

Is There a Natural Morality?



“One phrase, only one, will dictate our conduct, the expression of Jesus himself:
“What you have done to the least of my own, you have done it to me.””

Professor Jerome Lejeune

June 13, 1926 - April 4, 1994

Forward

The inspired poem on the back cover speaks to the plight of frozen human embryos, often abandoned as “spare” embryos after a couple has successfully achieved a pregnancy by in vitro fertilization.

Dr. Lejeune admonished “it is perhaps not good to make spare children”. A woman undergoing an in vitro fertilization procedure receives hyper-ovulating drugs causing her ovaries to release multiple eggs at the same time which are then extracted and combined with her husband’s sperm in a petri dish (which is substituted for the fallopian tube in which fertilization otherwise takes place).

The resultant fertilized eggs (human embryos) are ordinarily taken 2 at a time for implantation in the mother’s uterus (so as not to risk conceiving more than twins at one time) in hopes of achieving a pregnancy.

The leftover human embryos (very small ‘spare’ children left behind) are frozen (cryopreservation in liquid nitrogen at -321 (minus) degrees Fahrenheit) for possible future use. Dr. Lejeune explained that as you lower the temperature, you slow down time until you come to a point where time stands still which the temperature of liquid nitrogen achieves.

If one of the two implanted embryos ‘takes’, the “spare” human embryos are saved for future implantation in the mother if she chooses to have another child or children. Time stands still for these frozen human embryos left behind which remain viable in excess of 20 years. They have to be returned slowly and gently to the warmth of life, causing “time” to resume for them, bringing them out of their state of ‘suspended time’.

In his testimony in the Tennessee frozen human embryo case, Dr. Lejeune spoke of frozen human embryos as being “packed together in thousands in a container refrigerated by liquid nitrogen, reduced to a number in a register and deprived of all liberty in a frozen world where time itself is stopped, these extremely young human beings are confined in a concentration can”.

The judge in the case understood what Dr. Lejeune was saying, but the French press back in Dr. Lejeune’s home country translated this as ‘concentration camp’. In a book later published about the trial “*The Concentration Can*” (Ignatius Press) Dr. Lejeune had this to say about the mistake in the French press:

“Meanwhile, in France it was translated “concentration camp”, a doubly faulty translation. In the first place, it is a can and not a camp, and, further, the concentration camp was a means of accelerating death, whereas the concentration can is a means of slowing down life.

It is true that in both cases, the concentration wall imprisons innocents.”(Dr. Jerome Lejeune, Ignatius Press, The Concentration Can, p 9.)

Today, human embryos have become the subject of commercial exploitation with in vitro labs selling ‘spare’ human embryos for experimentation. Many in vitro labs offer to reduce the charge for the procedure if the woman will agree to give up any of her ‘spare’ human embryos. The presidential administrations from President Carter through President Reagan and President Bush the elder, President Bush the younger, and President Donald Trump all forbade it. The Clinton, Obama and Biden administrations have condoned it. This has created a ‘market’ for human embryos to be sold for experimentation.

Not a person on the planet has benefited from human embryo experimentation! Our hope lies with adult stem cell experimentation which does not involve the vivisection and killing of a small human being. In adult stem cell experimentation the adult stem cells are taken, for example, as a small skin scraping from the patient which are then manipulated by the technician and introduced back into the patient’s body seeking to restore the health of that person. And, since they come from the patient’s own body, they are not rejected.

Dr. Lejeune authored a proposal of law to respect these early little ones and save them from commercial exploitation. The proposal of law is reproduced here in the hopes that prolife legislators will introduce and secure its passage in their state legislatures and prolife congressional representatives will introduce it in the U.S. Congress.

IF WE WANT TO REMAIN TRULY HUMAN, WE MUST RESPECT AND PROTECT THE YOUNGEST OF OUR KIN.

PROPOSAL OF LAW

Authored by Professor Jerome Lejeune

Article 1

Before the law, each human being is a person, from fertilization until death.

