yeah, it's just terrible.

**TIM:** The character development is awful.

**BRYN:** I mean, as someone who loves high school American TV teen dramas, I can promise you I have no problem with terrible narratives.

**TIM:** That's true.

**BEN:** Alright, there you go, you're our target audience.

**TIM:** Yeaah. Yeah, cos outside of your science, your brain is otherwise comprised entirely of trash.

**BRYN:** **[laughing]** Pretty much. Pretty much. So, for season one of Stellar Firma, our two wonderful characters Tixel Geistman and David 7 spent the entire season, as I recall, designing planets.

**BEN:** Yeah.

**TIM:** Correct.

**BRYN:** And I was brought in afterwards at the end of the season to talk about science with the two of you. Because there was loads of science'ish stuff discussed in that season. **[BEN: Science adjacent.]** Frequently.

**TIM:** Science-esque.

**BRYN:** Science-esque. I mean, it is in the very loosest of terms 'science fiction,' [TIM: Yeah!] and uh, so, yeah, it seemed like a great idea at the time.

**TIM:** Can you be a scientisn't? If you can be a scientist? Are we scientisn'ts?

**BEN:** I think we are scientisn'ts.

**BRYN:** That's... Right. Sure.

**TIM:** It's an excellent joke, you have to admit. **[begins to chuckle loudly at his own joke]**

**BRYN:** Okay...

**TIM:** You **have** to admit.

**BRYN:** Do I have to admit that? Do I, though?

**TIM:** You do, contractually.

**BRYN:** And as I recall, Ben took home a stunning victory from the first Tim and Ben Do Science episode.

**BEN:** Yes, yes. I did, I did.

**TIM:** Yes. It was a rout. It was a rout. I was very embarrassed.

**BRYN:** And then Tim felt awful and did a whole bunch of research and preparation.

**BEN:** He didn't.

**TIM:** Thank you, BBC Bitesize.

**BEN:** Did you act— Oh! **[begins laughing loudly]**

**BRYN:** In season two, Trexel and David spend uh, most of the season selling planets.

**TIM:** That's my domain.

**BRYN:** Which involved a lot less discussion of the technical details of the planets. **[TIM:** Yeah.] But there was still enough for me to spin little bits and pieces out there.

**TIM:** Yeah.

**BRYN:** Then you ended at this season in, what was it, the Internal Complaints Department, if I remember correctly?

**BEN:** Expediting, yeah.

**TIM:** Expediting.

**BRYN:** Yeah. And now in season three, in season three, what has our course been? We spent most of the season— The bulk of the season was in Consultancy.

**BEN:** Yes. Not in a beautiful little café like I wanted.

**BRYN:** And the final chunk in Business Warfare.

**TIM/BEN:** Yes.

**BRYN:** And I have to confess, it's been a lot harder to find in-depth discussions of anything approaching scientific relevance in this wonderful, wonderful season three. I would say the average episode

had one, sometimes two, sentences that I could vaguely relate to something scientific and bring up as an excuse to quiz you.

**BEN:** That's great! That's, you know, taking the tour.

**TIM:** And the thing about this is, because I did very poorly in our first episode of this, and there was a lot of science to get through— I, actually, 'won' is a strong term. But let's say I beat Ben and it was embarrassing for him in the second version of Tim and Ben Do Science. [**BRYN:** You did indeed.] And that was about a series that had much less science. Now, if we follow the rules, the statistical line—

**BEN:** I might as well leave.

**TIM:** That means this season, which has the least of all science, I should ace.

**BRYN:** It is indeed, the score is one-all, and in this scientifically— This porosity of scientific information, we'll see just what I can spend out.

**BEN:** I'm also gonna say just quickly to anybody who's thinking like, 'Oh, well, maybe they'll make it a draw, to have like a nice—' Absolutely not.

**TIM:** No, absolutely no. No, that's—

**BEN:** This is gonna be a proper, an intellectual knife fight. [**TIM:** Yeah.] Street rules.

**BRYN:** I mean I should also should mention, having just talked about how difficult it was to dig up scientific things to discuss in this season... It would be remiss of me not to mention, of course, the glorious, glorious episode 62.

**TIM:** What was that?

**BRYN:** Episode 62 being the one where nearly every reaction I saw was 'I can't wait for Bryn to listen to this one.' And, in fact, [**TIM:** Which one was this?] I'm pretty sure episode 62 canonized me as a character within the Stellar Firma universe.

**BEN:** Oh, yes! There was an annoying science man.

**BRYN:** David 7 looks something up on I.M.O.G.E.N. and literally says 'there's just a picture of an angry man with glasses shaking his head at us.'

**BEN:** Yes, yep, yep, yep.

**BRYN:** And I don't know about you guys, but I certainly choose to believe that that is me. That I am the angry man with glasses. [**TIM:** You're in the show.][**BEN:** Definitely heavily implied.] And I now exist within the Stellar Firma universe.

**BEN:** Uncredited cameo, let's say.

**TIM:** Yeah.

**BRYN:** I am part of Rusty Quill. I was invited to do the science episodes for Stellar Firma, specifically because I have a scientific background. I have an undergraduate degree in applied mathematics, and a master's degree in theoretical physics — with a specialty in cosmology, and my master's dissertation was on the topic of black holes. And since episode 62 included some in-depth discussion of black holes, and exactly what they mean, that was indeed playing in my house. And we will come back to episode 62 later. Okay, so, I have to say Tim, you mentioned when we did Tim and Ben Do Science number two that you'd been reading a lot of Bill Bryson as a

way to prepare. [TIM: I have, yes.] Have you put in any special background preparation this time?

**TIM:** Well, I have listened to more Bill Bryson, but it has been more sort of travel-based Bill Bryson. Much less science, not as helpful. I've listened to a lot of Cautionary Tales, an excellent podcast which taught me about things like Get-There-Itis, a psychological principle that affects pilots and ships' captains and things like that. [BEN: Yep.] Not a lot of science, though, so, I'm a little worried.

**BRYN:** And Ben... after your distressing, narrow, I will stress narrow defeat, in—

**BEN:** Yeah, yeah. Yeah yeah yeah.

**TIM:** Confirmed, narrow but decisive.

**BRYN:** Tim and Ben Do Science one, it was a crushing victory on your— And then followed by a narrow, but embarrassing, defeat.

**BEN:** Yeah, no, cos if we're considering the whole series as a continuous thing, I'm still ahead. It's just, you know, we decided to sort of, to discretely sever it.

**TIM:** It's not points accumulated.

**BRYN:** I mean, that's one interpretation.

**BEN:** Yeah, yeah, yeah, yeah, yeah. That's my hypothesis, is that I'm winning.

**TIM:** You're scum.

**BRYN:** Have you put in any preparation hours in order to reclaim your crown, or are you coasting on your natural ability?

**BEN:** I've just mainly been listening about the rise of fascism in the early 20<sup>th</sup> century, which I don't— It's not like, irrelevant to Stellar Firma? But it's not relevant to this conversation, I think.

**TIM:** Ben, have you been watching the news and therefore the rise of fascism in the early 21<sup>st</sup> century?

**BEN:** Ooooh, satire.

**TIM:** Oh, it's very depressing!

**BEN:** Christ, yeah. It was by-election day today. Didn't go well.

**TIM:** It's gone poorly.

**BEN:** Yep.

**TIM:** Gone real poorly.

**BRYN:** So, moving swiftly on, I will— As I explained, as my background being in physics and cosmology, it's not the only branch of science, much to my shock and disappointment.

**TIM:** What?

**BRYN:** And there are definitely bits of zoology and biology that could be discussed in relation to some of the outlandish claims made in Stellar Firma. And I'm just going to accept everything you've ever said about, y'know...

**BEN:** No, I think they're all pretty rigorously accurate.

**TIM:** I was— I toured my original choice of universities with an idea that I was going to study zoology, at once point I got a ‘U’ in my biology A.S. level? And that really quickly fell off the map.

**BEN:** I remember us having to have the conversation of, ‘Yes, Tim, but you are very bad at this.’

**TIM:** ‘It’s probably not gonna happen.’ Yeah, yeah, yeah. Well, the thing is, I’m not bad at biology. I’m bad at exams. [**BEN:** Yeah, no, you were bad at passing exams, which you need to do.] And unfortunately, they’re very important for being allowed to study biology.

**BRYN:** Yep, yep, yep.

**TIM:** They don’t take it on trust.

**BEN:** No.

**BRYN:** I haven’t studied any biology for about twenty years, but I’m just going to assume that at the very least I can say there’s a lot more leeway. It’s a messier area.

**TIM:** It’s a squishier topic.

**BEN:** I will just reassure you, Bryn, that every biological statement we’ve ever made in Stellar Firma has been peer reviewed by the journal *Nature*.

