Artificial in its own right

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Abstract

Genetic engineering and creation of artificial biological and non-biological organic systems is the only alternative available in the foreseeable future to counter the threats posed by synthetic nanotechnology and artificial intelligence.
Natural evolution proceeds at too slow a pace to keep up with artificial development. If the extrapolation of present trends is accurate then we must start developing organic-biological technologies as an alternative to traditional engineering technologies.
I would like to propose that the creation of new beings could be as attractive as the creation of a new architecture. The creation of "never before created creatures" is as creative as writing a sonata and can be as rewarding if we don't let our fears get the best of us.
Keywords: Artificial Cells, Artificial Creatures, Artificial Ecologies, Artificial Intelligence, Bio-Inspired Hardware Systems, Computational Autopoiesis, Computational Biology, Computational Embryology, Computational Evolution, Morphogenesis, Cyborgization, Digital Evolution, Evolvable Hardware, Cyborgs, Mathematical Biology, Nanotechnology, Posthuman, Transhuman.

Introduction

"Artificial in its own right" refers to the creation and burgeoning of artificial organisms. This includes everything from microbes to post humans.

I am postulating that the time when the measure of all things was "being natural" is now relegated to the footnotes of history. That the accustomed perceived positive value of natural is only relevant in its historical context and that this context has changed. The hegemony the "positive value of natural" is now a burden on our culture. If humans are to survive we must now build our future on the artificial. While nature still has her veto, she no longer defines the game. Evolution is no longer in the hands of nature[1] taking thousands or millions of years; today evolution is part of our culture and proceeding on the human time or post-human timescale.

I classify the artificial in to several groups and show their relationship. I then present some of the non-biological research that is relevant to artificial and future biology. This includes the systems biology, bioengineering, simulation and computational evolution. I hope to introduce you to what I will call the science of artificial biology.

I will divide the living world in to three groups. The first group includes biological based organisms, which include all the presently living organisms, which are carbon based, organic molecules and as far as we know have evolved over many thousands of years. The second group consists of all non-organic chemistry based organisms and as far as we know none exist today. The third group consists of all the organic based organisms which did not evolve directly from an existing biological based organism.

1. Biological
2. Non-organics
3. Organics

The argument is based on the premise that the rate of change is constantly increasing and that biological based organisms have the slowest rate of change of the three groups, thus the first group of biological organisms will not be able to keep up if their rate of change can't be improved.

The rate of change is constantly increasing and it is approaching a rate that exceeds the capacity of not only one human mind but also the capacity of our institutions. Given this the natural evolution of natural creatures has played out its role. In the future the artificial evolution of artificial creatures will take over.

Natural evolution has only been able to make use of a limited selection of materials. The most prevalent materials are the organic molecules with few if any exceptions. On the other hand the artificial ecosystem has made extensive use of inorganic materials so far, and is only beginning to make use of organic materials. A crucial aspect of this development is the increasing use of nano-scale design using both types of materials.

In computer science there has been a great deal of research on "autonomous agents". Computer scientists in their efforts to understand organization have come to study self-organization and the patterns it forms. This research has a parallel in the study of societies and the social sciences. Just as the biological sciences have their favorite "organisms" to study specific biological phenomena, the social sciences and the computer sciences have chosen insect societies to study "colony organization". These "agent based studies" are based on the interaction of individual agents, be they insects, computer programs or human beings.

What I am concerned with here is the use of living biological materials. The production of living tools! One of the purposes of this paper is to discuss some of the issues around biology as an engineering discipline.

I use the word artificial for that which develops at an accelerated rate due to the impact of culture. This is independent of the material or direct human involvement.

So as our knowledge increases we slowly come to realize how much we see reality through ourselves, just how much all our thoughts and we are a product of our environment. The very fact that we see time as we do is totally dependent on our life span.

The basic argument depends on an extrapolation of present trends in to the future and that present day expectations continue present trends. I feel it is also essential that I make the future I am predicting, visible and more understandable. I will use the media of film to show futuristic examples of designed creatures and their place in society of the future.

This has some difficulties, but given the present level of apprehension in this area, I hope the examples will show a somewhat more sympathetic view of future technologies.

