How to ‘Clone’ Sexually

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1. Introduction

Suppose Oedipus is born in Corinth in January 1980, grows up to be a time traveller, and in 2000 departs on a trip back to Corinth, 1979. He meets his mother, Jocasta, mates with her, and they conceive a baby who is born in January 1980. As it happens, the baby is himself.

Is this possible? Physically it is, in the sense that it is allowed by Einstein’s General Theory of Relativity (GTR). Gödel [1,2] was the first to show that there are solutions to GTR in which spacetime is shaped so as to allow closed timelike curves, and more recently other possibilities for closed timelike curves have been investigated [3-6]. A world with closed timelike curves would seem to allow a spaceship to make trips such as Oedipus’ journey from Corinth 2000 to Corinth 1979.

Is it logically possible? Gödel himself was worried by a paradox that has worried many before and after him. It would seem that instead of making love to his mother it would be within Oedipus’ capabilities to shoot her before his own birth. If he did, then he couldn’t exist and so couldn’t be there to shoot her; which involves an obvious contradiction. So on the grounds that it might involve contradictions, some have argued, time travel is not possible. However there is now an increasing consensus among philosophers of science that time travel is possible [7-10], since there are consistent scenarios concerning what could happen if time travel occurred. These won’t involve shooting your mother before she gives birth to you, which would involve a contradiction and so is impossible. And if a time traveller tried to bring about a contradiction, she would fail for some reason or other. Oedipus can try to shoot his mother, but whenever he does he slips on a banana skin or something.

But is it biologically possible? How could Oedipus and Jocasta have a child by sexual reproduction which is Oedipus himself? This would require that the father and child have identical genes, yet in reproduction the child inherits half his genes from his mother. In this paper we address the biological possibility of ‘cloning’ via sexual reproduction. Surprisingly, we are able to show that not only is sexual cloning possible biologically, but also in the case of time travelling incest, it is not even improbable.

2. The improbability of chance sexual cloning

A clone is usually defined by biologists as an organism or set of organisms that are asexually reproduced from one ancestral organism. Because clones are asexually reproduced, they are genetically identical with the ancestor. According to this definition, the essence of cloning is a form of reproduction (asexual rather than sexual), and the property of genetic identity is merely an accidental consequence of the essential property. If we accept this definition, the phrase ‘*sexual* cloning’ can only be an oxymoron. However, if we change the emphasis and define cloning in terms of genetic identity – a common enough practice these days, at least among non-biologists – then the phrase becomes meaningful. If the new definition is accepted, ‘asexual cloning’ refers to the generation of genetically identical offspring by means of asexual reproduction (the usual means), and ‘sexual cloning’ refers to the generation of genetically identical offspring by means of sexual reproduction.

Sexual cloning, as just defined, is theoretically possible but empirically improbable. To see how it is theoretically possible, suppose that Jack and Jill are two adult humans with different genomes. Suppose further that, for every locus at which Jack and Jill have different genotypes, Jill has at least one allele in common with Jack. In other words, even though Jack and Jill are not clones, there is no locus at which Jack and Jill do not share any alleles. This is very unlikely, given the degree of genetic diversity in the human species, but it is not impossible. Now suppose that Jill conceives a child with Jack. If the child were to inherit a particular set of genes from Jill, such that for every locus at which Jack and Jill are not identical homozygotes, the allele inherited from Jill were identical to the allele not inherited from Jack, then the child would be genetically identical to Jack. In such a case, a clone would have been produced by sexual reproduction, and we could therefore legitimately describe this as a case of 'sexual cloning'.

To see how unlikely this is in practice, consider first the chances that Jack and Jill have the requisite degree of genetic similarity. Although Jack and Jill need not be genetically identical, they have to share at least one allele in common at every locus. What is the probability of such a situation occurring by chance? There are about 100,000 genes in the human genome, of which about 30 per cent are polymorphic [11]. In other words, for about 70,000 genes in the human genome there is only one variant of that gene (one allele). For the remaining 30,000 human genes, there are at least two variants (two alleles), and often many more. Even with the unrealistically conservative assumption of a mere two alleles for each polymorphic locus, however, there would be enough genetic diversity in the human gene pool to gives us a total of $3^{30,000}$ genetically distinct types of human being. This is because for each polymorphic locus, the two alleles combine to produce three possible genotypes, and each polymorphic locus can potentially assort independently.