**BRYN:** Excellent, excellent.

**TIM:** Yes. We had a hotline.

**BEN:** Yeah.

**BRYN:** So, my first question is— Very, very early on in episode 51, I.M.O.G.E.N. claims a specific value for the density that David 7 has achieved with his epic level workouts. [**TIM:** Right.] Which of the two of can get closest to the value quoted by I.M.O.G.E.N. for what David's density is?

**BEN:** I don't even know what the unit of density is. Also, Tim wrote that line. So that's unfair.

**TIM:** I wrote that. I wrote that line. I looked it up, but I can't remember. I will have looked that up.

**BEN:** It's pre-researched.

**TIM:** I'll have looked up... a dense material, and used its value, but I couldn't even tell you what— Could you tell us what unit of measurement density is measured in, as a start?

**BEN:** Yeah, I don't even know what that...

**BRYN:** I'm not gonna tell you. Let's see if we can work it out. So, what is density? How do you calculate density, do you know that?

**BEN:** Mass by volume.

**BRYN:** Yes. Mass divided by volume. Do you know what the standard—

**BEN:** One point to Ben!

**TIM:** No, no, no... no. We didn't— We specifically said it's not fastest finger first.

**BEN:** I answered a question! I answered it, and it was right.

**TIM:** You were just talking about—

**BRYN:** We're not, we're not awarding points for small, tiny bits like that, Ben. The point goes for the overall answer.

**BEN:** Ah, just the calculation of density! Thanks, Bryn. Apparently that doesn't matter to science. We don't need density, it's just, you know—

**BRYN:** I think you'll find— Well, you know, the principle in a GCSE level exam, quoting the formula is the first part of the answer.

**BEN:** Everyone's a spherical turkey in a vacuum, are we? Great.

**BRYN:** Absolutely.

**TIM:** Chickens, Ben. They're chickens, come on.

**BRYN:** So, what is the unit of mass?

**TIM:** Unit of mass...

**BEN:** I mean... kilograms.

**BRYN:** It is indeed kilograms. And what do you think is the unit of volume?

**BEN:** Bignesses.

**TIM:** Millilitres squared. Cubed. It's cubic volume, isn't it?

**BRYN:** It's cubic, yeah. Did you say— What was the—

**TIM:** I think I said 'cubic millilietres.'

**BRYN:** So millilitres is already a measure of volume, so you do not need to cube it.

**TIM:** Oh, I see. Oh, I see!

**BRYN:** You're conflating two things.

**TIM:** It comes pre-cubed!

**BEN:** It does.

**TIM:** Cubic litres.

**BRYN:** Millilitres indeed does come pre-cubed.

**TIM:** Cuuuuubes. Cubes! It's the cubes. Just a plain old cube.

**BEN:** Cubic metres, right?

**BRYN:** It is indeed cubic metres. So—

**TIM:** Can metres not come pre-cubed? Ah, I've got loads of metres I need to cube ahead of a barbecue.

**BRYN:** So, the units of density are in fact kilograms per metre cubed.

**BEN:** Okay.

**TIM:** Okay, okay.

**BEN:** And they come together to become... kilometregrams.

**TIM:** Yes.

**BEN:** And that is the unit of density.

**TIM:** Now okay, so, so, kilograms in—

**BEN:** Wait, is the question now, 'What is the arbitrary number that Tim came up with'?

**BRYN:** Absolutely.

**TIM:** No, it absolutely wasn't an arbitrary number. **[Ben groans]** I'm certain if you googled it, you would find the substance I was, which was, it'll be like, lead, or gold, or something like that.

**BRYN:** I think it might be very close to gold.

**TIM:** Yeah.

**BRYN:** I'd have to check my list of densities.

**BEN:** Okay.

**TIM:** So the measurement is, 'If you have a cubic metre of gold—'

**BRYN:** Which is quite a big lump of thing.

**TIM:** 'It's a big old lump of gold. How many kilograms is it?'

**BRYN:** That would be a good way to guess the answer, yeah.

**TIM:** I'm gonna say five hundred kilograms.

**BEN:** I'm gonna say... a cubic metre of gold. Sixteen hundred.

**TIM:** No, it's gonna be— Yeah.

**BEN:** You've already answered, mate!

**TIM:** I've already answered. I'm hoping you've overshoot, but it's gonna be real heavy.

**BEN:** Yeah, I might have. Yeah, are we playing Price is Right rules?

**BRYN:** I'm afraid— I am gonna award the point to Ben. Ben remembered the formula, I think Ben got slightly close with the units, and he did technically have the closer of the two answers.

**TIM:** Is it like, ten thousand?

**BEN:** The density quoted for David by I.M.O.G.E.N. in that episode is 21,450 kilograms per cubic metre.

**BEN:** I absolutely nailed it. Just completely. Just right bang on.

**TIM:** Yeah, you really— Ben, well-deserved point. Well done. I hope you choke on it.

**BEN:** Wasn't that by a factor of... anything? Definitely not ten.

**BRYN:** So, indeed. I believe that is pretty close to gold, which one is one of the more dense metals. Do we have any idea about what the scale— What do we think— Do we know what any of the metals at the other end of the scale— What the least dense metals are, and what sort of value they might have? If we think that gold, and therefore the top of the scale, is about 21,000, twenty one and a half thousand—

**BEN:** Aluminium's quite a light metal, I think. So that's probably on the lower end.

**BRYN:** It is reasonably light, aluminium.

**TIM:** Is tin an alloy? Tin's an alloy, but what's it an alloy of? Cos tin's very light.

**BEN:** Yeah. Bronze and... copper?

**TIM:** Copper. Copper's very—

**BEN:** No, no, no! Bronze is an alloy as well. It's copper and... Ah, thinking back to my crafting game— No, bronze is copper and tin!

**BRYN:** I believe tin is an element.

**TIM:** Is tin an element?

**BRYN:** Yeah.

**BEN:** Yeah, no, sorry, bronze is copper and tin. That's why I got all—

**TIM:** I'm gonna go tin. Tin's gotta be one of the lightest metals.

**BRYN:** I'm afraid neither of those feature in the list of the lightest metals. The lightest metals are actually metals that float in water.

**BEN:** Oh, are they like cobalt? Cos cobalt's a metal.

**TIM:** Francium. Caesium. Is it things like that?

**BRYN:** Tim's gotten a lot closer there. Caesium is closer.

**BEN:** Ooh, californium.

**BRYN:** The lightest— The least dense metal is, uh—

**BEN:** Sodium! Sodium!

**BRYN:** Almost, yeah. Sodium, I think, is second or third? The lightest metal as far as I could tell is lithium. Although it may be radium, but radium's a bit more complicated, so I'm gonna say it's lithium.

**TIM:** But sodium was pretty close. [**BRYN:** It was very close.] It was closer than the factor that Ben was wrong when he got a point, just putting it out there.

**BRYN:** So if we take lithium as the least dense metal, what do we think the density of lithium might be, roughly?

**TIM:** So if it floats in water...

**BEN:** And we want a cubic metre.

**BRYN:** Effectively, yeah.

**BEN:** I guess if we choose the cubic metre as the thing...

**BRYN:** Now, it floating in water may be a slightly misleading thing. But...

**TIM:** Because... because iron ships float in water, cos that's due to displacement.

**BRYN:** Because of displacement— Absolutely yeah.

**BEN:** So gold was about 20— 'ish, 21,000, about. So the lightest one—

**BRYN:** And I believe a thousand almost exactly. It's just very conveniently happens to be close to a very round number.

**BEN:** I'm gonna say... eight hundred. For a cubic metre.

**TIM:** I'm gonna go a little under that. I'm gonna go... six hundred. I'm gonna go enough below that I'm not being like—

**BEN:** Yeah, no, no, you didn't say seven hundred and ninety nine, so I'm all good.

**TIM:** I don't wanna be that guy. So six hundred kilograms per cubic metre.

**BRYN:** Pretty good, pretty good. Point to Tim there, because that makes it— Because the correct answer I believe is 530.

**TIM:** Ooh, pretty close.

**BEN:** I had 500 in my heart but I was like, 'That's ridiculous.'

**TIM:** Ah, you should've gone with your heart and painted with all the colours of the wind, Ben.

**BRYN:** So yeah, so the density of metals ranges from about 530, 500-ish, to about 22 and a half. So yeah, David's density, quite near the top of that range.

**TIM:** Pretty dang dense.

**BRYN:** A much tougher question: do you know what the densest metal is? It's quite an obscure one.

**BEN:** What that says is it's "not lead."

**TIM:** Can I ask a question?

**BRYN:** You can always ask extra questions, yeah, if you think it's gonna help.

**TIM:** So in terms of, uh, the periodic table, cos it's ordered by number of, oh gosh, is it protons and neutrons? It's number of protons and neutrons [**BRYN:** Yes.] cos helium has one, hydrogen has two, so on.