All action of intervention, biological or medical, is licit only if its direct or indirect goal is to evaluate, to protect or to restore the health of that person.

Article 2

The human body is inalienable.

The products of the human body can be acquired with the agreement of the donor, properly warned of the use that will be made of them.

The gift of organs, freely consented to for direct therapeutic purposes for the recipient, must preserve the physical and psychological functions of the donor.

The consent of minor or incapable persons, which might be attested by their legal representatives, is submitted to the authority of the judge of the guardians and can be accepted only for regenerable organs.

Postmortem surgical removal must maintain the respect due to the dead person.

Article 3

The human embryo is inalienable.

The donation of embryos is forbidden, and agreements for the procreation or gestation on the behalf of other people is illicit.

No human embryo can be submitted to any exploitation whatsoever.

The pursuit of its continued development until its term, in the organism of the mother, must be offered to each embryo before another embryo is conceived.

Article 4

The human genome is inalienable.

It cannot be made the object of any ideological or commercial exploitation.

No manipulation of the human genome is licit, with the exception of the therapeutic interventions conforming to the three preceding articles.

In the interest of the person, or in that of the descendant or by order of the court, investigations of genetic constitution and biological filiation are licit.

Introduction

The late Dr. Jerome Lejeune (1926-1994) was to the world of genetics as Einstein was to the world of physics. He discovered the X21 chromosome responsible for mongoloidism (Downs Syndrome) for which he received the Kennedy Award from the hand of President John F. Kennedy himself.

Jerome Lejeune MD, Ph. D., was professor of fundamental genetics at the Rene Descartes University of Paris, a fellow at the Pontifical Academy of Sciences (Rome) and a fellow of the American Academy of Arts and Sciences (U.S.), the Royal Society of Medicine in London, the Royal Society of Science in Stockholm, the Science Academy in Italy, the Science Academy in Argentina, the Institut de France of the Academie des Sciences Morales et Politiques, that is, of Moral and Political Sciences, a special academy in France; and also the Academy of Medicine in France.

His published paper “*Is there a Natural Morality?*” which follows was written around the time of his testimony in the world famous Tennessee Frozen Human Embryo case in the Blount County Circuit Court, Maryville, Tennessee, August of 1989. He testified to the equal humanity and personhood of preborn children as embryos. Based upon his testimony, the court found frozen human embryos to be “**CHILDREN IN VITRO**” for the first time in the history of law; a truth our nation’s Supreme Court has yet to acknowledge.

Dr. Lejeune’s testimony in that case is reproduced in a book entitled “The Concentration Can”, Ignatius Press, 1992 and in the book “Symphony of the Preborn Child” which may be viewed and downloaded at <https://naapc.org>

In his paper “*Is there a Natural Morality?*” Dr. Lejeune points to scientific truths that are firmly established and will not change with time. Courts must come to the **TRUTH** if the **TRUTH** is to come to the courts. Dr. Lejeune opens his “*Proposal of Law*” with this **TRUTH: “Before the law, each human being is a person, from fertilization until death.”** Only when our Supreme Court acknowledges this **TRUTH** will it live up to the words written in the marble on the top pediment of the Supreme Court building: “Equal Justice Under Law”.

A humble man with a towering intellect, Dr. Lejeune had the ability to reduce complex scientific understandings to simple speech and down to earth examples that we can all readily understand.

Looking to the future he left us with these words:

“There remains, however, another question. Our power grows daily. We are going to make new beings (bacteria, vegetable, animals) by ways other than natural or artificial selection. By that very fact we are certainly going to modify the destiny of man before he perhaps modifies himself. I do not know if we shall be able, during our lifetime, to modify the human brain, but no one can show that this will always be impossible. In short, we are going to become more and more powerful.

The biological bomb is probably more dangerous for humanity than the thermo-nuclear bomb. Then we will indeed require something to guide us. It will be necessary to establish or rediscover a term of reference. Who can tell us whether this will be good or bad? Who will teach us that? In my profession as physician and geneticist, such questions arise every day.