The time is past when as Protagoras' said, "Man is the measure of all things; of what is, that it is; of what is not, that it is not."[2] The naive acceptance of anthropocentrism as providing the horizon is no longer tenable. The days of Frankenstein are past, the future belongs to Frankenstein.

It is absolutely necessary that we develop bioengineering and genetic engineering science and technology if the organic creatures are going to compete with the non-organic creatures.

I would like to propose that the creation of new beings could be as attractive as the creation of a new architecture. The creation of “never before created creatures” is as creative as writing a sonata and can be as rewarding if we don't let our fears get the best of us.

Discussion

The rate of the rate of change

There are several “changes” that punctuate this; the most prevalent is the changing time scales. The rate of change is increasing[3].
The advances in the computer capacity have increased our ability to collect facts and build a knowledge base; Computers gas increased our ability to analysis and present our knowledge and this increase, increases with each technical advance. This increased ability to handle large and ever more complex systems feeds on it's self, growing at an ever faster rate.
The question is can the human brain keep up. The answer is a resounding no!

The most important aspect of all these time-lines is the ever-shorting time frame. Each of the following time scales becomes shorter than the one preceding it, while at the same time the amount of change increases in each time scale. The change is measured in the increasing diversity of structures and processes in relation to a period of time.

Big bang time scale

From a biological perspective nothing happened on the Big bang time scale for the first 20 billion years. At 10 billion years ago matter began to clump i.e. the stars formed. It was only 4600,000,000 ago the earth formed. See the appendix and references for a detailed time line.

Geological time scale[4]

With the formation of the earth around 4.5 billion years ago the earth's geological history starts, the measure of time is in the million of years.
From this point, we still had 1000 million years before biological evolution started.
Geological time is divided in to Era: Units of a Billion Years since the beginning of the

planet. We are now in the Cenozoic era. Each era is divided in to Periods and Periods are divided in to Epochs.

Up until now things were moving at a natural pace. The pace has quickened. It took 16 Billion years (biochemical traces 3.875 billion years ago)to stumble on the first organic molecule[5], and only another 1 Billion years more to stumble on the first cell, but after that there was so much living stuff laying around that new creatures popup[6] much faster. Scientists have made baby steps in artificially reproducing some of the building blocks of life[7]. One paper gives the rate of evolution of a genus as about 8 million years[8], these numbers vary due to the level of organization considered, chemical, cellular, Organismal, ecological and so on. There are many works which cover the discrepancies in the know rates of Evolution at different levels of organization; I have listed several of them here if you want to investigate them further.
Rate of Evolution and Unification of Evolution Theories[9], Limits on the Rate of Evolution[10], Horse Evolution[11]

Historical time scale.

Cultural Stage: Each Epoch is divided into biological life, or cultural stages...an anthropologists or biologist's opportunity to set each time period to event which is considered significant by the classifiers

The time scales change from periods of billions to millions to thousands, to hundreds of years in an ever decreasing time period and increasing rate of change. We finally arrive at the human time scale where individuals get names.

Whether you take the father of chemistry to be Laurent Lavoisier in 1750 ad, or Jabir bin Hayyan in 803 ce the present age of enlightenment is very new.

Again it is the acceleration in the rate of change, which is important here. Each of the previous time scales becomes shorter than the one preceding, while at the same time the rate of increase in the diversity of structures and processes increase.

Behavioral timescales

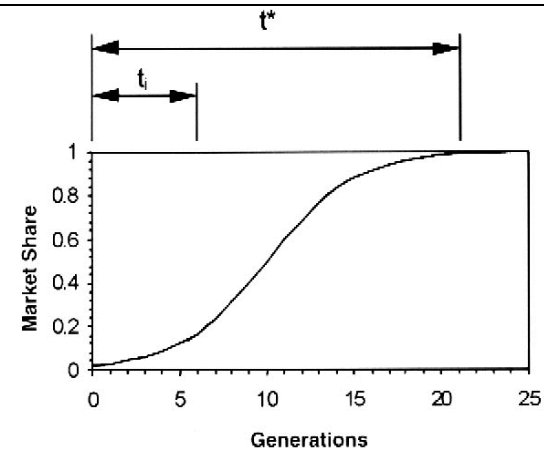
If we assume the human time scale limited by our rate of learning then the average human lifetime is close to the limit of the human timescale.