**BRYN:** Exactly, yep.

**TIM:** So it's gonna be in the bottom right hand corner. I bet there's a special column for like noble gases and stuff which confuses things. So it's bottom right, excluding like two or three rows.

**BEN:** Oh, you said it was obscure. Oh, no, you said it was obscure.

**BRYN:** It's complicated, because the atomic number which is the key thing of the period table, is not the only thing which affects it. But it obviously a [**TIM:** A factor.] a key factor.

**TIM:** Now, here's a followup. Is it one that exists in nature, or is it on that special bottom one of elements that can only be created in a lab and won't exist?

**BRYN:** I don't know.

**TIM/BEN:** Ohhh!

**TIM:** Do I get a point for stumping teacher?

**BEN:** At this point we're playing 'Guess Who' with the periodic table. I wanna call foul on this question. I don't think we should.

**TIM:** Does it have a mustache? No.

**BEN:** Yeah, exactly. Well, I'm actually gonna answer before this, so I'm gonna take—

**BRYN:** It's not, no no, it's naturally occurring. Okay, I wanted to check, because I wasn't certain, but it is— I was right. It's naturally occurring, and it's not one of the really weird ones, actually. It's just a slightly obscure one.

**BEN:** I'm gonna say it's uranium. I think— I'm gonna say uranium because I think nuclear metals, like radioactive metals, are very heavy, and that's kind of the problem with them is that they're too, they're too full of things, and they gotta ahhhh.

**TIM:** I'm gonna think of another radioactive metal. I'm gonna go plutonium.

**BEN:** Which would've been my other answer. I'm gonna be very annoyed if I, uh...

**TIM:** Cos I think plutonium is more unstable than uranium. I think. But again, I'm gonna shock you here: I'm not a nuclear physicist.

**BRYN:** Plutonium is indeed slightly heavier and slightly more unstable than uranium.

**TIM:** Yess.

**BRYN:** It is, however, not naturally occurring in nature, and in fact the best way to get plutonium is to go through nuclear processes with uranium.

**BEN:** Ahhh.

**BRYN:** The answer to the question is osmium.

**TIM:** Osmium.

**BRYN:** Which is a metal most people haven't even heard of it.

**TIM:** From the land of Oz. Is it from Australia?

**BRYN:** And I'm not sure I had heard of it until I looked up the answer to this question.

**BEN:** I thought osmium was the cousin of Osmosis Jones, but...

**TIM:** Wow, that is a specific reference.

**BEN:** It's a fun— Hey, Neil Patrick Harris is a pill. All-time great role. Wait, sorry, it's not Neil Patrick Harris, it's another guy with three names. It's David Hyde Pierce. I got bamboozled by his three names!

**[Tim and Bryn laugh]**

**TIM:** All potentially first names.

**BEN:** Hyde?

**TIM:** Well, I was thinking Dr. Jekyll and Mr. Hyde, and then I saw the flaw in my argument. It's very specifically a surname.

**BEN:** Oh no, his name was Hyde Hyde. And Hyde Jekyll. It was very weird.

**TIM:** Related to Heidi Klum, but not in the way you'd exist.

**BEN:** Bryn, help. Are we having a closeness point, or was it a just an getting the right answer point?

**BRYN:** That was a getting the right answer point, and to be honest, I didn't expect either of you to know it. Because I didn't know it until I looked up the answer earlier, so, yeah. Osmium. **[TIM: Osmium.]** Just random, hanging out in the periodic table, being super dense.

**TIM:** What's osmium for?

**BEN:** I'm just glad that my methodology wasn't wrong.

**TIM:** No, it was good. It guided me to my answer.

**BRYN:** These were sensible ways to make educated guesses, so well done to both of you there.

**TIM:** Because Bryn, every element has to be for something, because everything's for humans, what's osmium for?

**BEN:** Just vibin', man.

**TIM:** Just vibin'. It's just chilling.

**BRYN:** I think it's just quite a weird, quite an obscure element. I don't think we use it for much. I mean it is— The denseness does make it pretty hard, and it's probably useful for that reason. But, my followup question is going to be: later on in the season, Trexel I believe tries to stab David with a knife.

**TIM:** Mmm.

**BRYN:** And at first he thinks it's a joke knife, cos of course it doesn't do any harm to David, and then he stabs himself and hurts himself.

**TIM:** Yeah, in the leg, yeah.

**BRYN:** Now, is it realistic that if David is that dense, David has the density of a very dense metal, does it necessarily follow that he could not be stabbed by a knife?

**TIM:** No.

**BEN:** No.

**TIM:** Because density doesn't mean hardness. Because you can be hard and brittle, you can be dense and soft.

**BEN:** And if the answer for 'what is the name of that scale,' if that is the question, I've been trying to think of that since we started recording, cos I had like a feeling that it might come up, and I cannot remember. But I can tell you what's top and bottom on it.

**TIM:** Ooh, go on then. Tops and bottom.

**BEN:** At the bottom is talc, and at the top is diamond.

**TIM:** And bottom talc and top diamonds are both things in their own right.

**BEN:** I'm pretty sure bottom talc and top diamonds are both stans from Jojo's Bizarre Adventure.

**BRYN:** I'm gonna give you both a point there. I'm happy with the information both of you provided.

**TIM:** Which in some ways is the same thing as neither of us getting points. Thanks, Bryn.

**BRYN:** Yes, so. Density and hardness are not necessarily related. They can be, and diamond is pretty dense for a non-metal, and osmium is quite hard, but osmium is both hard and brittle. So, because different forms of stress on material can cause different reactions.

**TIM:** And you can, you can take a— I know what I'm about to say is not an element, but you can take a substance like steel, and if you

quench it after heating it, it's very hard but very brittle. And it's still the same stuff.

**BRYN:** Absolutely. Absolutely.

**TIM:** It's the arrangement of the atoms. Are they lined up? Are they all over the place? Wobbly-wobbling in? I know very basic metallurgy.

**BEN:** He's trying to bamboozle you, Bryn. He's trying to extract another point.

**TIM:** Give me your points.

**BRYN:** Okay, I'm gonna hop on to episode 59. Which, actually, was one of my personal favourites of the series.

**BEN:** What happened? Was it good?

**BRYN:** Episode 59 was the one where Trexel kept giving useless rhyming puzzles.

**TIM/BEN:** Oh! The puzzle master!

**TIM:** Turn it twice, and turn again! Do not go! It is not your friend! Even past the goblins' lair — oh, look! A fun little fair! The goblins set it up to con you out of your sweet anon.

**BRYN:** Absolutely.

**BEN:** God, they're just under the surface at any moment, like a great white that will burst forth and consume a child.

**TIM:** I'm just bubbling away.

**BRYN:** I enjoyed that episode immensely. It was glorious. Definitely one of my favourites. I think the use of the word 'squawkward' in a rhyming scheme was the thing that actually made me burst into tears with laughter.

**TIM:** If Keats had any bravery, he'd have done it.

**BEN:** Yep.

**TIM:** But he's a coward.

**BRYN:** But there was a single sentence in that episode which I'm going to choose to pick apart because it made me very angry.

**BEN:** Ahhh. The gamut of emotions.

**BRYN:** Which was the discussion of dry ice, and what dry ice might be. What did Trexel claim was dry ice?

**TIM:** Gosh, what did Trexel claim was dry ice? What did I claim was dry ice?

**BEN:** Ice, but you put it under a hair dryer or something. Where you hang it out. It's going to be a very literal interpretation of dry ice.

**TIM:** Yeah. Yeah, it's really cold sand.

**BRYN:** Trexel claimed that if you just take some ice and heat it up, you get dry ice.

**BEN:** Yep.

**TIM:** Correct. Science.

**BRYN:** And you could not be more wrong. I'm going to give a point to Ben there for correctly remembering the show you were both in.

**TIM:** If you heated dry ice, I'm guessing you would just get gas. Cos it's sort of trying to become gas really aggressively.

**BRYN:** Well, this is my question. What is dry ice?

**BEN:** Dry ice is... oh, god, what is it? It is— Isn't it like dehydrated—

**TIM:** Water.

**BEN:** Oh, it's, um. It's dehydrated carbon dioxide. Or it's just carbon dioxide, I think.

**BRYN:** It is indeed carbon dioxide. I don't think dehydrated is the word you mean, because dehydrated means to 'have the water taken out of it.'

**TIM:** Condensed?

**BEN:** Yeah, it's frozen or something. Like it's, um, super-critical? No. That's a different thing. I'm just naming science terms now, Bryn. Help. Help.

