Part 1

A lake of many reflections

(Qinghai Lake, China, 1614)

All morning you have been watching the innumerable birds alighting, forming intricate flying beautiful designs over the crystal mirrorlike blue lake waters, then blanketing the shores.

Many patterns emerge to you as the hours pass under your watch. Groups of similar birds seem to take off in near-perfect tandem. They fly and shift directions seemingly at random but in near-perfect concert, while occasionally splitting into multiple groups following separate paths and breaking the initial flock into many pieces.

You make another game of trying to determine when a flock will split, and eventually gain some skill: patterns in the flock indicate an upcoming split, and with practice you can estimate how many groups, and with roughly what numbers, the path will diverge into.

You make another game of trying to follow a single bird, but fail again and again, your eye sliding amongst what seem like identical copies. When the pack splits, you find that you can never quite be sure which group the bird you originally chose has ended up in. You figure it's more likely to have ended up in whatever is the bigger flock, but try as you might you cannot make it definitive.

As you enter the drowsy hours of mid-afternoon, you imagine yourself as one of the birds, taking off from the shore, lost amidst your brethren. Your group splits, and splits, and splits again, growing smaller and smaller as other paths are lost to you. In each moment, your choices feel both random, and dictated by the surrounding birds. As you soar, you spy

a figure reclining on the lakeside, watching the intricate flying beautiful design of which you are a part. Beside you, you see an errant dove.

> In the case of most physical objects, on what I call the *standard view*, the criterion of identity over time is the spatio-temporal physical continuity of this object... Can there be gaps in the continued existence of a physical object? - Derek Parfit, *Reasons and Persons*

> In an eternally inflating universe, anything that can happen will happen; in fact, it will happen an infinite number of times.
> - Alan Guth

There are probably a few people on Earth who, though not close relations, look surprisingly similar to you. There are, after all, billions of living people, and (allowing some blurring) only so many basic shapes of noses, eyes, and so on. Yet differences would be easy to spot if you met these people; they'd only be similar, if strikingly so. But imagine that rather than 10^{10} people on Earth there were 10^{100}. It would take Kalpas of time to meet them all, but if you did so, you would undoubtedly find very many who look virtually identical to you. Still they would not *really* be identical. Genetically, for example, there are of order 15-20 million identifiable spots in the human genetic code that vary[1] among actual people. Even with just two possibilities for each variation that is 2^{10^6} possibilities, a vastly larger metakalpa sort of number. And if we wanted to be *really* exacting about it, to find someone literally, perfectly, identical to you down to the location of every atom, we already know how many possibilities there are: about $10^{10^{29}}$ arrangements of the bits – still metakalpish, but vastly bigger still.

Why should we care? After all, the Earth has just 10^{10} or so people. But let's think bigger. The *Universe* is definitely quite large, and and quite possibly *infinite.* What does it mean if it is?

There are lots of ways we can imagine an infinite Universe being. But by far the most interesting cases are those that are in accord with the "cosmological principle" of uniformity that we met in Ali's workshop. We might (as Einstein and decades of cosmologists did) simply postulate that the Universe is infinite and obeys this principle. We also saw, though, that if *eternal inflation* is true, then the Universe/Multiverse as a whole *manufactures* such regions, and throughout all spacetime contains infinitely many post-inflationary regions, each of which is infinite and governed by the cosmological principle.

The crucial aspect of the cosmological principle – indeed what is essentially its definition – is that space is *statistically uniform*, meaning that the probabilities governing, say, the configuration of a randomly chosen cubic meter of space are the same everywhere. In turn, this means that as we include more and more spacetime, eventually we will *run out of possible distinct configurations* and have to repeat the one that you, right now, are in. This is a spatial version of precisely the same argument we applied to the Thangka painting in the box: if the painting evolves in the box for long enough, eventually it runs through all possible states, and has to start repeating ones it has been through before. In space, given enough volume that is split into regions of some finite volume, there simply are not enough unique configurations of such a volume that

all of the regions can be distinct: with a big enough overall volume, *all* must be repeated. And letting the volume get unboundedly big, we conclude than in such an infinite universe you are just one of *infinitely many* instantiations of exactly the same physical configuration.

Still, why should we care? After all, you are very unlikely to meet any of your vague doppelgängers on Earth, let alone an exact duplicate $10^{10^{29}}$ miles away. So what do they matter?

Well, that depends upon how seriously the Djinn's nefarious duplication experiments are taken. Imagine that the Djinn, right now, creates a duplicate of you 50 light-years away. You may not care. But suppose in doing so he destroys the original? That's what we might call teleportation, and you may well be hesitant or terrified to have such a procedure applied to you. But would it not be far preferable than simply killing you outright? After all, "you" would at least still exist, and it is quite possible that "You" would feel nothing different than you do going to sleep, or even after a momentary lapse of awareness in your waking life.

But should you not feel *just as consoled*, if facing a sudden death, by the duplicate that is not 50 but $10^{10^{29}}$ light-years away, and created not by the Djinn but by the brute power of infinity and statistical inevitability?

If not, why not?

To sharpen this question, let us lay out some assumptions – many shared with the analysis of the Djinn's experiments – and see where they lead us.