Now in the evolution of technology the time frame has shifted to a 10-year period. See **Time Line of Genetics** in the appendix

When the rate of change exceeds the human's behavioral timescales (the time to learn exceeds the life time of an individual), then the stage is set for a "faster" organism to evolve.

Evolutions Sweet Spot

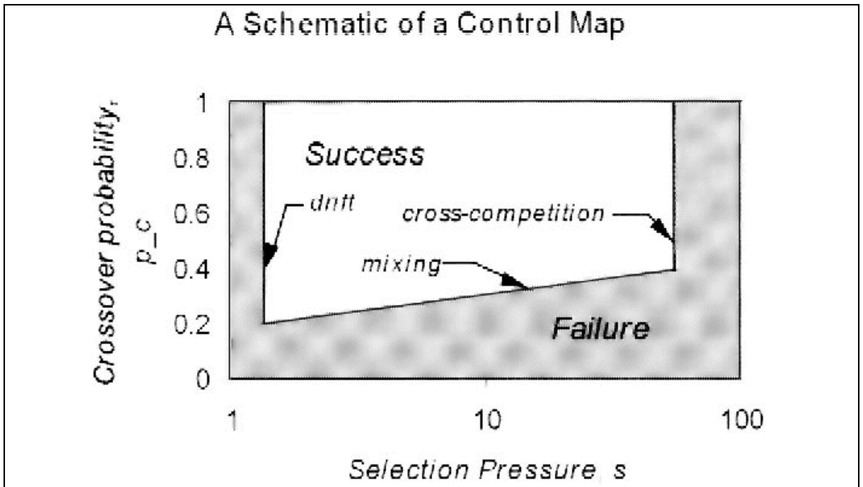
The science of change, which includes evolution, is coming into its own right. The following example is derived from Evolutionary Design by Computer[12]. Evolution can be analyses by considering it a race and its Sweet Spot. The race is a race between innovation and selection. Innovation can be genetic recombination, mutation or any process that produces a change in traits. The selection process has been analyzed and has parallels in markets share.



The race between innovation and selection, Peter Bentley, p110.

Selection has a takeover time, which is the time to go from one individual of a type to a population of individuals of the same type. The other important time is the innovation time, which is the mean time for the production of a new trait.
The key requirement for evolution is that the relation between innovation time and takeover time must be such that there is time enough to produce innovation and sustain a pool of innovation. It upon this pool of innovation that selection then works. If selection works too rapidly or the pool is not sustained the situation of premature convergence (the diversity decreases too rapidly for new phenotypes to stabilize) exists. Premature convergence severely limits the rate of evolution.

It is important that the population size be large enough for a statistical analysis. When the innovation time and the takeover time are in the same order of magnitude a state of mixing or steady state innovation exists. There are two other phenomena that can limit evolution. At low rates of innovation stochastic fluctuations dominate a population in the region know as the drift boundary. The other limiting process occurs when the selection pressure is very high. When the selection pressure approaches the population size independent traits start competing with one another. This severely reduces diversity and limits evolution slows due to cross-competitive interference.



Zone of success in simulated evolution, Peter Bentley, p112

When the rates of innovation and the population size are within the same orders of magnitude you have the “sweet spot”, a situation when evolution can proceed at an optimum rate.

The artificial advantage

Natural evolution has only been able to make use of a limited selection of materials. The most prevalent materials are the organic molecules with few if any exceptions. On the other hand the artificial ecosystem has made extensive use of inorganic materials so far, and are only beginning to make use of organic materials. A crucial aspect of this development is the increasing use of nano-scale design using both types of materials.

How ever the wider selection of materials is not the main advantage that artificial ecosystems have.
It is the shorter time scales which gives artificial evolutionary it’s major advantage. Artificial systems evolve thousands if not millions of times faster that “natural” systems.

The advantage of non-organic materials has bee stressed throughout engineering. There are areas where organic materials have superior engineering qualities, however these qualities stem from the nano-scale of the materials structure. As artificial evolution begins to operate on the nano-scale, the artificial material qualities will exceed even the best organic materials.