**BRYN:** You are getting a bit word soup here.

**TIM:** Is it superliminal? Is it...

**BRYN:** It is solid carbon dioxide.

**BEN:** Ah, right, okay.

**BRYN:** So carbon dioxide in its natural form is a colourless, odourless gas.

**TIM:** Hm.

**BRYN:** But, when you freeze so it becomes solid, it is a kind of white chalky substance, and then because it's natural is a gas, it vaporises very easily, and then you kind of blow it into the air, and while it is transitioning between states, it has the appearance— the smoky appearance that we associate. So, just a quick safety warning: don't use dry ice in a badly ventilated room. [**TIM:** No, cos it replaces all the oxygen.] You do not want a lot of extra carbon dioxide in your room. Not healthy.

**BEN:** I was gonna say, that's why you can feel a bit lightheaded if there's a bit too much dry ice.

**BRYN:** So this brings me on to my next topic of questioning, which is the states of matter. Do we know our states of matter? And, one thing I'm not sure about, is I feel like I probably have asked this question before in one of the other science specials.

**BEN:** Neither of us will remember.

**BRYN:** There are five, or maybe six, states of matter.

**BEN:** Okay.

**BRYN:** How many of them can we name?

**BEN:** Well, it's solid liquid gas plasma, those are the easy ones.

**BRYN:** Yup.

**TIM:** And the other one.

**BEN:** They start to get names which start to sound—

**TIM:** Keith state.

**BEN:** I think they start to sound like, ridiculous. Cos I think one—

**BRYN:** The final two are slightly weird sounding.

**BEN:** Is one of them flux?

**BRYN:** No.

**BEN:** Okay, fine, fine.

**TIM:** Does one of them **[CENSORED BLEEP]**?

**BEN:** Uhh... Mmm. Interesting.

**TIM:** The podcast won't hear that, cos they'll have had to bleep it out.

**BEN:** Yep.

**TIM:** Work it out from the rhyme, people!

**BEN:** I respect your commitment. It doesn't rhyme. It begins with the same letter, it doesn't rhyme.

**TIM:** It's assonance. I've watched *Educating Rita*. It's assonance.

**BEN:** Thanks, Michael Caine.

**TIM:** Or, I'm gonna teach you about knowin' yourself.

**BEN:** And I have bad opinions, because I'm an old man now.

**TIM:** I'm an old man. I don't know. I'm gonna hold up the flag. I don't know. And that's very brave of me to admint.

**BEN:** Piss off.

**TIM:** And deserves a point.

**BEN:** Ugh, there is— and I think it's like— Oh, oh, oh! Is one of them a superfluid?

**BRYN:** Yyyy....es. That's not the name of it, that's a description.

**BEN:** Aaah, okay, well. I don't know the name of it.

**BRYN:** Okay, the final two states of matter, the first, the one that we have observed, created in a lab, and can confirm actually exists, is called a Bose-Einstein condensate.

**BEN:** Okay, fair enough.

**TIM:** That was on the tip of my tongue.

**BEN:** Also, is the last one bloomin' dark matter or antimatter or something?

**BRYN:** No, the last one is a fermionic condensate.

**BEN:** Ah, yeah, no.

**TIM:** Aaah. Now. Is that old... En...rico... Fermi? Enrico?

**BRYN/BEN:** Yes.

**TIM:** Yes. Yes?

**BEN:** Yes?

**BRYN:** You're naming a scientist.

**BEN:** You named it.

**TIM:** You know what? Knowing the first name of scientists that have the things named after them is harder than you think. Cos it's never like, David Zellerman.

**BEN:** Yeah, and no one sits there and says Alfred Einstein.

**TIM:** No, they just Einstein. Simple. Quick.

**BEN:** Did I get that past Tim without him realizing? Okay, okay. There is a point at which like I have to make it clear that I'm not an idiot, but also...

**TIM:** No, but like Heisenburg— what's Heisenburg's first name? What's Fahrenheit's first name?

**BEN:** Oh, Fahrenheit's first name. Isn't it like...

**TIM:** Little Billy Fahrenheit?

**BEN:** It's like, Anton Fahrenheit or something. Wasn't he French or Italian?

**TIM:** But do I not have a slight point? Will you concede that, Ben?

**BEN:** Look, Tim. I was making a goof about the one scientist that everyone knows the name of. And I got the name on purpose, and then got worried that everyone think on Tumblr would roast me for not knowing Albrecht Einstein's name.

**BRYN:** Well done for knowing his first name, Tim. It's not worth a point, but it does make me happy.

**TIM:** Damn.

**BRYN:** Yes. So the Bose-Einstein condensate, and the fermionic condensate are very weird. Cos they are basically subatomic states of

matter, produced— Kind of elevated up into the microscopic level by keeping things very cold. And it's just weird, and it's not relevant to real life.

**TIM:** It's the stuff you're only gonna find it out in space, away from the all the good stuff.

**BRYN:** You can't even find it in space. You can only find it in a lab.

**TIM:** Not even in space!

**BRYN:** You have to make it yourself, basically.

**BEN:** Take that, space.

**BRYN:** Solid, liquid, gas, plasma, are the actual, helpful, useful ones. Very quick descriptions of each one. I imagine at least three of these are kind of a gimme.

**TIM:** Solid is... it doesn't flow. A solid doesn't flow.

**BRYN:** Excellent.

**TIM:** A gas expands to fill the shape of the vessel it's in...

**BRYN:** Very good.

**TIM:** And a liquid... ffff... fff... does... the third one.

**BEN:** I think a liquid can just flow. I think that's acceptable.

**TIM:** Yeah, liquids flow, and gasses also flow, but have other properties.

**BRYN:** Yep.

**TIM:** Such as expanding to fill the vessel they're in. And plasma is only, it's something like it's the transition, like you're never just staying as a plasma, you're transitioning? I can't remember.

**BEN:** I think it's a— is a plasma a liquid beyond its boiling point. So it's like a [TIM: That hasn't turned to gas.], it should be a gas, but it's kept in a liquid state because of pressure?

**TIM:** Social pressure. Social pressure.

**BEN:** Or it's just— Either that or what I'm describing is a liquid, because it's under pressure.

**BRYN:** Yeah, that would still be a liquid, I'm afraid. Cos if you apply enough pressure, and then heat a liquid, but it's still a liquid, it's still liquid.

**BEN:** Oh, and that's how you make something go supercritical! We're dancing around the thing I think I know.

**BRYN:** Yeah.

**TIM:** Although you can't, you can't— This is gonna sound thick— You can't compress a liquid, can you? Liquids can't be compressed.

**BRYN:** Correct.

**TIM:** But compression is not the same— A liquid is under pressure.

**BRYN:** Yes. Compression and pressure are different.

**TIM:** Yes, okay. I just wanted to make sure that that was the case.

**BRYN:** Obviously closely related, but you can separate them out.

**BEN:** But the big question is will it blend?

**TIM:** Will it blend? Will liquids blend? Almost always yes.

**BRYN:** Alright, so, a plasma is very hot, and very dense, and crucially: charged.

**BEN:** So the himbo of states of matter.

**TIM:** Yeah. Hot, dense, and expensive.

**BRYN:** So, one of the key things about a plasma is essentially, it is under such extreme conditions that the atoms within it have separated, so the nuclei and the electrons are no longer bound together, and they're both flowing.

**BEN:** That really blended.

**TIM:** Much like a pressurized marriage.

**BRYN:** So it is similar to a liquid in some ways, Ben, so you're right to compare as the most closely to a liquid.

**BEN:** I know it was like, yeah, when sci-fi is doing plasma, it's always like wibbly wobbly.

**BRYN:** Yeah, yeah. But it requires very extreme conditions of both heat and pressure to achieve it. And it's most commonly achieved in something like the sun.

**TIM:** So, so, I— for some reason, I was under the impression that like, at a point inside a flame, you know, in a fire, that was something to do with plasma. Or is that just superheated gas?

**BRYN:** That is just hot gas, yeah. There's no plasma in the fire. You need really special conditions to achieve a plasma.

**TIM:** I mean, I've got a pretty efficient stove, Bryn. I'm pretty sure I could make plasma in it, thank you very much.

**BRYN:** You cannot, I can assure you of that. [**BEN:** Agree to disagree. Agree to disagree.] I was about to give both of you a point for that little

section, and now I'm not giving Tim one. So Ben, congratulations on your point.

**BEN:** Yes. Hubris.

**TIM:** Hubris.

**BEN:** Hubris.

**TIM:** Just because I'm really, really boastful about my range.

**BEN:** He's got an auger.

**BRYN:** My final question on this topic is: Do you know the name for the transitions between each of these states? So, again, we've thrown away the two crazy condensate states. We're gonna throw away plasma as well, cos it's complex and it requires such specialized conditions. The remaining three: the common, everyday, solid, liquid, gas.

