Notes on *Horizon: Playing God* (BBC 2, 17th January 2012)

Section	Summary of contents
Start – 01:53	**Opening credits**: In the opening sequence, Rutherford points out that mankind has recently developed potential to radically redesign nature. Life as programmable machines. Starting to change our world. Unsettling, granting ourselves unprecedented control. High stakes game – can the power be abused?
01:54 – 09:07	**Farm**: Rutherford visits a farm in Logan County, a research facility belonging to Utah State University where principles of farming are being combined with latest science to create animals that "shouldn't really exist". Prof Randy Lewis explains the attractive properties of spiders' drag-line silk to him, and the fact that the spiders' cannibalistic tendencies make them impossible to farm directly in order to produce adequate quantities of the material. The solution? Transferring the gene for the silk protein into a goat, generating "spider-goats". The goats have been engineered to produce the protein for spider silk and extrude it in their milk. When challenged that this is "bizarre", Lewis counters that he considers the goats to be "normal". Goats are milked in usual way. The only difference from regular milk is the addition of the extra protein – it is not visible at the stage. (08:10) Explanation that gene coding for the spider silk protein initially transferred into goat embryo.
09:08 – 11:32	**At Lewis' laboratory**: milk filtered to remove fats and leave only the proteins. From purified protein comes the silk. Pulled out, laced onto spool. The silk is "biocompatible", potential for clinical use, tendon and ligament repair, doesn't cause immune response in the body. Contrast 1000s of years of selective breeding to pick characteristics for goats versus one generation to make radical transformation.
11:33 – 16:15	**Country church**: If transferring one gene is impressive, Rutherford notes, how about having the potential to move the whole genetic code for an organism? The recent ability to do this raises crucial questions about how far this power should be taken. In 2010 Craig Venter's team were accused of "playing god" when they produced "*the first ever synthetic life form*". Synthia, or *Mycoplasma mycoides JCVI-syn1.0* the

	more formal name for the organism, is "*the only lifeform on earth whose parent is a computer*". This is a reference to the fact that the sequence of DNA in Synthia was decided in advance using online genome databases and then the DNA molecules themselves were produced chemically as a series of shorter sections assembled together to make the complete genome for the cell. In truth re-creating not creating life. [Demonstration using candle wax to draw cells (14:15). Slightly confusing – looks like nucleus in middle of cell, but bacterial cell doesn't have a nucleus. Putting printed sequence into the cell also hard to follow unless you understand the experiment *a priori*.] An unprecedented degree of control over life.
16:16 – 20:55	**San Francisco**: organisms as biological machines. "Synthetic biology". Ron Weiss (Massachusetts Institute of Technology) – programming biology. DNA as parts, built into circuits. Life in computer code can be accessed on any computer. Can get parts online. "Biobricks" approach, registry of parts. Biocircuits. Useful applications, e.g. potential cancer therapies, "targeted assassin". Mixing components for a biological machine in San Fransisco cafe. Brave New World.
20:56 – 25:35	**Seafood restaurant**: Democratic nature of biobricks. Student groups. iGEM – international Genetically Engineered Machine competition. Cambridge iGEM team, Cat McMurry. Squid. Colour change reflectin protein. Biobricks online. Beauty of open source, synthetic biology model = much of hard work already been done for you. Real progress becomes summer project v years of work. You then make your product available for others to use. Standardised toolkit.
25:56 – 33:11	**California laboratory**: Playing god as business opportunity. Amyris, to develop technology that might change the world. Dr Jack Newman. Industrial scale – "synthetic biology at full tilt". Integral role of robotics. Reengineering yeast to produce diesel not ethanol. Farnesene, oil from apple skin, also in biodiesel. Oil production. Microscopy – oil and cells separated in water, cells go to the bottom, the oil droplets rise to surface. Pilot plant, separating by centrifugation diesel from water and cells. 3 continents, expanding plants. (32:33) Fuel still diesel so global warming issues persist. Where should we draw the line between potential uses and safety (33:00)? Modified cells can't legally leave lab, but products can. An uneasy bargain.
33:12 – 34:17	**Beach**: Question – should synthetic biology be allowed out of the lab at all? How real is the threat? Self-regulation Added