Of course there are always some who suggest that we alter morality whenever any innovation seems to require it or a disruption of the mores suggests it. This method has no future because it cannot surmount the decisive difficulty: “Technology is cumulative; wisdom is not.”

So what are we left with? Wisdom itself. “What you have done to the smallest of mine, you have done to Me.” If specialists remember that, science will remain an honest servant of the human family but, if they forget it, if they forget that there exists above all a supernatural morality, everything could be feared from a denatured biology.” (Dr. Jerome Lejeune, *Is There a Natural Morality?* Lecture, 1989)

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Is There a Natural Morality?

by Prof. Jerome Lejeune

1. The Animation of Matter

In his quest for the truth, the biologist comes upon a two-fold evidence at the two extremes of the development of a human being. This evidence is clear: spirit animates matter.

First of all, take the macro and micro structure of the brain, from the most complex connecting network that we presently know on earth (measuring 200,000 kilometers in length, if one calculates in neurotubules) to that extraordinary play of synapses which causes a flow of particles to be engulfed by the receptive membrane when a vesicle bursts and emits a chemical mediator.

Curiously, our machine for eliminating the fortuitous and keeping only the deducible, mark of reason, is a computer of particles with an incredible velocity. In the synapsis itself, particles pass one at a time into each of the channels. Maxwell's demon (imp?) is at the bottom of this system which deciphers and puts order in the universe.

Most wonderfully, the least thought triggers this flow of ions and this extraordinary counting of particles. Spirit truly animates matter.

At the very outset, when a being begins its carrier, it is the genetic information which, accidents apart, dictates all its qualities. According to the felicitous formula of the mathematicians, the being called to life is reduced to its simplest expression.¹ The language is, of course, extremely miniaturized. In the head of a spermatozoid, there is a linear meter of DNA. If one brought together all the DNA molecules which will define each and every quality of each and every one of the five billion men who will replace us on this planet, the amount of matter would be about equal to two aspirin tablets.

What we know, beyond any possible doubt, is that all the necessary and sufficient information is present from fecundation, that is, from the moment when the information carried by the spermatozoid and that carried by the ovule are joined in the fertilized egg.

¹ Note that "essence" precedes "existence" here. Indeed, the coded message of DNA will be transcribed in RNA which will then be spliced. Secondly, proteins which are the machine tools of the cell, will be constructed in conformity with the code of the messenger RNA. Given the translation machine (the cytoplasm) on the one hand and the DNA formula on the other, one could know exactly the "essence" of the new being even before it is expressed, that is, even before "existence" of its properties is recognizable.

This idea that spirit animates matter is, in a way, inscribed in our very language. We use the same word for an idea that comes to mind and for a new being coming into existence. In both cases, we speak of conception. This is not a poverty of our vocabulary but implicit recognition, if I may put it so, that at the very beginning, soul and body, spirit and matter, are so interlocked that it is impossible to speak of one without the other. And language never has.

This leads us to consider the biologist's first responsibility: to explain to his contemporaries that molecular biology wholly excludes Cartesian Dualism according to which there is spirit on one side and body on the other. Living matter does not exist; there is only animated body, but animated by the nature of man.

A question immediately suggests itself. Are there Instructions for Use of this human nature? Is there a natural morality? Were I to express my thoughts very respectfully, if a bit abruptly, I would say that the Decalogue is the user's manual and the Commandments of the Church the instructions for maintenance for human nature.

But one would first of all have to establish that human nature does indeed exist. This is fiercely debated. Talk of human nature is not fashionable nowadays and, not too long ago, it was

pretended to be demonstrated that the human condition was, in fact, only a kind of convention admitted by one society, but different for another, with no way of knowing which was good.

