The most important question in science

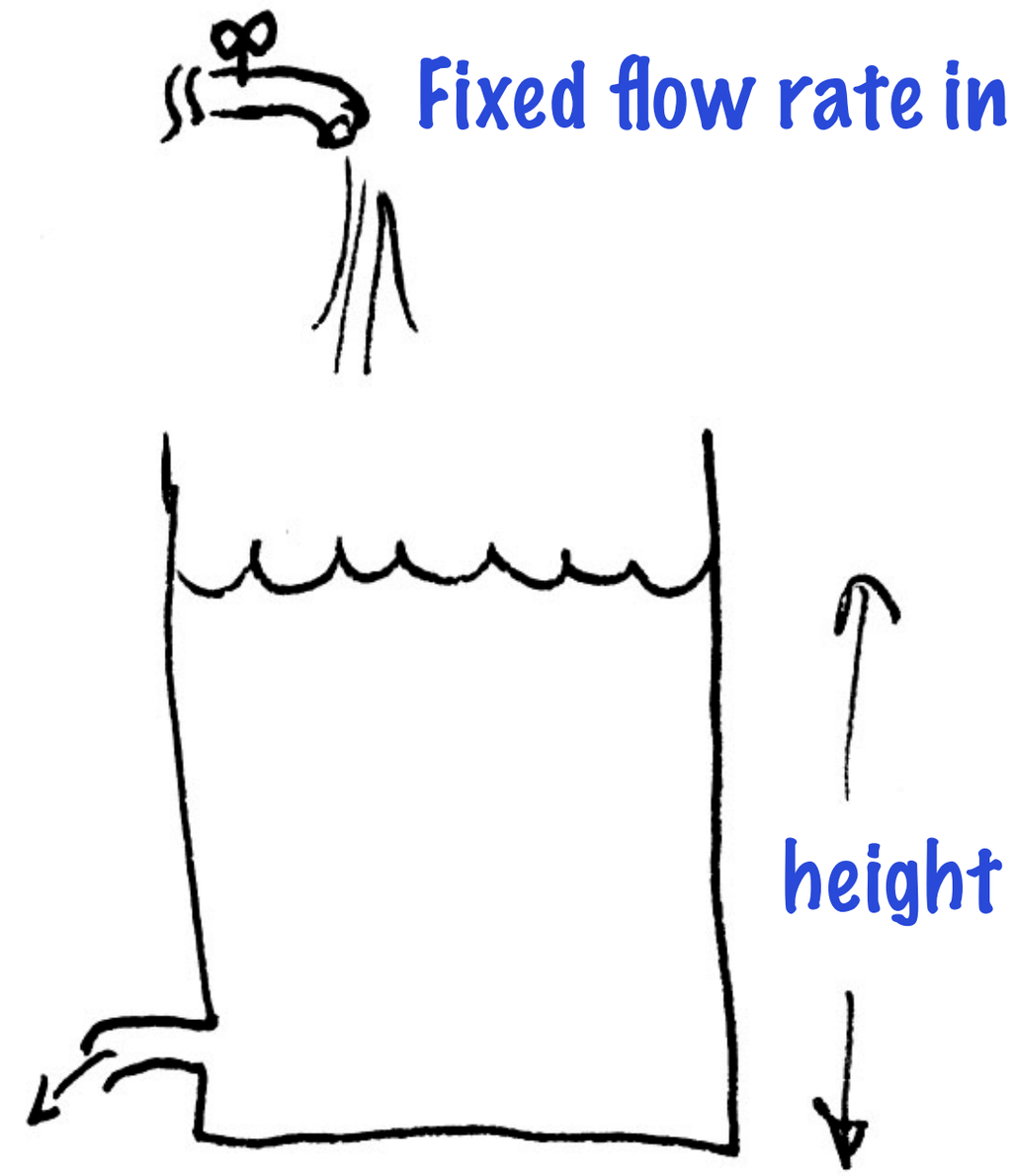
(Maybe the ONLY important question.)