It is expected that artificial organisms will possess superior strength and agility, and at least equal in intelligence, to the genetic engineers who created them.

Let us look at the definition of artificial

Webster’s New World Dictionary[13] defines artificial as:

1. Made by human work or art, not by nature; not natural.
2. Made in imitation of or as a substitute for something natural; simulated
3. Unnatural in an affected way

4. Pretended feigned
5. Cultivated; not native, as a garden plant

The definition in its own right

Many authors have tried to define artificial, but have been only partial successful.
In Massimo Negrott's "The Theory of the Artificial[14]" Massimo gives the following definition in what he calls "the first level definition"

"In order to be defined as artificial, an object or a process should satisfy a necessary condition, that of being designed and built up by the man, and a sufficient one, that of aiming at reproducing some natural object or process.
Furthermore, as a basic assumption, the artificial object or process should be made by means of different materials and procedures as compared to the ones which characterize the natural object or process."

This definition reflects one of the often-made assumptions:
That artificial is defined in contrast to natural. Another assumption that anything artificial is made by man. A third assumption is that something artificial uses different material and procedures when compared to "natural" objects.

A simple thought experiment, I hope will illuminate the underlying concepts involved here. Let's say that we discovered that the present world was made by aliens and was not "natural" and that the aliens showed us the natural world, which was very different from what, we know.

What would this mean, how would it change our view of natural and artificial?

Without going into the observable details of such a discovery, we can immediately say that our feelings of "natural" have been "violated". A feeling of astonishment and loss would surely affect many of us. So one question that will help us understand the artificial is to ask what is this "loss" and where does it come from.
This thought experiment where the artificial and the natural become the same, provides an opportunity to ask ourselves what is the difference.
Is it, this "loss" that defines what is "missing" from the artificial as we perceive it today?
Note the fact that it is the artificial that is missing something, not the natural is another clue.

I use the word artificial for that which develops at an accelerated rate due to the impact of culture. This is independent of the material or direct human involvement.

It might be to far back, but historically, the word synthetic has many of the connotations of the artificial. In its historical setting the word synthetic was most closely associated with chemistry and the making of synthetic materials. Rayon, nylon and finally plastics were the new substances of the period. Synthetic lacks some of the overtones of "artificial" Synthetic things have the property of being "real" and at the same time artificial.

So an interesting line of reasoning is, what would the difference be between Artificial Life (ALife), Artificial Intelligence (AI) and Synthetic Life (SLife) and Synthetic Intelligence (SI)?

Our senses

A photograph embodies some of the qualities of the artificial. The photograph captures a view of reality that is more “real than real”. Everyone has noticed the difference between a picture and how things look to us. The question becomes is it the photograph, which is most accurate, or is it our view?
Our senses limit what we can see, if our eyes could see a wider range of radiation, for example the ultraviolet spectra[15] , everything would look different, as shown below.

http://vertigo.derby.ac.uk/BiologicalImaging/Shows/fys97/Eddie/biology.html

On a personal level, each one of us are familiar with the changes in our sense of taste (smell) when we have a cold and the peculiar feeling when your sense of touch has been numbed at the dentist or when our foot has fallen asleep. All these experiences give each one of us an opportunity to sense reality from another perspective.
These examples are limited by the fact that we sense “less” that we normally do, how ever there are a few technologies that have allowed us to experience “more” that our natural senses.
I will only name, the sense of motion and speed which the car and airplane have given us. The senses of wonder some of us have, when you take your first flight and experience the world from a bird’s eye view. Less common but scuba diving allows us to experience some of the fish’s world. Abet we can only image how pail both of these “assisted” senses are in comparison to the “real” thing.

I expect you have seen the dramatic effects of slow-motion photograph[16]. Our reality is limited not only by our senses but by our existence in time. Our “pace” of existence is probably the most limiting senses of them all. Our sense of time so infiltrates and captures us that we are hardly aware of it at all.

This was brought home to me most vividly in a slow motion film that presented the life of a starfish. As I watched the starfish on the sea bottom; they sat motionless, with a slight movement of their “arms”, catching food as it floated by.