If there is a natural morality, it would be wise to conform to it, not in order to direct science (for natural morality is itself an object of science), but rather to direct the uses of science and to decide about the technical applications of our knowledge, and how to put it to good use. Science is indeed the Tree of Good and Evil. It provides both good and bad fruits. Our whole responsibility as scientists is to collect the good fruits and not to offer the bad ones to our contemporaries and our descendants.

2. From Human Nature to Natural Morality

Of course it is difficult to define human nature; nonetheless, we must try to grasp what it is. For a geneticist like myself, the first step is simply to say, "Well, we know with certainty that this enormous genetic message, 10^{11} of bases in DNA, corresponds to a phenomenal quantity of information. Moreover, we know that it is because the conceived being has this information that it is human. In other words, the most modern and objective molecular genetics can be epitomized in a rough paraphrase of the beginning of St. John's Gospel. "At the beginning there is a message.

This message is in life and this message is life; and if this message is a human message, then, this life is a human life." Of course, one must decipher this message and that is already underway, but it is not necessary to get into overly technical details on how to read these extraordinary Tables of the Law of life which are inscribed in our DNA.

It would, however, be quite insufficient to consider only DNA. DNA is like a magnetic tape on which the symphony of life is inscribed, but it must never be forgotten that the rest of the fertilized cell is like the magnetophone which will decipher the code and play the symphony. When we speak of the quantity of information expressed in bits, this is not only what is inscribed on the tape, but also what is involved in the machinery that reads the ribbon and executes what it means.

Then it is not only some 10^{10} to 10^{13} bits that are involved, but an absolutely enormous number which at present no one can state precisely.²

² Even if one day this enormous number were estimated (and there is no theoretical reason why it cannot be), there would remain the great difficulty left unsolved by the theory of information. When the length of a message has been measured, one has in no wise measured its "signification." To repeat without error such variants as "bla bla bla," "ran tan plan," and other, "ron et ron petit patapon," could require a quantity of information equal to a sonnet of Petrarch! The "quantity" of information in the DNA of a chimpanzee is comparable to that in the DNA of man, yet it is quite certain that the DNA of man tells something more: since man speaks.

The first notion, then, is a genetic definition of the being. For the second notion we must return to our opening remarks on the brain. One need only remove the cranial dome to find in man the frontal areas and the Broca and Wernicke zones that are absent from the primates. These zones are necessary for articulate speech and coherent thought.

Without getting into comparative neuroanatomy, one can perhaps make a rough but nonetheless quite convincing observation. I travel a lot and no matter where I go there are two extremely instructive places I like to visit -- the university and the zoo. In the universities, I have frequently met eminent colleagues who shake their learned heads and wonder if, when all is said and done, their children when very young were not some kind of animals. But at the zoo, I have never seen a meeting of chimpanzees asking themselves, when all is done (and not said!) whether their children would not some day grow up into University members!

About a zoo, why not go in Australia? Down there you would meet rather stupid bipedal creatures for whom aborting their babies looks perfectly natural--I mean the kangaroos--and more precisely the King Kangaroos, roughly the size of a man.

At two months of age, the baby King, two centimeters long, is

aborted. He looks like a little sausage with one claw on each of his rudimentary limbs. He does not know where the maternal pouch is, (nor whether it exists at all) but he feels gravity. He climbs right up in the fur, and if the mother kangaroo stands still he will not fail to reach the pouch and fall inside it. Then, comfortably, he will suck a tiny nipple and grow for another seven months.

The remarkable thing is that the mother kangaroo will let him do so. She would not allow any other being to accommodate itself in her pouch! Obviously the recognition of the tiny sausage as a kangaroo being is somehow written in her nervous system.

If nature has taken the trouble of wiring the meager brain of a mother kangaroo, so that she could recognize the "kangarooiness" of the little kangaroo, I cannot believe that with their one and a half liter brain, the scholars have not been endowed with the faculty of recognizing the human dignity of the tiniest humans!