PN 5/2009

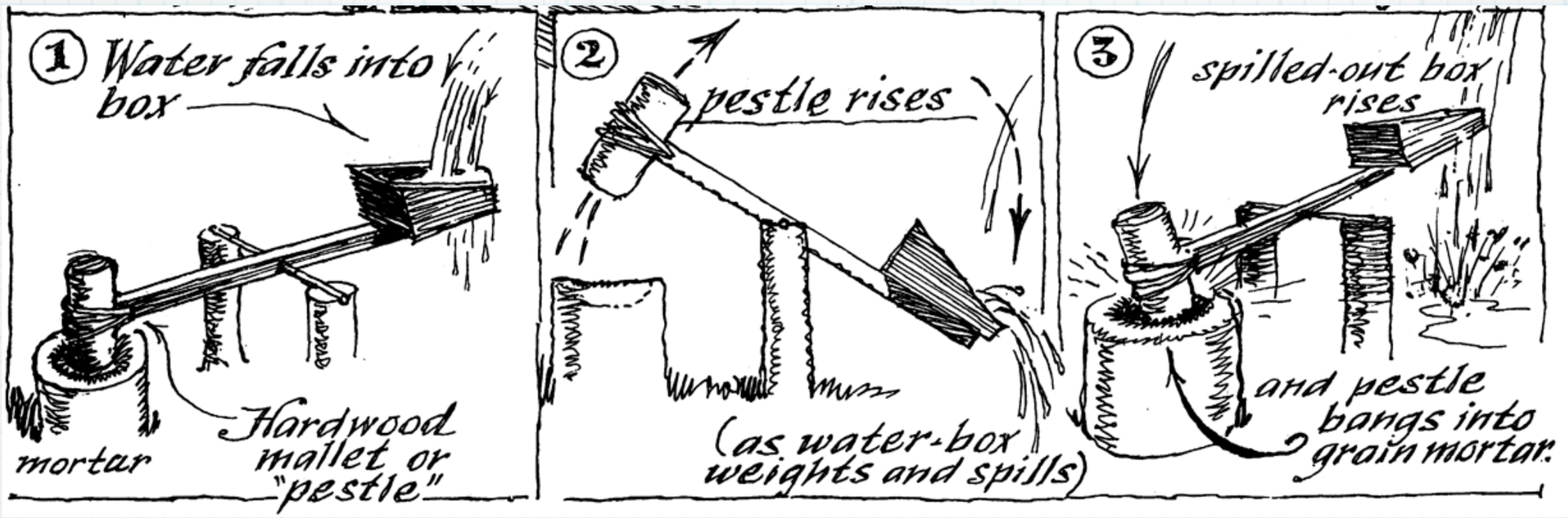
Warning: I am an amateur. If this interests you, find an expert.

* A tipping point example
  * Negative feedback within a certain range, then positive
  * Bifurcation = sudden change of equilibrium point
  * If you were a bug you would have no idea you were near, or even beyond, the tipping point. You wouldn't notice anything special till suddenly you were flung off...
  * (unless you were a very sophisticated bug who could infer how your system looks from the outside, despite being inside it, and deduce its global behavior and state.)

* A less obvious control system: this one is continuously driven.
* It selects a steady-state height, the one for which flow rate in matches rate out
* No tipping point.



* A driven system with a tipping point: again, negative feedback up to a point, then positive.