To my amazement, the film then went on to speed up the starfish life to a rate comparable to my own sense of time. The starfish came alive with movement, visiting their neighbors, and running around busily carrying on their business. The great activity of the starfish had gone completely unnoticed to me. At my pace of life I was rushing by too quickly to notice.

So the next time you think about evolution or geography, try to picture how it would be if you could watch the mountains grow and move.

I don't have time to fully develop the concept of cyberspace, but I do want to mention one aspect of cyberspace which is related to simulation.
Cyberspace is the continuation and evolution of photography and video As a photograph captured things in time, a movie captured motion in time, cyberspace captures process in time. Cyberspace (experienced simulation) brings not only things and motion, but process to our attention.

Connotations of artificial

The concept of the Artificial encompasses many diverse ideas and connotations. I will briefly present size types of the artificial life, which are relevant to this paper. **Cyberic**, **Robotic**, **Synthetic** and **Organic**. All of these categories refer to the implementation and realization of a living organism. I illustrate these categories with examples from films, however the Cyberic, and Robotic exist today, Cyborgs and the Organic-Natural parts exist to some degree in prosthetics, surgical implants and transplant patients.

The **Cyberic** category contains two groups, and includes both the intelligent computers and the virtual reality simulations. The cyberic is also a realization within a computer with out another physical implementation. The other categories have a realization in the physical world.

> **Virtual reality** is the most abstract group, it is different from the others in that a whole community or ecosystem is involved, Tron (1982), Total Recall, Matrix, and Thirteenth Floor all represent this group.
> **Intelligent computers** are the similar to the virtual reality group, except only one being is simulated. they have been around for years, HAL from 2001 (1968) is the most well known.

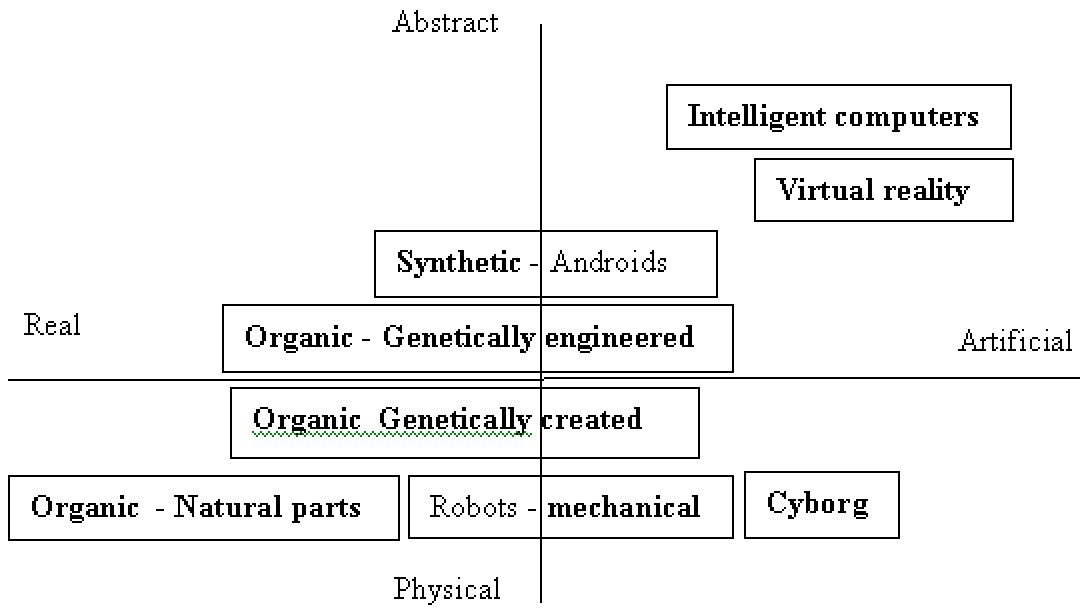
The **Robotic** category includes two groups.

> The **mechanical robots** include such famous robots as Gort (1951), R2 D2, Forbidden Planet's Robby (1956), number 5 and the Bicentennial Man. This category was the first to appear in literature and film. I reserve the Robotic for mechanical representations on the scale of the mechanical as opposed to the nano scale. It remains to be seen which of these categories nanoscale technology will fall. The **Cyborgs** are a mixture of human and machine. The Borg of star Trek, Robocop (1987) and Terminator are the best known.