For my part, I conclude that human nature is evident to all. On this planet, man is the only creature who asks himself whence he comes, who he is. He is also the only one to have discovered, (and this from the beginning) that there is a connection between the passion of love and the reproduction of his kind. The most gifted or the best trained chimpanzee never has nor ever will know that there is a connection between copulation and the

appearance nine months later of a little ape who resembles him. Man has always known that Pagans quite rightly represented the god of love in the form of a child. This peculiarity, this knowledge which is, as it were, genetically inscribed in the heart of man, gives to his behavior, and especially to his amorous behavior, a dignity that does not exist in the rest of the life world.

If one agrees that there can exist a natural morality, it follows immediately that to dissociate love of the child and the child of love is an error in method. Hence the quite natural prescription of continual abstinence in the chaste celibate and periodic continence in the happy marriage. If monogamy indeed corresponds to human nature and if morality reserves to the husband the prerogative of being the only one authorized to deposit reproductive cells in the inner temple that is the wife's body, one then arrives quite simply at fundamental moral notions. Contraception, which is making love without making babies; extracorporeal fecundation which is making the baby without making love; abortion, which is unmaking the baby; and pornography, which is unmaking love are not in keeping with the natural dignity of man.³

³ The mocking remark that morality is ill placed in the bottom of panties exhibits ignorance of neuroanatomy. The cerebral projection of the genital organs is at the upper extremity of Rolando fissure in the interhemispheric surface, very close to the limbic system. That is to say, the genital is the only corporal representation to be in contact with the center of the emotions that move us: those which aim at preservation of

When technology gives us control over the very young human being, over the embryo which can be formed in a quasi-alchemical phial, and even brought back from a frozen state, this natural morality teaches us that young as he might be, as fragile as he might be, the human embryo is member of our species and by that fact ought to be protected from all exploitation. He is not a stock of spare parts to be drawn on at need. He is not a commodity to be frozen and unfrozen at will. He is not a consumer good for sale or exchange. He is quite precisely our neighbor, our likeness, our brother.

3. Stumbling Block or Sageguard?

It must now be asked if this morality, unchanged throughout time, amounts to an embarrassment for research. That is, is it an unfortunate taboo or, on the contrary, a precious guide? I would not pretend to give an a priori answer. Rather I will examine three examples.

A. Respect of the Couple

the being (hunger, thirst, aggression) and the preservation of the species (reproduction, protection of the young, love). It follows that we are so made that whatever concerns the genital directly involves the moral, neurologically speaking. Hence the impossibility of mastering emotive behavior if the will does not command also, and perhaps first of all, conscious and deliberate genital behavior..

The conjugal act is the only natural mode of depositing male reproductive cells into the feminine body, through the union of two persons. This physical union which alone renders valid and definitive the engagement of the persons is a desired and deliberated act of the spouses.

Fecundation of the ovule by the sperm, will eventually take place hours later, but the fusion of the reproductive cells is then a consequence of body physiology and is beyond the conscious and deliberate control of the spouses.

There is a fundamental difference between carrying in the male gametes (by union of the persons, i.e., the act of love, truly speaking) and the fecundation of the ovule (at the cellular level). As a consequence, if the technician carries the gametes he substitutes himself for the husband and, through a syringe, he achieves the act naturally reserved to the union of the persons. In this sense, there is substitutio personarum.

On the contrary, when the technician suppresses an obstacle preventing the fusion of the reproductive cells or alleviates an hormonal difficulty or anything else hampering fertility, he achieves adjutorium naturae which is the very purpose of medicine.

This operational distinction, which is in full accordance with

the Vatican instruction Donum vitae, is not at all academic. May I take the liberty of quoting a woman having just had her embryo transferred after extracorporeal fecundation. It is a little shocking possibly, but how enlightening. The anesthesiologist, the biologist and the gynecologists had performed the procedure in a respectful atmosphere accommodated with soft music. Instants later, to her troubled husband asking how the thing happened, the would-be mother answered abruptly, "I made love with the three!"