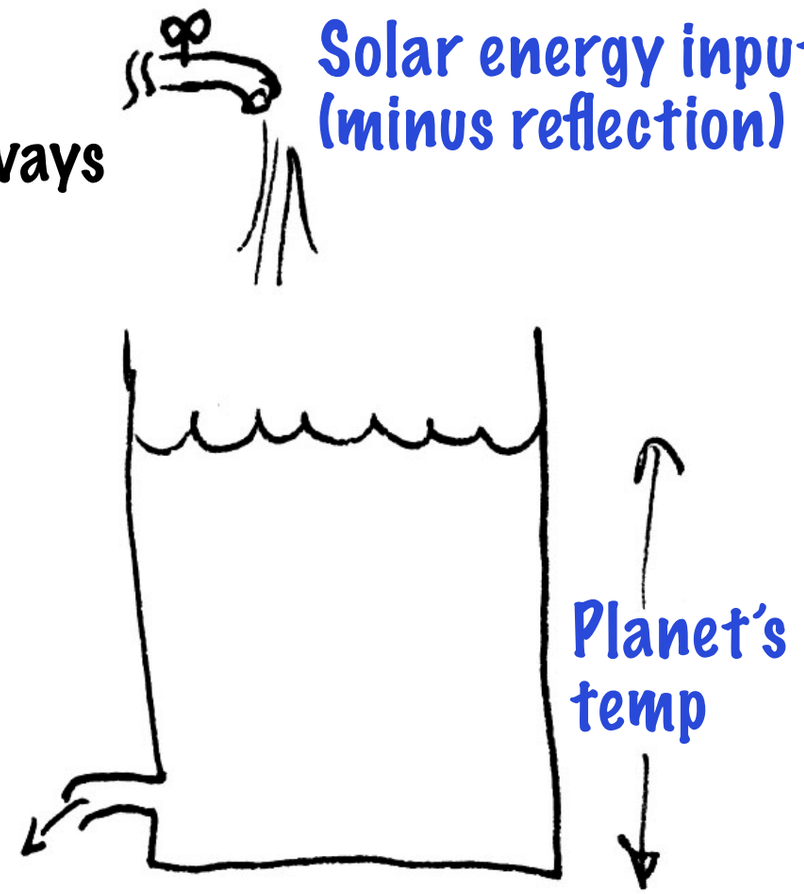


Suppose the water box is leaky. If the opening is big enough, or the input flow rate is small enough, the system will NEVER tip.
But if we make the opening smaller, we'll get a response to continuous flow that is:

★delayed,
★sudden,
★violent.

* The Most Important Question (OK, four questions):
  * Why has Earth climate been so stable for so long, despite slow increase in solar output?
  * Is there a tipping point? Are we close? If so what is the other steady state like?
* Does it matter?
  * The last time this much CO2 was dumped, it made most of Earth uninhabitable and lasted quite a while.
  * When you hear about "global warming" it may not seem so huge:
    * "So the temp goes up a few degrees. So maybe Atlanta will get too hot, but Saskachewan and Fargo will get nicer. People can move."
    * "So the sea level goes up a few meters. So maybe we lose Lower Manhattan and London; but Chicago and Denver will be OK. We can adapt."
    * I'm not thinking about little stuff like that. I'm wondering about Abrupt Climate Change -- a tipping point.