**BEN:** It's boiling and melting.

**BRYN:** So, that is indeed one of them. So when a liquid turns into a solid, it's called melting. Do we know the names for all the other potential transitions between the three?

**TIM:** Evaporation from a liquid to a gas.

**BRYN:** Yep.

**TIM:** Condensation, gas to liquid.

**BRYN:** Correct.

**BEN:** Oh, he's quick. Okay, mm. At one point 'supercritical' is gonna be the correct answer.

**TIM:** It's gotta be.

**BEN:** I think you're right, in that like when it gets into like supercritical states, it transitions without going through like one of the middle ones. But I can't... I'm just... I'm very confused.

**BRYN:** Each transition is actually quite a slow process. So it takes energy to change the temperature of a substance, and then it takes energy to change a substance from one state into another. So, the supercritical description is essentially... you've already achieved that amount of energy being present, but you haven't yet changed the state, because you're artificially maintaining it.

**TIM:** Like when you super-chill water, and it takes kinetic energy to make it freeze. So you can put a bottle of water in the freeze, and take it out and it's still water, and hit it and it suddenly freezes. Cos it's supercritical.

**BRYN:** That is an example of a supercritical state.

**BEN:** Ahhh.

**BRYN:** So I think the one you're thinking of is the artificially maintained liquid that basically as soon you give it a release from the pressure, will instantly vaporize. Well as normally—

**BEN:** Right, so it's about speed.

**BRYN:** Normally, evaporation is slow because it has to draw in energy to achieve the change. [**BEN:** Okay, so.] So what do we have? We have melting, evaporation, condensation.

**BEN:** So we need the—

**BRYN:** No, 'boiling' not the way to describe it.

**BEN:** Yeah, it's the other way. But a gas to solid, right?

**BRYN:** So, the names for the two that are— the relationship between gas and solid are the hard ones, because they're much less common. Did we define the— Well, we have, we've used it in conversation, the change from liquid to solid is known as freezing.

**TIM:** Yes.

**BEN:** Yeah, yeah.

**BRYN:** Tim has given us that one just by discussing the process, right.

**TIM:** I'm just always talking about freezing, you know. It just comes up.

**BEN:** He's a very cool guy.

**BRYN:** So, the two hard ones...

**TIM:** So, I don't think this is one, but I wanna know what it is. When you can like, precipitate something from a metal, or you could— There's a thing a chemistry where it's like you're taking a precipitation. What is that?

**BRYN:** So, a precipitation is similar, because something is transitioning from a liquid to a solid, so you can also call that freezing. But, crucially, with precipitation, you've got a mix of lots of different chemicals within your liquid, and only one of them is turning into a solid. So you're precipitating out part of your mix.

**TIM:** I see. So when you— Salt water you'd evaporate sodium out of H<sub>2</sub>O.

**BRYN:** Absolutely, yeah. So, you know, there's lot of— We're getting into chemistry, and there's lots of other words for other ways you can do this when you've got mixes of—

**TIM:** Back to Bunsen burners. It always comes back to Bunsen burners, you know that.

**BRYN:** Absolutely. That is science. A Bunsen burner is science.

**TIM:** That's just science. That's just science flame. I think the short answer is no, Bryn, we don't know. Cos Ben's making his Popeye face, but he's getting no facts.

**BEN:** No, I'm racking— The brain is being racked, there are nothing in these racks, these racks are empty.

**TIM:** Have you put the brain on the wheel? Are you gonna break the brain on the wheel and see if that gets it?

**BEN:** Yep. I 'm gonna draw and quarter my brain.

**BRYN:** So, when a solid turns directly into a gas, it is known as sublimation.

**BEN:** Annn.

**TIM:** Oohh. Rings a bell.

**BRYN:** And it's very rare, but there are some that do it. The one that people may have encountered is Iodine ... or Iodine. I no longer know how to pronounce that word.

**BEN:** You've consumed too much American media.

**BRYN:** But it is solid in its natural state, and it very easily changes into a gas, and it can undergo sublimation even just generally at room temperature. And the reverse, I believe is called, I'm actually terrified of getting this wrong, cos this is the one you encounter least often, and I think it might be called deposition, and it's similar to condensation, except that it depositing a liquid out of a gas, it deposits—

**BEN:** It has to appear in court.

**BRYN:** —a solid out of a gas.

**TIM:** Ben, that was a better joke— I was trying to think of a way to insert that joke, and I think Bryn moved past it too quickly. Well done.

**BEN:** I saw— Yeah, I saw your brain going and I was like, we've got the same joke in our head and I'm gonna have to strike.

**TIM:** Whatever it says can be used in evidence!

**BRYN:** Well, I'm too worried about getting this wrong. No, deposition, okay, good. I had to check it again.

**TIM:** So is dry ice going through sublimation because it is solidified CO<sub>2</sub> and it's turning directly to a gas from a solid?

**BRYN:** Exactly, and that's why it was one of the questions in this section, because that was the original inspiration for discussing the states of matter.

**TIM:** But we talked for so long that I sort of forgot. And thought I was making a clever connection, as opposed to "it was the point."

**BRYN:** Yep.

**BEN:** That makes sense. It's leaving a deposit. I don't get the sublimation. It's becoming sublime? It's some— bloomin' scientist waxed lyrical.

**BRYN:** Uncommon words because it doesn't occur very often, but interesting that it's, you know, in some ways, potentially part of our everyday experience of science. Solid, liquid, and gases. Um, just gonna draw attention to the fact episode 71, it's claimed that science hides from Trexel, and I just wanna approve that message.

**TIM:** It won't return my calls.

**BRYN:** Okay, okay. So before we go onto the glory of gravity and space/time, of which— Oh, god, I'm so excited to talk about. Space.

**BEN:** The final frontier.

**BRYN:** Absolutely. What do we know about space? Crucially. There's a lot of discussion in the season of Stellar Firma about potentially ejecting people into space.

**TIM/BEN:** Yes.

**BRYN:** If a human, or human'ish, in the case of Trexel and David 7, human'ish body is ejected into space without external protection, what four different things are likely to kill that person?

**TIM:** Coooold.

**BRYN:** Now obviously, some of them are quicker than others, so in actual fact, one of them will be the first cause of death. But there are four different potentially lethal things.

**BEN:** Tim's gone with cold, yeah.

**TIM:** I was gonna say the cold, the cold.

**BEN:** Suffocation? There's no oxygen, famously. Famously no oxygen.

**BRYN:** Yep, that's two. Yep.

**TIM:** All of your moisture will evaporate off of you because of the low pressure.

**BEN:** And decomp... is that decompression?

**BRYN:** That is indeed decompression. So, the...

**BEN:** Oh, and uh, radiation. You'll be killed by the radiation.

**BRYN:** Brilliant!

**TIM:** Depends where you are in space, surely.

**BRYN:** Interesting point.

**TIM:** If you're in really, really, really deep space—

**BEN:** No, no— I think—

**TIM:** The background radiation's gonna be enough.

**BEN:** Yeah, because you're not protecting by an atmosphere, just the general background radiation. I mean, it's probably not gonna kill you— It won't be the first thing that gets ya, but it's not good for you.

**TIM:** You'll suffocate before you get a tumour, certainly.

**BEN:** Yeah,

**BRYN:** Yes. So two of those four things are very much affected by where in space you are.

**TIM:** Cos if you're near a sun, you're not gonna freeze to death, you're gonna burn to death.

**BRYN:** Well, indeed.

**TIM:** Well, you're not gonna burn to death, cos you can't burn without the oxygen— You're gonna be too hot to live.

**BRYN:** Well, y-y...

**BEN:** Too hot to live.

**TIM:** Which is the name of my new album. Tim Meredith. Too Hot to Live.

**BRYN:** Too hot to live!

**TIM:** Too hot to live!

**BRYN:** Again, I'm—

**BEN:** And too cold to die.

**BRYN:** You— Between the two of you, you got both of those things there, and you even brought up the caveat. I'm very impressed. I give you both two points for that.

**TIM:** I felt like I had more there. I felt like I had more.

**BEN:** You started— You said words first, but we had this whole conversation.

**TIM:** Ben, that's how you got all your points last night, and you know.

**BEN:** That is not, that is not! We've had like, the Bryn Monroe holistic science experience.

**TIM:** Which is the name of Bryn's album.

**BEN:** Yeah.

**BRYN:** So, yeah, so. If you're out in very deep space, far away from any stars that a source of radiation and heat, the cold is worse, and the radiation is better.