A realistic, or more precisely a surrealist description (that only a woman could discover) of the substitutio personarum we were discussing previously!

It remains to be remarked that consequences of extracorporeal fecundation are frightening for the human embryo - the technician who fosters him for two or three days in the incubator or deep freezes him for years in liquid nitrogen, is, in fact, the only person having truly parental power over him. Hence all the dangers of exploitation, all the perverse abuses already invented or yet unimaginable!

Conversely, the child conceived in corpore materno is protected from all these attacks, by the very place of his conception. The womb is not only a shelter incomparably better equipped chemically and physiologically than the most sophisticated

laboratory, but this secret temple is also possibly the only place really designed for the coming into the world of a new human being, committed to eternity.

The term secret temple is not pure metaphoric poetry, I learned in Japan. The Reverend Mother of charming sisters near Hiroshima taught me that in Chinese script, the uterus is defined by two "conjis." One means "shrine," the other means "concealed." When men try to tell the true story, no matter if they speak French, English or Japanese, when it comes to figuring out the place of the beginning of life's adventure, they reach two concepts: secret and sacred.

If I can propose an opinion, I would surmise that the long trip outside the mother's body implied by in vitro fertilization, is not a favorable solution. Progress in adjuorium naturae will soon make it an obsolete, undesirable and unnecessary complication. Two schools will appear: The one will fight sterility by plastics, grafts, molecular biology or what have you; the other will obstinately pursue extracorporeal fecundation. But its avowed purpose will no longer be the fight against infertility but an arbitrary dominion over human destiny.

B. Respect of the Embryo

By respect of the embryo I mean the human embryo. Is this a

taboo that retards research? I don't think so. The history of the past three years is very illuminating on this score. Three years ago, our colleagues in England tried to get a law enacted that would permit the experimental use of human embryos not yet 14 days old. I had the honor of appearing before the British Parliament to give a geneticist's opinion. What had been proposed was this:

If you give us the right to use 14-day old embryos, we will study different illnesses and obtain knowledge leading perhaps to a cure for mental retardation, cystic fibrosis of the pancreas, muscular dystrophy, Trisomy 21, and hemophilia.

In my testimony I was obliged to remark in a quite matter of fact way, that one could not study in a 14-day old embryo a disorder in a brain that had not yet formed, nor difficulties of blood coagulation (e.g., hemophilia) because the organs which form blood cells are not yet differentiated, nor an anomaly of the muscles which will appear only a week later. Finally, the project in no way enabled one to elaborate a logical basis for saying these experiments are scientifically necessary and absolutely indispensable for the study of the five diseases. I can tell you - and this is amusing - that this extremely simple intervention was very badly received. The scientific weekly, Nature, entitled it "A French Influence in Britain." Something

quite shocking. Nature went so far as to promise a free subscription to anyone who would provide a research project demonstrating the falsity of what I had said. That was three years ago. Nature has published no such thing and, to my knowledge, no one has received free that excellent scientific publication.

The truth is that it was not necessary to manipulate human beings. For in the course of these years, the gene of cystic fibrosis has been discovered. The gene of muscular dystrophy has been cloned and the protein it makes, dystrophine, is now known. Great progress has been made in the understanding of Trisomy 21 and hemophilia. Genetic engineering has made the anti-hemophiliac factor in artificially controlled bacteria, blocking one possible means of transmission of AIDS. All this without harming the life of a single premature human being.

But what about frozen embryos? They are accumulated by thousands in a crowded deep freeze tank. The low temperature brings time to a stand still! How is it called in history, this hopelessness of arrested people, concentrated in a hostile place where even the time was also arrested? Do you remember some half a century ago?

Today, people are questioning what to do with frozen embryos. Kill them? Or keep them for experimental benefit? These same

questions were asked fifty years ago.

The only answer is very simple. Concentration camps must be forever strictly verboten.