First, looking at in the Djinn's experiments we assumed that there is no *separately essential "self"* that exists "on its own," but rather that the "self" is a mental process, albeit a central one, inextricably tied to other mental abilities and processes such as our memories, sensations, thoughts, decisions, and so on.

Second, we assumed that whatever the exact (and fairly mysterious) connection between and "internal" description of mental processes and "external" description of the action of synapses, biochemical signaling, and so on, that these two descriptions are in one to one correspondence. Thus a *state* of the physical system of our body is also a *state* of mind.

These two together imply that "you" right now are tied to "you" in the past and future by your memories and predictions, along with the continuous history of your physical body from the past and into the future, in a way that feels fairly natural and familiar. But it also suggests that were you to *sever* or *split* that continuous history, there would be something of a mismatch. Your internal experience could only be of a single, continuous, internal mental history, whereas from an external view there might be a large spatial or temporal "gap" between one moment and the next (teleportation), or a bifurcation between one moment and the next (duplication).

It follows, then, that any sensible stringing-together of a succession of states could be "You" as long as these states look like they represent the physical evolution of a human like you, but independent of whether these states actually "reside" in the same spacetime environment, or whether there is a single successor or antecedent to any given state.

In the teleportation experiment, this is unsettling, as it *feels* like there should be some difference between succession in a single place, versus a spatially discontinuous successful. It's hard to put a finger on what that difference is, but you can at least feel reassured that there is a single history even if discontinuous. The duplication experiment brings out the discomfort that arises if that uniqueness of the history is undermined.

An *infinite* universe makes things really, really strange. Consider the string of states that you remember going through, and let's assume that such states actually did exist in the world

but that there is no particular *unique* thread passing through successive states to hold them together. Well, then, it seems likely that the string of states you remember was strung together by states *all over the universe* – because if you don't require it, what would be the chance that "Your" state 1 minute from now would just happen to be the one "here and now" rather than somewhere else?!

As bizarre as this sounds, it may not be so crazy to think this way. Consider the collection, all across the universe, of states just like yours right now. You could even include a chunk of your environment if you wish – take along whatever you'd like; however much you include there is *still* an infinite set of copies. Now consider this big collection all at once. This is an *ensemble* that can be treated statistically, if only we had a theory that would describe an ensemble of physical systems to which we can attribute a single state describing the probabilities of things "happening" on the basis of that state. But we have such a theory – it's called quantum mechanics!

Indeed a quite popular variant of the "epistemic" interpretation of quantum measurement is that the state really always should be considered to describe an *ensemble* identically-prepared systems. This ensemble is often considered "fictitious," but what if we take this ensemble to be the *actual* existing ensemble of duplicates across the universe? A few researchers have actually taken this crazy idea seriously enough to think through the mathematics of it[2], and it actually holds together. What this work showed is that if you are about to perform a quantum experiment, in which quantum mechanics predicts probabilities P_A and P_B for outcome A and B, then after the experiment there will be version of you that saw A and that saw B, and that *if you count them up*, you'll find that across the universe a fraction P_A saw A and fraction P_B saw B. Thus if you say "after this experiment I will be a randomly chosen post-experiment version of me," then you'd recover the probabilities of quantum mechanics: P_A for A and fraction P_B for B. [3]

This is quite a radical point of view: "you" exist not "here and now" (which are relative not absolute) but scattered across the universe like so many identical birds on a lake that take flight. The flock of "yous" does not, however, do just one thing: it splits and splits and splits into groups that see different outcomes of uncertain physical processes. If you repeatedly just assume that you are a random choice of bird, then the sequence of outcomes you should expect to see are those predicted by quantum mechanics. And like in the many-worlds view of quantum mechanics, every outcome of every experiment happens to someone – not within the wavefunction, but somewhere out there in the universe.

So where does this put us (as it were)? If we accept *either* the many-worlds view of quantum theory *or* if we assume that the Universe is infinite and statistically uniform, *and* we accept that our mental state *now* is just a product of our physical state *now*, then we end up in a rather perplexing situation, far down a rabbit's hole, place where from the internal view it seems we cannot be killed, or even rendered fully unconscious. Should we accept this? Or should we treat it as so fundamentally absurd that it impels us to reject one or more of our hypotheses, or seek other flaws in our reasoning?

For many years I was deeply suspicious of the many-worlds view of quantum theory, for this among other reasons. But an infinite universe has always seems quite plausible, and eternal inflation has made it more so. Then I became fairly convinced that the two situations are essentially the same.

Now I don't know exactly what to think. Do you?

1. EN: http://www.nature.com/nature/journal/v467/n7319/full/nature09534.html?foxtrotcallback=true
2. EN: "Born in an infinite universe: A cosmological interpretation of quantum mechanics" by
Anthony Aguirre and Max Tegmark
Phys. Rev. D 84, 105002; see also "Multiverse interpretation of quantum mechanics" by Raphael Bousso and Leonard Susskind
Phys. Rev. D 85, 045007
3. EN: This might sounds self-evident, but what's interesting is that the proof does not assume the "Born's rule" connection between quantum amplitudes and probabilities: it *derives* that connection.