The **Synthetic category includes** Androids, which are similar to robots, except they were assembled of synthetic material, and they resembled humans in form and capacity**.** Data

of Star Trek fame is the best-known example. Here the synthetic refers to representation on the chemical scale, this includes nanotechnolical implementations.
The **Organic** category is applied chemical scale implementations, which are closely related to present day biological organisms it includes three groups

> **Natural parts**, includes the most famous being, made from the surgical assembly of natural parts, Frankenstein uses this technique to create his monster.
> **Genetically engineered** humans such as Vincent in Gattaca (1997). Generally are not considered artificial, however this is a question of degree.
> **Genetically created** this last group is made from genetically or assembled manufactured parts; this includes Blade Runner (1982) and Existenz.



This figure illustrates the relation between the artificial and the abstract.

Cyber and artificial

The relatively new term "cyberspace" can help us understand the artificial. Cyberspace can give us a further understanding of the artificial. Cyberspace is the first concrete example of the artificial which exceeded the natural. Until now the natural was always the "more complete" and the artificial was the one that was missing something.

Cyberic development has one very great advantage over the other categories; it allows implementation directly related to abstract and theoretical constructions, unfettered by practical physical considerations.

A simple example of this, can be seen in the everyday use of "cut and paste" on the computer. I have reproduced some of the icons from the computer desktop to help illustrate this.  The use of the image of scissors for "cut" is a modern example of an Icon. I won't go into the use of Icons, but let me only mention that all the images from religious icons to computer icons is heavily laden with symbolism and metaphor. I refer you to Robert Haskell's[17] "Cognition and symbolic Structures: The Psychology of Metaphoric Transformation for further discussion.

Returning to the computer scissors, these artificial or cyberspace scissors has many of the properties of traditional scissors. I did not say “real scissors” here because the computer scissors are also real, I use them every day to cut. The computer scissors work much better than conventional scissors, cyber-scissors, can cut out something while not changing the original, cyber-scissors can make a copy when they cut maybe Xerox scissors would be a good name. I can correct my cutting with out damaging the original and the list goes on.

Cyberic implementations are extremely powerful. They free development from the limits of the physical world thus allowing unfettered development of theoretical and idealized solutions and solutions that transcend impedance barriers and other limits found in the physical world, but there is a high price for this freedom from constraints.
The combinatorial explosion in the development space becomes enormous and difficult to analyze. The “search space” of possible implementations far exceeds the useful or comprehensible. Development of cyberic systems requires that methods be found to limit the developmental space to a manageable and comprehensible level.

Giga pets probably represent the most widespread and successful cyberic organism. The closest competitor could be the cyberic ecologies represented by computer games. I would like to name one cyberic ecology that I find representative of the trend. MAXIS produces a line of cyberic environments.

The latest is SIMS, which I will simply call a cyberic dollhouse. However the dolls are cyber-alive. I do not want to give the impression that this “game” is an accurate scientific model of real people.
MAXIS also produce SimLife. In SimLife you can design and build your own animals and plants from the genetic level. Other simulation products included SimAnt, SimEarth, SimFarm, and SimCity. SimCity became one of the most popular computer games and was only superceded by the Sims.

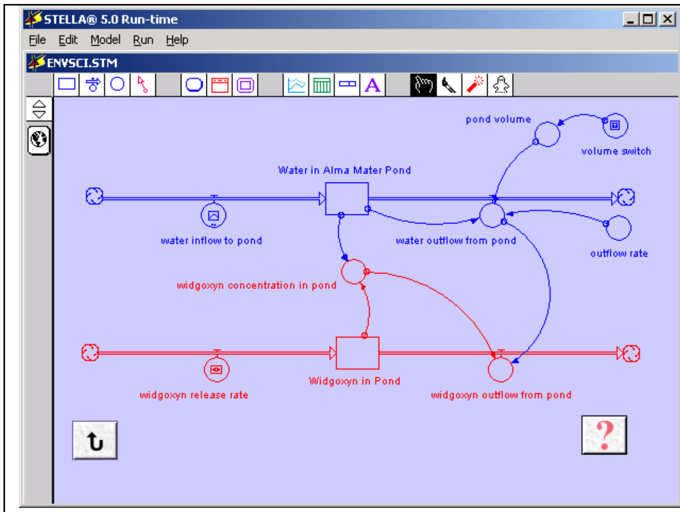
These examples are an attempt to show the face of future simulation in biology. This includes the level of realism that can be attained, including the mechanisms as well as the emerging behavior behind the actual creatures. The field of computer simulation is no longer limited to mathematical models, but is expanding to include the simulation of all aspects of the physical world. Chemical reactions are not only simulated at the ensemble level but at the actual molecular level, combining physical phenomena such as location and diffusion with the thermodynamic properties.