At this point, let me simply quote a phrase from our colleagues of the Max Planck Institute who wrote (in Nature):

The abuse of these techniques through experiments with human embryos (and pre-embryos if one considers a pre-implantation embryo not to be an embryo), must be condemned by the scientific community.

This declaration appeared a few months ago and I take comfort from the thought that the scientists in a country where the denatured doctrine of the Nazis was once enforced by the law, are restoring dignity to biology. As an honest servant of medicine, biology must be at the service of the patient, and must never again treat him as an experimental animal.

C. The respect of Mankind

If respect for human nature is not an obstacle to research, is it a safeguard? I tend to think so. I will take a very recent example under discussion at the present time - the abortive pill, RU 486. It is an anti-progesterone, a false key that blocks the site on which progesterone, the hormone indispensable for the progress of the pregnancy, normally acts. In technical terms,

this product is called Mifepristone; in practical terms, it is the first specialized anti-human pesticide. One can imagine, without any mistake in reckoning, that if this product is industrially manufactured it will kill each year more human beings than were killed by Hitler, Stalin, and Mao Tse Tung combined.

To eliminate the extremely young humans by a binary ammunition (anti-progesterone for poisoning and prostagladine for expulsing) is precisely the beginning of chemical warfare against humanity!

4. The Way, the Truth and the Life

There remains, however, another question. Our power grows daily. We are going to make new beings (bacteria, vegetable, animals) by ways other than by natural or artificial selection. By that very fact we are certainly going to modify the destiny of man before he perhaps modifies himself. I do not know if we shall be able, during our lifetime, to modify the human brain, but no one can show that this will always be impossible. In short, we are going to become more and more powerful. The biological bomb is probably more dangerous for humanity than the thermo-nuclear bomb. Then we will indeed require something to guide us. It will be necessary to establish or rediscover a term of reference. Who can tell whether this will be good or bad? Who will teach us that?

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Of course, there are always some who suggest that we alter morality whenever any innovation seems to require it or a disruption of the mores suggests it. This method has no future because it cannot surmount the decisive difficulty: "Technology is cumulative, wisdom is not."

So what are we left with? Wisdom itself: What you have done to the smallest of mine you have done unto Me. If specialists remember that, science will remain the honest servant of the human family but, if they forget it, if they forget that there exists above all a supernatural morality everything could be feared from a denatured biology.

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PCR is also capable of amplifying single minisatellite molecules and analysing single human cells (Jeffreys et al. 1988b). However, during the large number of amplification cycles needed to produce sufficient PCR product for detection, some loci show, in addition to bona fide amplification products, the occasional appearance of spurious products generated during PCR. Another significant problem in our experience is the inadvertent contamination of PCR reactions with minute traces of recombinant DNA or the products of previous PCR reactions. Nevertheless, individual identification based on DNA analysis at the level of one or a few cells is a feasible proposition.

With the greatly improved sensitivity provided by PCR, individual-specific DNA typing systems can be extended to the analysis of minute samples such as hair roots, 0.01-0.001 µl blood stains, urine, submicrolitre amounts of saliva and microscopic traces of semen. Another advantage is that crude cell lysates can be subjected to PCR (Li et al. 1988; Jeffreys et al. 1988b), obviating the need for purifying DNA.

Mapping variant minisatellite repeats

Even the most variable human minisatellites seldom show complete uniformity of repeat sequences in all alleles. Instead, variant repeat units are frequently present, often intermingled with the "normal" repeat units throughout an allele (Jeffreys et al. 1985a; Wong et al. 1986). Using PCR to amplify minisatellite alleles followed by end-labelling of the PCR product and partial restriction endonuclease digestion of repeat units, it is possible to explore this internal variation as a new source of minisatellite variability. Examples of this analysis of internal variation in different amplified alleles from the hypervariable locus detected by minisatellite clone AMS32 are shown in Fig. 4. Restriction enzyme HinfI