**BEN:** And Kelvin just comes up and beats you to death a baseball bat.

**TIM:** Yeah. Just yelling the word 'naught.'

**BRYN:** Ah, that pesky Kelvin. He gets everywhere.

**BEN:** Just with a tiny like, 50s sci-fi jetpack and like a fishbowl on his head.

**TIM:** Have you seen that really, really bleak comic, Kelvin and Hobbes? It's about a completely frozen tiger.

**BRYN:** Yes, so. If you are pretty close to a star, the cold is not going to be a problem. You will in fact overheat. And that isn't due to the radiation. The radiation and the cold are sort of inverses of each other, because temperature in space is really a measure how much radiation there is, because temperature doesn't exist when you don't have a substance to measure the temperature of.

**TIM:** It's gotta be vibrating something to be hot.

**BRYN:** It's, there is— You can measure temperature in other ways, and in fact we do, and therefore we can say that the temperature of space is actually 3 Kelvin, more or less.

**TIM:** Cos there is some gas in space, it's just very, very, very, very thin. Is that correct?

**BRYN:** Y...yyyes.

**TIM:** I suppose where in space you are. If you're in space on a planet, there's gonna be loads, Tim. I retract my statement.

**BRYN:** No no no no. I wasn't planning to ask this question, but I think this is a good one. In interstellar space, if you take a cubic metre, how many molecules are you likely to find in that cubic metre, and what will they be?

**BEN:** Hydrogen, and...

**BRYN:** Correct.

**TIM:** Is it less than one?

**BEN:** [crosstalk] There can't be less than one, otherwise there wouldn't—

**TIM:** [crosstalk] Is it like statistically less than one? No no, but like, if it's like, over an area per cubic metre—

**BEN:** Oh, it's an average? Ahh, no, but molecules get everywhere, Tim. I don't think— I mean you can say less than one if you think you're being clever.

**TIM:** Well, I'll say one, and you can guess, Ben, and we'll see who's right.

**BEN:** The thing is, it's a cubic metre, and molecules are very, very small.

**TIM:** Yeah.

**BRYN:** Molecules are very, very small.

**BEN:** Yeah, so I'm gonna say...

**TIM:** I'm just hoping that you overshoot it enough that I'm still correct.

**BEN:** I probably am. I probably am, cos I'm gonna say to the power of... So I'm gonna say...

**TIM:** You think loads.

**BEN:** I think— no, I think very few, but relative to the number of molecules we're used to.

**TIM:** Sure. Cos there's absolutely buttlloads.

**BEN:** There's just, there's just so many molecules all around us.

**TIM:** Mate, you won't believe how many molecules are around us.

**BEN:** Tim, I hate to inform you: you are made of molecules.

**TIM:** Ah, dang it.

**BEN:** Ten to the power of eight.

**BRYN:** I'm afraid Tim is a lot closer.

**BEN:** Ahh.

**BRYN:** In an average cubic metre of interstellar space, you will find... four molecules.

**TIM/BEN:** [surprised noises]

**BEN:** That's not very many!

**TIM:** I'm pleased with myself.

**BRYN:** That is not very many at all, is it?

**BEN:** No.

**BRYN:** No, I mean, it's pretty close to a true a vacuum.

**BEN:** Yeah.

**TIM:** Yeah.

**BRYN:** A true vacuum being zero. Now, Ben has correctly identified that some of those molecules will be hydrogen.

**TIM:** Some will be helium.

**BRYN:** And helium. So, yes, the four molecules between them will all be hydrogen and helium. What do we think the ratio is? Do we think it's three and one, or two and two? Do you think if it's three and one, which way?

**BEN:** I think it's three to one on hydrogen.

**TIM:** I think it's— Hang on. Cos I think it's three heliums and one hydrogen.

**BEN:** Hydrogen three, helium one. Wolverhampton nil, Hull City two.

**TIM:** South at Cira, moderate to poor. I think it's because hydrogen is so reactive that it will want to become helium, but if there's three helium already, the one the hydrogen hasn't got anything to react with.

**BEN:** It's like nah mate.

**TIM:** That's my reasoning, because it's four, and they can't get out of the cube, so it has to stay at three to one.

**BEN:** Oh that's, yes, no, fair enough.

**TIM:** Cos this is a cube on its own. We're not talking about space and you've taken a portion. You've got an isolated cube—

**BEN:** Cube of space.

**TIM:** A cube of space, with walls.

**BEN:** You went out with a fish tank and you closed the fish tank and you took it back it to Earth.

**TIM:** Yeah. So that's just maths, mate, and I can't be wrong, cos that's maths.

**BEN:** It is maths, he's got me there.

**BRYN:** I'm gonna give a point to Ben.

**TIM:** Dammit! Not maaaths.

**BEN:** Celebratory sip of wine?

**BRYN:** So. You did say one thing that was correct there. Which is hydrogen is very reactive, Tim. However, hydrogen in its natural state is already a molecule. It is H<sub>2</sub>.

**TIM:** Ooooh.

**BRYN:** Two hydrogen molecules have reacted with each other.

**TIM:** I can't believe hydrogen did me like that.

**BRYN:** Helium is incredibly unreactive. So helium is just helium, but hydrogen is H<sub>2</sub>. Both hydrogen and helium are the only two substances formed initially after the big bang. Everything else in the universe was formed in the core of stars in nuclear reactions. But hydrogen and helium, been there since the beginning, cos there the two simplest ones. Now, you correctly said hydrogen is very reaction, but it already has reacted. [**TIM:** Yeah.] But also, in a meter cubed, you only have four molecules... even if they were four incredibly reactive molecules, the chance of any of them reacting with each other? Essentially zero.

**BEN:** Just zooming about feeling lonely.

**BRYN:** Because they are absolutely tiny, as Ben has correctly stated.

**BEN:** Thank you.

**BRYN:** And even if they're confined into that metre cubed, they could bounce around forever and never hit each other. I believe I would have to do some maths how likely—

**TIM:** They couldn't bounce around forever and hit each other, Bryn, very importantly.

**BEN:** Ooooh.

**BRYN:** Yes. Not in an infinite amount of time, but I believe it would take more than the current lifetime of the universe for them to have a good possibility of hitting each other.

**TIM:** I just like to “well, actually” you about the definition of forever.

**BRYN:** No, that’s fair, that’s fair.

**BEN:** Yeah, it’s like a screensaver. It’s like waiting for the little DVD thing to actually hit a corner perfectly. It’ll never happen.

**TIM:** It’ll never happen. It’s not in the programming.

**BRYN:** Ah, that was fun. I’m glad we got there.

**TIM:** I’m glad you finally had fun on one of these episodes, Bryn. That’s the first time he’s had fun.

**BRYN:** Ah, that’s not true. I love them, you know that.

**BEN:** One molecule of fun. Have we got to the fabled episode 62?

**BRYN:** We were still talking about space. We’re still talking about the things that kill you in space, weren’t we? And that’s how we got into what’s left there in space. So, yeah. Radiation is gonna kill you very slowly in most parts of space, and the only time it’s gonna be anything like the most dangerous of the four things you will encounter is when you’re quite close to a sun.

**BEN:** You’ll get cooked.

**BRYN:** And essentially— yes. You are burning to death, but it’s radiation burns.

**BEN:** Aw, well, that’s nice, that’s good to know.

**TIM:** You said that as if it was like, “But don’t worry, it’s just radiation burns. The happiest burns of all.”

**BEN:** Yeah.

**BRYN:** Well, I wanted to, cos— Just now, Tim you said, “Well, you’re burning to death, but you’re not burning to death because there’s no substance to burn you.”

**TIM:** Yeah, yeah.

**BRYN:** Well, it, you know— I wanted to accept that you are essentially correct.

**TIM:** It’s closer to being microwaved.

**BRYN:** Essentially, yes. So, of the other three things, given that radiation is the slowest by a long way, which one do we think kills you first?

**BEN:** Decompression.

**TIM:** I’m gonna say no. I think weirdly you can be in a vacuum— I think being in vacuum and being under no pressure is very unpleasant. It’ll blind you because all the moisture will go out of your eyes and things like that, but your skin... is enough... to keep you from depressurizing, I believe. I don’t think...

**BEN:** I think you get an embolism pretty bloody quickly.

**TIM:** I think you’d suffocate first. I think we are surprisingly robust in some ways to that, because I think I listened to something about them trying to work out what would happen if there was a, you know, decompression or you were outside without a space suit or something.

**BEN:** Alright, well.

**TIM:** Have I remembered that correctly, Bryn?

**BRYN:** Point to Tim.

**TIM:** Yesssssssssss.

**BRYN:** Yeah, so, the decompression— It's slightly a trick question, because actually the thing that kills you is the combination of the pressure and the lack of oxygen.