	measures to prevent accidental release called from within the field. Contradiction. In lab v out in the world doing stuff.
34:18 – 36:02	**Café**: Discussion on ethics continues. Key issue is control. Synthetic cells inbuilt safety mechanism, a "kill switch", growth only possible in controlled conditions and with ongoing dependence on certain nutrients. Analogy to a box of safety matches – not 100% guarantee of safety. Life does tend to find a way. Creating and manipulating life is a high risk game.
36:03 – 38:02	**Woods**: Jim Thomas, ETC watchdog. Initially called for ban on release of synthetic organisms. Now see bigger issues are the industrialisation of the innovations – need to provide nutrients for the synthetic organisms. The use of plant biomass (e.g. sugar or eucalyptus) in order to become food for organisms that will then, for example, make plastics. Living things as feedstock. Raises issues of land ownership and land usage (37:35). With the human population increasing the poorest in society could be put at an even greater disadvantage by these developments.
38:03 – 41:20	**Driving**: What about intentional harm = bioterrorism. Suburbs (38:32): Sunnyvale, California. Conversation with Rob Carlson (expert of biorisk and advisor to FBI). (39:20) long way from high tech labs. Biotechnology now cheap and accessible, can set up a lab anywhere. Biomaterials orderable online include viral vectors. Comparison between BioBricks registry as a source of potentially harmful components and hardware shop as source of components for nailbomb. Carlson argues there are no components analogous to nails in the BioBricks registry. Over time however, bits like that may be. Currently, he continues, there are easier, non-biotech means to cause trouble if you so wished. (41:15) "*It's much easier to fixate on the threat than it is to embrace the opportunity from these new technologies*" (Carlson)
41:21 - 45:33	**Community centre**: BioCurious, community-based project, where you pay membership to conduct real experiments. "Biohacking" = DIY biology. Public, including children, doing real experiments with proper research equipment. GFP into *E coli*. "*You ain't seen anything yet*". Comparison to Microsoft's foundations in a garage. Prejudicial term "hacker". Potential of technology in universities, industries and communities.
45:34 – 51:07	**NASA**: another boundary = putting synthetic biology inside people. Dr David Loftus, Medical Direcotr at NASA Ames lab. Astronauts run risk due to radiation exposure. Investigating potential to treat astronauts for radiation sickness by using

	bacteria engineered to deliver therapeutic molecules. (47:39) Meeting of synthetic biology and nanotechnology. (NB coming together of various technologies – computing, robotics, nanotech). Safely containing the engineered bacteria in a biocapsule made of carbon nanotube. Won't be rejected by the body. Cells can't escape from nanotube but the therapeutic molecules can. Under skin, respond to radiation exposure? Novel drug delivery system. When? "*Just around corner*". 2-5 years. For all of us? Biological machines
51:08 – 57:21	**Driving at night**: Intriguing and unsettling. Controlling our thoughts? MIT Ed Boydon at MIT. Synthetic neurobiology. Electrical engineering background. Entering info into the brain using lasers. Animal experimentation (53:50). Mouse light responsive brain, molecules put into neurons. Eye spot from algae, turning flagella. Electrical pulses when hit by light. Virus putting these molecules onto surface of neurons – on/off switches. Controlling emotions? Cyborg mouse. The Matrix? Science fiction can be really inspiring for new technologies. Billion people some brain disorder. 20th century pharmacology. Affects normal and damaged neurons – side effects. Hit the defective, ignore the rest. Absolute cutting edge of ethical debate.
57:22 – 59:14	**Review of earlier clips**: Summarising, all based on idea you can use natural world as source of spare parts. New lifeforms, biological machines. Playing god. Access to this technology at breathtaking speed. "*Whatever you think of the uneasy bargain that surrounds synthetic biology, one thing is absolutely clear. We have created for ourselves unprecedented power over life itself.*" (58:22)