cuts every 29 base pair repeat unit to produce a continuous ladder of labelled DNA fragments. The absolute number of repeat units per allele can therefore be established, without reference to molecular weight standards or control DNA samples. In contrast, HaeIII only cleaves at a variant repeat unit which, on average, accounts for approximately 70% of all repeat units. As a result, the ladder produced by HaeIII is discontinuous. For any allele, comparison of the continuous HinfI ladder and discontinuous HaeIII ladder allows each repeat unit to be classified as to whether or not it is cut by HaeIII, resulting in an unambiguous binary string encoding the number of repeats and location of variant repeats along the allele. In principle, up to 10^{60} different alleles at the locus detected by AMS32 could be distinguished using this system, in contrast to approximately 100 alleles by conventional gel electrophoresis and Southern blot hybridization. In addition, alleles are distinguished by an unambiguous binary code, rather than by estimated molecular weight (with attendant error margins). It remains to be seen whether such an allele coding system can be technically simplified to the point where it can be routinely used in forensic analysis to establish matches between alleles in a suspect and in a forensic specimen without the need to estimate allele sizes or to provide side-by-side electrophoretic comparisons of DNA from the suspect and the forensic sample.

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To amplify minisatellites, oligonucleotide primers from unique sequence DNA flanking a minisatellite are used to drive the amplification of the entire block of minisatellite repeat units. The size of the PCR product is therefore determined by the allelic number of minisatellite repeat units. PCR products are subsequently detected by Southern blot hybridization with a minisatellite probe.

Faithful amplification of minisatellite alleles up to 5-15 kb long can be achieved. However, fidelity is lost at high numbers of PCR amplification cycles due to out-of-register annealing of minisatellite DNA strands at high concentration of PCR product, resulting in the profile degenerating into a heterodisperse smear of PCR products. For this reason, visualisation of PCR products by hybridization is advisable, although with careful control of PCR cycle numbers it is possible to amplify alleles up to 5 kb long to the point where they can be directly visualised by electrophoresis on an ethidium bromide-stained agarose gel (A.J.Jeffreys, R.Neumann and J.A.L.Armour, unpublished data; see also Boerwinkle et al. 1989; Horn et al. 1989).

Since the PCR reaction is best terminated during the early exponential phase of accumulation of product, there should be little or no interference between different loci being amplified. In practice, at least six different minisatellites can be simultaneously co-amplified from the same DNA sample and the products simultaneously or sequentially detected with appropriate locus-specific minisatellite probes. Simultaneous detection produces a PCR-derived DNA "fingerprint" (Fig.4) which can be readily obtained from as little as 1ng genomic DNA and which shows a good degree of individual specificity (the chance of false association between unrelated people is estimated at approximately 2×10^{-5} for the six minisatellite loci so far developed for PCR amplification).

[illegible]

The Invitation to Life

To you from the ones who cannot speak yet:

We are cold and know little life; We are near, yet we have traveled a great distance; We are young, yet so old; we are almost near death; We live on only one thing, and it is hope, a hope to where we belong; We cannot cry, 'cause we have yet to learn, and you seem to be deaf.

And perhaps, if you will come to sit among our table of life, where we so long to be, you will wish to see the Host of this party, because the host is the Life, the Beginning, and you cannot have the ending unless you have the Beginning.

So, the setting, we hope, is warm, and the music that will be playing is the sound of laughter, and something to the theme of "Joy to the World," and perhaps if you come, you can see us.

You will be led into a small, dark room that is very cold, and life does not stir here, and you will be asked to place your hand among our cold and dying hearts; You must be strong to see our life frozen, to be able to see where the crying has stopped, and where love does not grow, because nothing can grow here.

The air is too cold, and it must be something of hell to our souls. And we wish we could pray to God to get us out, but we have yet to learn.



And so, the table shall be set around this cold room, and I wish we could do better, but this is our home, so maybe you can put this aside, and be our guests, because the chairs are very empty, and it seems no one will come, and you are the only one; But perhaps, you can bring the sun, and then, I will join you.

~Ruth Palmer~

Trinity University July 16, 1998