**BEN:** Yeah, cos isn't it a thing of like, is it a thing that um— If you were hypothetically wanting to survive in space, you'd want to empty your lungs, because if you tried to— Because you'd pop if you tried to like— [TIM: Yeah.] So, effectively, if you tried to beat the suffocation, you'd die from the decompression. If you tried to beat the decompression, you'd die from the suffocation first.

**BRYN:** Well... almost. Uh, so, my understanding, and this section is gonna get very gross, we may have to content warn this section.

**BEN:** People dying in... hypothetical ways.

**BRYN:** Yeah, yeah. So, I mean, Tim is right about your eyes suffering terribly from that. But your skin would mostly keep you in tact, even though you'd essentially bruise everything. [TIM: Yeah.] All the way through? Uh, in quite a nasty way. I believe that our current best guess, given that we have never conducted an experiment, and, you know, fingers crossed we never will, is that the vacuum would actually suck all the air out of your lungs very rapidly, and then the transfer of air between your blood and your lungs normally relies on there being air pressure within your lungs. And if you truly emptied your lungs, i.e. a vacuum, your lungs would in fact work the opposite way, and start to suck [TIM: Out of your blood!] the oxygen out of your blood. Which is a sort of unpleasant.

**BEN:** An oxygen Hoover.

**TIM:** Bryn. It's not sort of unpleasant. [BRYN: Yes.] I think you're safe in safe in saying it's just straight up and down unpleasant.

**BRYN:** Yeah, sorry. That was classic British understatement.

**TIM:** “It’s a little— It’s not great for you. Um, we will say that.”

**BEN:** “It’s a little bit— I would describe what happens in your lungs as a bit of a kerfluffle.”

**BRYN:** Yes. So, you in fact, you essentially die of lack of oxygen even quicker than you would, say, if you were trying to hold your breath underwater.

**TIM:** Cos you’d still absorb a little bit of oxygen from the water.

**BRYN:** —because you are actively losing oxygen due to the interaction of the, yeah, due to the vacuum. And yes, our— We used to think that people would pop, but we now believe, my understanding is that your skin is actually surprisingly good at not doing that in that situation. But as I’ve said: we’ve never really tested it.

**TIM/BEN:** No.

**BRYN:** And hopefully we never will.

**TIM:** Until tonight, ladies and gentlemen! Live and in front of you!

**BEN:** The ghost of Yuri Gagarin.

**BRYN:** Ah, ah, before, again: I’m hyping episode 62, cos I’m just so excited about it, but, one other question I want to ask: at the beginning of episode 66, we meet David, who is still counting squats.

**BEN:** Yes.

**BRYN:** From the end of the previous episodes.

**BEN:** Yeah.

**BRYN:** The previous episode, episode 65, ends with David counting one, two, three. The beginning of episode 66, David is counting: one million and one, one million and two—

**BEN:** Because I am nothing if not very basic.

**TIM:** That's a lot of squats per second.

**BRYN:** Well, this is my question. Given that David is performing one, **perhaps** if we're very generous, two squats per second... has he counted accurately? So, firstly, my first question is gonna be—

**BEN:** Well, okay, the answer is no.

**TIM:** No. No.

**BRYN:** Yeah.

**TIM:** We've worked that one out. Because, like, a lifetime is a few million seconds. It's like, three or four— No. Is it even that?

**BEN:** Or it's like— that's ridiculous, Tim.

**TIM:** No, how many million second is like, eighty years?

**BEN:** Well, there's sixty seconds in a minute, and there's quite a few minutes in a.. you know.

**TIM:** Is there a lot of them?

**BEN:** Yeah.

**BRYN:** So this my question—

**BEN:** No, you can't, this is cruel. Cos you're asking both me and Tim to do mental math on machine which have calculators in them.

**TIM:** But we're not gonna use them.

**BEN:** I know we're not gonna not, but...

**BRYN:** How... How long is a million seconds? And if you want the advanced one: how long is a billion seconds?

**TIM:** A million seconds is...

**BEN:** Tim. Tim. Tim. We're going to have to do this unpodcast-friendly silently, because if you describe your working you'll be helping me.

**TIM:** Yeah, okay.

**BEN:** So we should have a think, and get an answer, and then say go.

**TIM:** Right. Sixty. And then... sixty times...

**BEN:** Stop it!

**TIM:** Cos that's what I'm gonna do, Ben. Because—

**BEN:** So there's... so there's... so how many seconds are there in a minute?

**[Tim and Ben begin counting from one]**

**TIM:** Cos the thing is: large numbers, for most people, very quickly become meaningless. And for me especially. I've got a medical condition about how little I understand numbers.

**BEN:** Ahhhhh, are you dyscalculic?

**TIM:** It was part of the test.

**BEN:** Ah, son of a gun.

**TIM:** I'm covered.

**BEN:** There you go.

**TIM:** I can't do anything.

**BEN:** Actually, that does mean, that cos this is an exam, you do legally have to get extra time.

**TIM:** Yeah. That's true. But the thing is the extra time won't help me.

**BEN:** No.

**TIM:** I won't suddenly be like—

**BRYN:** Is this legally an exam? Am I a publicly accredited examining body?

**BEN:** Hang on a minute.

**BRYN:** Not to my knowledge.

**BEN:** So that means Tim gets to bring a laptop into an exam, which means he can use the calculator app on his computer, which is unfortunately for me.

**TIM:** I mean, I'll google, that'll be the easier thing to do.

**BRYN:** Tim, I think your estimation skills have shown to be pretty good so far this episode.

**TIM:** Oh, don't butter me up, Bryn.

**BRYN:** So I think go with your heart. [**TIM:** Go with my gut.] Go with your gut, not your calculations.

**TIM:** Uh, a million seconds is... thirty years.

**BEN:** Okay. Uhh. Right. So.

**TIM:** Why the [bleep] not, eh?

**BEN:** Three... hundred... hours. Wait. Yeah. Three hundred hours... is... wait, no, hang on. Hang on. I'm going back in the tank.

**TIM:** He needs this. He's had a really tough couple of weeks, and he needs this.

**BEN:** Oh, no, I'm being an idiot. Wait. No, I'm not being an idiot. Yeah, it's roughly three hundred hours, so... that is... let's say. Okay, I'm gonna say it's a hundred days, which is completely wrong, but I feel like is close enough.

**BRYN:** The correct answer is eleven and a half days.

**TIM:** Wow. So not thirty years then, eh.

**BRYN:** I'm gonna give Ben a point because three hundred hours is pretty good. Three hundred hours, twenty four hours in a day, ten days, 240...

**BEN:** I got that bit wrong. That was the bit I got wrong. Well, cos I did it through— there's three thousand six hundred seconds in an hour, so I just went bomp bomp bomp bomp.

**TIM:** You may as well be making hissing noises as far as I'm concerned.

**BRYN:** So a million seconds is eleven and a half days. So, reversing that calculation, if David 7 was accomplishing about, you know, eleven and a half squats per second—

**BEN:** That's...

**BRYN:** Constantly... four twenty-four hours.

**BEN:** That's a lot.

**BRYN:** Maybe...

**BEN:** Also, was he doing squats, or was he doing, um, pushy-psy-downsies? [**BRYN:** That's a good question.] Which I think are press-ups. I think those are press-ups.

**BRYN:** I mean that...

**TIM:** It's difficult... He's got his own vernacular.

**BRYN:** Only you can answer that sort of thing.

**BEN:** I cannot. You know I cannot.

**TIM:** You know what? If I had a better memory, I should have had a better chance at that, because a question on Taskmaster "how old is Frank Skinner in seconds?" And it must have been like, not two million, but two hundred million.

**BEN:** Ahhh.

**TIM:** And I think that's where I got confused.

**BRYN:** Well, Tim. I'm gonna give you a point.

**BEN:** For watching Taskmaster?

**BRYN:** Because I asked two questions. I asked how long is a million seconds. The answer is eleven and a half days, and I'm taking Ben's answer of 300 hours to very close to that. You answered thirty years, which is pretty close to how long a billion seconds is.

**TIM:** Ahhh.

**BRYN:** I think it's something like 32, maybe 33? But if you're rounding, thirty years'ish is about a billion seconds.

**TIM:** In Frank's case, it was nearly two billion years— No, it was just over two billion years, cos he's like sixty..

**BEN:** Do you mean seconds?

**BRYN:** Two billion years...

**TIM:** Sorry, two billion seconds.

**BEN:** Oh, no.

**TIM:** He's two billion years old.

**BEN:** Frank has existed since...

**TIM:** Did you know that Frank Skinner was there at the dawn of time?

**BRYN:** Ah, well, that's controversial. When would you say the dawn of time is, Tim?

**BEN:** See, Tim, you'll have noticed that I started to say something like that. Remember that I don't know—

**TIM:** Yeah, it's not that far back, cos it's not gonna be like 1980...

**BEN:** No, cos I think— I can't remember how old the Earth is, but I think the Earth is aroundabout... the Earth is some billion years. Is it 5.6 billion years old? God, this might be— Now, the trouble is I've been roped into now making wrong statements that I was specifically trying to avoid because the answer is 'I don't know.'