Now, what is the chance that two unrelated humans drawn at random will have the requisite degree of genetic similarity for sexual cloning to be possible? In other words, what is the chance that, for each locus at which the two people do not share the same genotype, they share at least one allele in common? Under our unrealistic assumption of two alleles for each polymorphic locus, there are three genotypes at each such locus: these may be designated, according to the standard notation, as AA, A*a* and *aa*. If we suppose that the frequency of each allele is 50 per cent (again, this assumption is very unrealistic, since the frequency of alleles will vary unpredictably at each locus), and if we suppose that the human population is at the Hardy-Weinberg equilibrium, then the frequencies of the genotypes are as follows:

Genotype	Frequency
AA	25%
A*a*	50%
aa	25%

The chance of two individuals having *no* alleles in common at a given polymorphic loci is then equivalent to 12.5%. So the chance of two individuals having at least one allele in common at any polymorphic locus is 87.5%. The chance of two individuals having at least one allele in common at every polymorphic locus is therefore $0.875^{30,000}$. This is a vanishingly small figure. To get an idea of how small it is,...

Even under our unrealistically conservative assumptions, then, the chances of two randomly chosen individuals having the requisite degree of genetic similarity for sexual cloning to be possible are vanishingly small. The chances of sexual cloning actually occurring, however, are even smaller. Even in the unlikely event that two people of the requisite genetic similarity mate with each other, it is still highly improbable that any offspring produced would inherit just the right set of genes from each parent for them to be genetically identical with one of the parents. For this to occur, at each locus where the parents were not identical homozygotes the offspring would have to inherit the allele in common from the non-clonal parent, and the other allele from the clonal parent. For example, if Jack is A*a* and Jill is AA, then the offspring must inherit *a* from Jack in order to be a clone of Jack (a 50% chance), or A from Jack if the offspring is to be a clone of Jill (also a 50% chance). If Jack and Jill are both heterozygotes at a given locus – that is, if Jack and Jill are both A*a* at the locus in question – then the offspring must inherit A from Jack and *a* from Jill or vice versa (again, a 50% chance). For each locus at which Jack and Jill are either both heterozygotes or have different genotypes, then, there is a 50% chance that the right combination of genes will be inherited in order for sexual cloning to occur. Even if Jack and Jill only have 20,000 loci at which they either have different genotypes or are both heterozygotes, the probability of sexual cloning occurring by chance is only $0.5^{20,000}$.

To calculate the probability of sexual cloning occurring by chance, then, we must multiply the chance of two individuals of sufficient genetic similarity mating ($0.775^{30,000}$) by the chance of an offspring of such a couple inheriting the right combination of genes ($0.5^{20,000}$), which gives an vanishingly small figure that we have not calculated.

3. The Solution: incest and timetravel

We saw that to have the degree of genetic similarity necessary for cloning, Jack and Jill must share one allele at every locus. If at a particular two-allele locus Jack has the pair AA then to be a suitable partner to clone Jill must have either the A*a* or the AA pair at that locus, thus making it possible that, as Jack passes on the A allele, Jill also passes on the A allele, such that the offspring inherits the AA pair, ie is a clone of the father. We calculated that the chances of finding a partner with the requisite genetic similarity at every locus on the genome is $0.775^{30,000}$. Here we assumed that the partner is drawn at random from the population.

However, suppose now the partner is not drawn randomly from the population, but instead is the biological mother; in other words, a case of incest. Since in sexual reproduction one allele at every locus is copied from the mother, a biological mother and son pair is guaranteed to have the requisite genetic similarity, sharing at least one allele at every gene site. So the probability that one's mother has the genetic similarity required for cloning is not $0.775^{30,000}$ but one. Jocasta is guaranteed to be the right partner to clone Oedipus when mating with Oedipus, because she is his biological mother. If Oedipus has the AA pair at a given locus, it is guaranteed that Jocasta has at least one A allele at that locus, such that cloning is possible. Thus incest overcomes the first improbability of sexual cloning.

But we also saw that there is a second improbability associated with sexual cloning. Even given that reproduction is occurring with partners having the requisite genetic similarity, it still remains improbable that the offspring will inherit the right allele from each parent for every polymorphic gene site. We calculated this probability to be $0.5^{20,000}$, which is the probability that any child will have the genome they do given the genomes their parents have. Incest does nothing to overcome this improbability. So, still it is remotely improbable that Oedipus and Jocasta will successfully clone.

However, time travelling solves this second improbability. We saw in section 1 that philosophers have shown that a time traveller will never kill his mother before his own conception, since that would involve contradictions. If someone attempted such a murder, something would happen to prevent it. We will assume that this solution is correct. The frequency of successful attempts is certain to be zero. (Here we factor out cases involving resurrections, or mothers who are also time travellers.)

By similar reasoning, then, the chances of young Oedipus, offspring of time travelling Oedipus and *his* biological mother Jocasta, inheriting his father's genome are not $0.5^{20,000}$ but one. For any other inheritance would involve a contradiction, since old Oedipus is the later stage of the young Oedipus, and one's genome cannot change through life. It is certain that there will be no cases—frequency zero—of time travellers conceiving themselves who do not pass on the appropriate genes. If the father has AA at a site, and the mother A*a*, then with certainty the offspring will inherit an A from both the father and the mother. It seems time travelling overcomes the second improbability of sexual cloning.

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