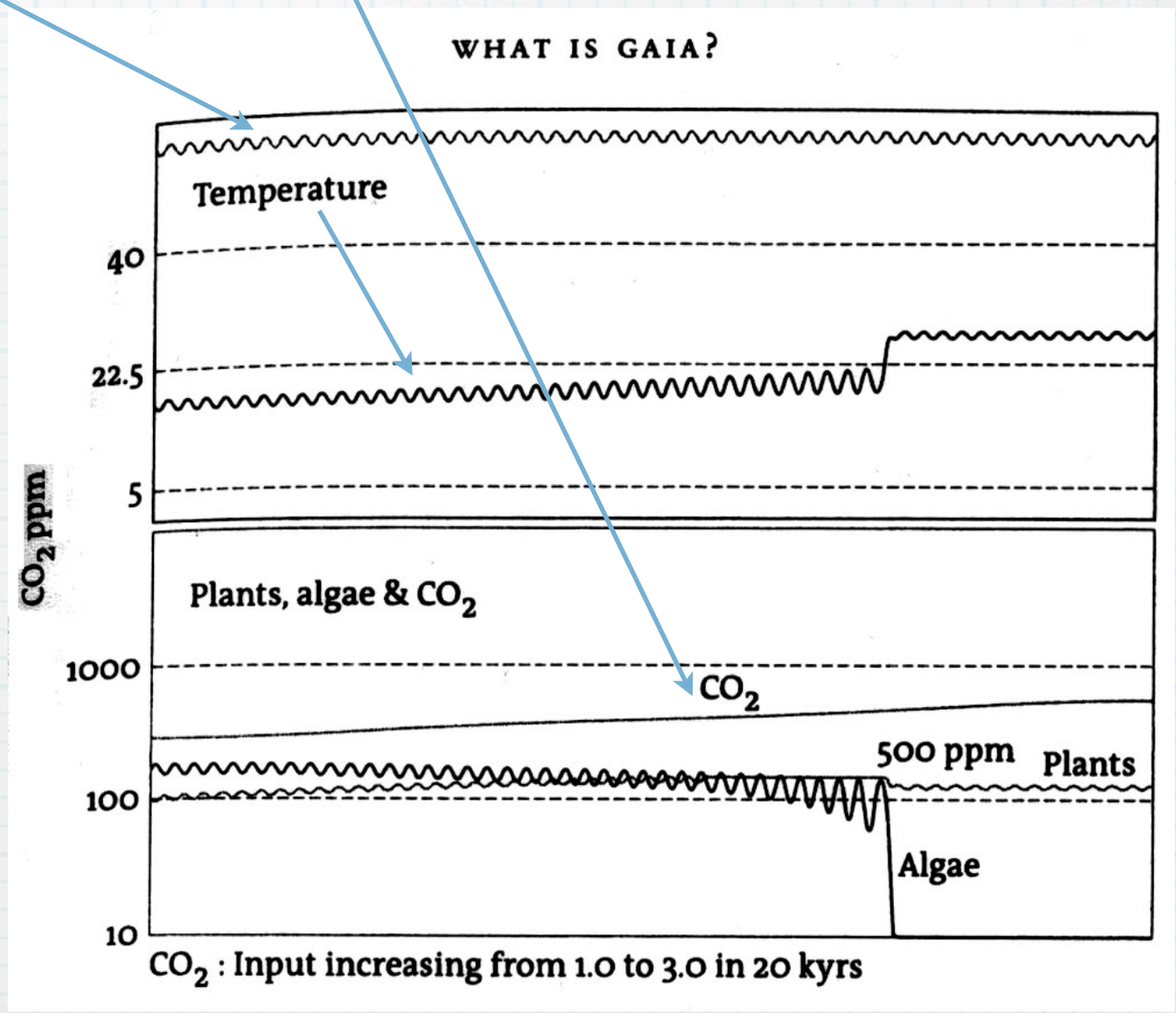
- What sets the temperature of a dead planet (like Mars):
- When solar input goes up, surface temperature goes up.
  - Here the "leak" depends on the presence of greenhouse gases, which trap heat, "shrinking the opening."
  - You can't change the solar input.
  - To get a lower steady-state temperature you could increase the opening (reduce greenhouse gases).
  - Or you could increase reflection (clouds, polar ice).
- If Earth were like that, and it got too hot, we could always get serious at that point and reduce CO2 emissions.
- But maybe on Earth there's a tipping point.



* In contrast to Mars, Earth's climate been stable, despite changes in solar input (indeed, a net overall increase). Why?
  * Hmm, our bodies also regulate their internal temperature despite changes in exterior. We have negative feedback stabilizing our temp.
  * Gaia idea: "A tightly coupled system whose constituents are the biota, the atmosphere, the oceans and the surface rock... [with] self-regulation of important properties like climate and chemical composition..." -- James Lovelock
* Similarly Earth's atmosphere has been stable, and very far from chemical equilibrium (e.g. very different from Mars), despite episodes of volcanic CO2 dumping etc. Why?
* Known negative feedbacks:
  * Plants catch light. Instead of heating the surface, they use the energy to capture CO2 and make O2, so less warming. And more CO2 -> more plants eating CO2.
  * Weathering of rocks, with the help of plants, is another negative feedback (pulls CO2 out of atmosphere).
* Daisyworld model
* Nobody really knows how this beautiful self-regulating system got set up in the first place.