**TIM:** "Hey, Tim, let's not say things like 'for example'..."

**BEN:** I know! I'm a fool.

**BRYN:** 5.6 billion years is our current guess for the age of the sun.

**BEN:** Oh! Oh. Okay. I think, okay! So that number was in there somewhere.

**TIM:** I mean, that is still very wrong if you've, if the question was "how old is the Earth," how old is the sun is a very wrong answer.

**BEN:** No no no no no! But at least that was a number that is relevant on an astronomical scale.

**TIM:** Ehh.

**BRYN:** How old do we think the Earth is, give or take?

**BEN:** Not 5.6 billion years, let me tell you.

**TIM:** Two...

**BRYN:** It's a bit younger than the sun, yes.

**TIM:** Two and a half billion years.

**BEN:** 1.2 billion years.

**BRYN:** Four and a half billion years.

**TIM:** Aw, I was close, those, points for Tim.

**BRYN:** It's a lot closer to the Sun. The Earth has also been around for a while. How long has single-celled life been around?

**BEN:** Uh, 600 million years.

**TIM:** I think it's a bit more than that. I'm gonna go 800 million years.

**BRYN:** You are both way off. Single-celled life has been around approximately, to our best guess, four billion years.

**TIM:** Well, there you go!

**BEN:** Oh, not on Earth. Right. Wait. Or on Earth?

**BRYN:** It's not a lot younger than the Earth itself.

**BEN:** Sorry, I just said a sequence of very stupid things.

**TIM:** Well, you know, to be fair, Ben, we have discovered single-celled life on other planets, so if you found— Have we? Have we done that, or have I imagined that?

**BEN:** I... think so?

**TIM:** I think we've discovered bacteria in some places.

**BRYN:** There is some evidence of it.

**BEN:** Yeah.

**TIM:** So there is a reasonable assumption that somewhere in the universe, that there is much older bacterial life. [**BRYN:** Yeah.] I mean, there's, there's mathematical evidence that somewhere in the universe there is advanced life, so that's quite a broad statement from Tim.

**BRYN:** Yeah.

**BEN:** Ah, unless you deal with that cheeky Enrico Fermi and his ol' paradox.

**BRYN:** Hehe, yes. How long has multi-cellular life been around, to our best guess?

**BEN:** Oooh, multi-cellular. Um.

**TIM:** Is it similar to the ratio of how long cinemas and how long multi-screen cinemas have existed?

**BEN:** Ahh, yes.

**TIM:** If you take that as a ratio, that... cos, okay. I'm gonna say... I think it's gonna be remarkably, it took a remarkably long time for two cells to **[CENSORED BLEEP]**. Sorry, I swore again. It's taken a remarkably long time for two cells—

**BEN:** That's, wait, hang on, no, sorry, just hang on a minute, do you—

**BRYN:** I think that's a very good way of putting the transition from single to multi-cellular life.

**BEN:** Yeah, I want you to— So, just, two single-celled **[TIM:** 'Well, hang on a minute, you look nice.'] organisms decided to get it down, and were like, munched themselves into each other so hard.

**TIM:** Well there is, there is evidence that in a cell, things like the ribosome... is... is it the ribosome, or the energy factory is a bacteria, and it got inside something else, and became— You know, so it's like, it was an individual thing that lived on its own, and then it got inside a cell, and then look, was like, 'It was great here.'

**BEN:** We have established on this podcast biology questions are all true. Whatever you say, it is true.

**BRYN:** That is the principle which we're working at, yes, so well done, Tim.

**TIM:** And I'm pretty sure it's not ribosomes, it's— What's the thing that makes the power and the energy in a cell?

**BEN:** A nucleus?

**BRYN:** The mitochondria.

**TIM:** The mitochondria, I think. That sounds right. Bryn's smarter than me. I'm gonna trust Bryn. And if you're wrong, email Bryn.

**BEN:** Well, a biology point for Bryn. He's on the board. He's not actually been performing very well— he's got no points so far, but he's got on so far.

**TIM:** One billion years.

**BEN:** I broadly agree with Tim on the time scaling thing, so I'm gonna say... 1.6 billion years, cos again, trying to be close but not [**TIM:** Be a dick.] pisstakingly close.

**BRYN:** It is, our best guess currently, pretty close to one billion years. [**TIM:** Yesss!] I am forced somehow to give a point to Tim for that section.

**TIM:** I love rules when they go in my favour.

**BEN:** Yeah. I should have said one point— naught point nine nine billion years.

**TIM:** Yeah, recurring.

**BRYN:** Yeah.

**BEN:** Yeah.

**BRYN:** So yeah—

**BEN:** An hour off of Tim's answer.

**BRYN:** That's the age of various things. So, Frank Skinner, who is allegedly two billion years old—

**TIM:** Yeah yeah yeah yeah.

**BRYN:** Was or was not there at the dawn of time, depending on what you're calling the dawn of time.

**TIM:** Strangely, he doesn't count as multi-cellular life. That's just one very complex shape.

**BEN:** That they've painted a face on.

**TIM:** Yeah yeah yeah. I mean, after a while it was awkward having him around. [**BRYN:** Outstanding.] So like, 'Let's make him a comedian, go on, three lines on a shirt.'

**BRYN:** I don't know if I have any questions about this one, but in episode 69—

**BEN:** Nice.

**BRYN:** Nice. David 7 crushes a wastepaper basket into a disc on his face.

**BEN:** Yes.

**TIM:** Yes.

**BEN:** Yes.

**BRYN:** And—

**TIM:** Did you just wanna say this out loud?

**BEN:** And when Trexel correctly points out that the side of his face isn't even flat—

**TIM/BEN:** Yeah.

**BRYN:** So— Is it— Someone— I can't even remember who, says David scared it.

**TIM:** Scared it flat.

**BRYN:** I'm not— I don't have any followup questions. I just feel it's worth bringing up in this Science Special.

**BEN:** Well, I think— I feel like if David slapped that can hard enough and fast enough, it would turn into a disc, because it would effectively explode from the point on his face. So it's not moulded by the face, it's slapped off a single point, expands, and then if he takes it away—

**TIM:** No—

**BRYN:** But it wouldn't stay in a single piece in that case.

**TIM:** And also, when you say, it its—

**BEN:** Aaaa, no, no, sorry, we didn't say what this can was made of.

**TIM:** And also, Ben, and also Ben, you say it hits a point on his face— all of the parts of it don't hit that point at the same time. It's a wastepaper basket. Like some bits of it are gonna hit it much sooner—

**BEN:** We didn't say how big it was! No one has ever established a scale for David.

**TIM:** Okay, if... If... Okay, let's say this. If the wastepaper basket [**BEN:** Yep.] is the size of [**BEN:** Of a thimble.] of one cell, then yes, because it hits the side of one cell, and flattens.

**BEN:** Have I not mentioned that David 7 is Galactus, the Planet Eater?

**TIM:** I see. I see.

**BRYN:** Never came up.

**TIM:** Never came up. Okay. Well, okay, Bryn, you've correctly pointed that out as a thing we said.

**BRYN:** Also, also, I mean, Jenny's not here, so I can't criticise Jenny for the things she has said.

**TIM:** Oh, you can. We will.

**BEN:** She did establish the foot thing.

**BRYN:** But, episode 60 features a Hartro line that something is a "cornucopia of sound projectile science."

**BEN:** No, that sounds reasonable.

**TIM:** What a phrase!

**BRYN:** That sentence made me sad. My notes literally say next to that quote, "What even are these words?" That was apparently my thought while listening to that bit.

**TIM:** What is this?

**BRYN:** Okay, so, I think we've decided— I think we've covered enough there, and I've been talking nonstop about the glory of episode 62 that, in fact, we're gonna do a secret special bonus Tim and Ben do Special where the entire—

**TIM:** We're secret and special.

**BEN:** So secret we're putting it on the feed.

**TIM:** Yeah.

**BRYN:** Where the entire, entire episode will be about episode 62, and episode 62 alone. Um, so, I guess this contest to be continued, and we will

only find out who wins when you guys step into the Thunderdome of black holes and space-time.

**BEN:** Ah, love it. It's like a rubber sheet, everyone. It's like a rubber sheet.

**TIM:** Like a rubber sheet made entirely of helpful lies.

**BRYN:** So, until then, thank you for joining us, and we hope to see you on the special super-secret bonus Tim and Ben do Science, uh, which will probably be quite soon.

**EVERYONE:** Byyyyyeee!

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