* Unfortunately there are also positive feedbacks:
  * Ocean circulation: Hotter means no turnover (thermocline) means no algae means no photosynthesis. That's why tropical seas are clear; that's why whales have to migrate annually to cold seas.
    * Less photosynthesis means more CO2 -> Greenhouse effect -> hotter.
    * Less algae also means less sulfide release means reduced clouds, reducing solar reflection (albedo) and increasing solar input.
  * Greenland ice: warmer temp means less ice -> less reflection -> increased solar input.
  * Warm temperature activates soil bacteria that release CO2.
  * Warm temp brings more water vapor into air; water vapor, too, is a greenhouse gas. (Think about Venus.)

* Is there a tipping point? Are we close? If so what is the other equilibrium like?
  * Kump and Lovelock's 1994 model incorporates several of these mechanisms. They assumed steady solar input but dumping of extra CO2.



* The system abruptly flips to a new, hotter, stationary state.
* A few degrees in global average temp is a lot. It would change a lot of land to desert.
* Sorry -- there is no reason to think that Gaia "wants" to save us from the consequences of our actions.
* And there is no reason to believe that the change that follows a tipping point will be gradual.

* Attitudes:
* "Maybe its wrong. It's just math."
  * It's true that many theories are wrong. OK, so let's see YOUR evidence that it CAN'T happen. Even if there's just a 1% chance it's right -- that's too much. Are we willing to bet EVERYTHING that it won't happen?
  * Scientists don't often articulate this, but the propositions we desperately wish to be true are the ones we must mistrust the most.
  * It's true there are still big uncertainties, e.g. concerning clouds. But uncertainty can go either way. Mere uncertainty is not evidence that things are OK; it's just an opportunity for wishful thinking.
  * ANYWAY, you can't trust my generation any longer. We're the ones who handed you this situation. You will have to evaluate this for yourself.
* "God set it up, and God will take care of it, if that's His plan."
  * We can't disprove this passive attitude. But surely God won't mind if we help.
* "Earth is an organism. Humans are an infection." There are three possibilities:
  * Organism could eliminate the infection. Bad.
  * Infection could kill the organism. Seriously Bad.
  * Symbiosis. That's our best hope. It's also a good attitude.

* Why have I wasted your time when I don't know the answers?
* I haven't wasted your time. I have told you the Most Important Question in Science.
* You could study Earth Systems Science. Then someday YOU can tell ME the answers.

- Options
  - Nuclear energy
  - Fewer people
  - Fewer cattle
  - Massive reforestation
    - (With new improved species of trees...)
  - Huge reflectors in space???
  - Mainly, stop worrying about the little stuff and get to work on the big stuff.

* "Why are you depressing us? Do you want to spoil our graduation?"
  * I'm not depressing you. I'm offering for your consideration a possible direction for your professional life. A very appropriate graduation gift.
  * People who know they are dedicating their lives to something big and important are not depressed. What may be depressing is knowing you're NOT doing that. E.g. if you have such a purpose, you won't fall victim to worrying about others' opinions of you.
* "I'm not talented in science."
  * In science there are a lot of brilliant people doing clever, unimportant things. There is room for merely smart people doing less clever, more important things.
  * It's also going to take politicians, economists, diplomats, writers, educators.... People with conviction need to scramble into action. If a million people, with the right scientific, political, ethical, legal... skills, get on it, a few may push the right door and it will open.
  * Starting about now, you get to make the big choices that will create your future brain. (Up till now you just had to do what so-called adults told you to do.)
    Or maybe you already have some more important project for your life?
* "Lots of people are already taking care of this."
  * But maybe YOU are the one who can have the big idea.

* Humans are very smart. We have overcome many lethal challenges.
* We have even overcome our first truly global systems challenge based on our own emissions: The ozone hole (not cured yet, but improving). In climate change the stakes are much higher, but there is still some time.
* We are bugs on the chair, but we're smart enough bugs to start to see the whole system "from the outside."
* But being smart is no good if we squander it on games. Now we need to find correct answers to big questions, fast.

* What I just said:
  * Tipping points
  * Analogy to the greenhouse system
  * Feedbacks in Earth system
  * Climate change may be abrupt.
* Reading:
  * Kerry Emanuel, "What we know about climate change" 2007.
  * Kump Kasting and Crane, "The earth system" 2d ed 2004.