Simulation also represents the best attainable user interface to access the fact and the state of knowledge on any given subject. The ultimate knowledge base will use simulation as the ultimate user interface.

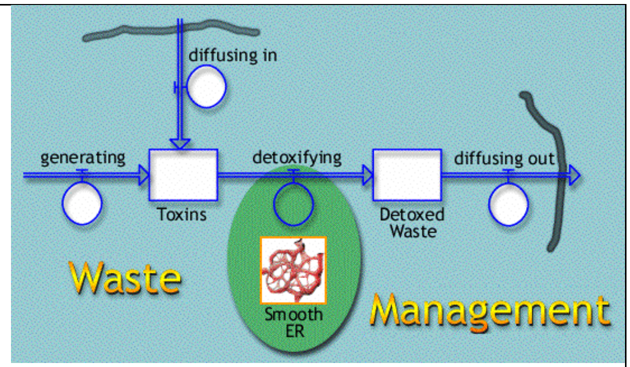
Present simulation tools capture different aspects of knowledge and to different degrees. Just like Expert systems it is necessary to capture knowledge, store knowledge, present knowledge and explain results to a human user. Simulation environments offer the best technology to achieve this goal.

The order of knowing moves from observing to writing about it, to teaching it, to doing it. I consider simulation in class of doing it. Simulations contain the most complete, verifiable, sharable knowledge representation.

Biology as a discipline still covers all four stages of knowledge, generalization, focusing, application and consolidation.



Ithink, High Performance Systems, Inc.[18]

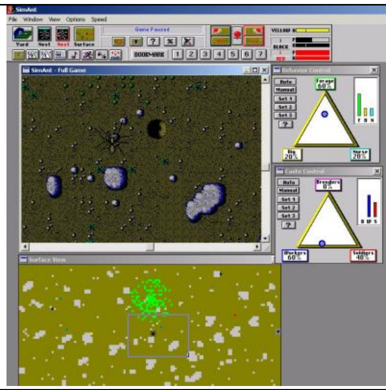


Many simulation models today have a graphic interface.

Academic cell simulation systems include:
MCELL[19], VCELL[20], ECELL[21], GENESIS[22]

E-cell[23], an environment for cell simulation (Japan)
VCell: University of Connecticut Health Center (USA).
Gepasi: Simulation of biochemical kinetics (UK).
In Silico Cell: Physiome Sciences Incorporated (Princeton, USA)
Mcell: A General Monte Carlo Simulator of Cellular Microphysiology

In order to show the future of scientific simulation I would like to give an example of MAXIS[24] computer games. MAZIS started out with educational simulations of insects, creatures and ecosystems. They then went on to simulate cities, individuals and small groups.

	
SimAnt, showing a simulated ant colony.	SimCity showing the bird's eye view

The simulation of a city was done most vividly in SimCity. SimCity is used in the architectural community as an educational tool for urban planning.

Sims by Maxis simulates people, interacting in a home environment. The simplest description is a doll and dollhouse simulation.	
	
The simulation of an individual personality and her local habitat.	

Maxis has released many simulation games; SimAnts simulated the world of ants complete with competitors. Another product, Creatures simulated evolution with mutations.

Simulations has the potential to become the standard interface to scientific knowledge repositories, making today's databases and their interfaces seem archaic. As the repository of human knowledge moves to the WWW and thus becomes machine-readable, all knowledge from textual to mathematical will be computerized. The trend is quite evident in Informatics where the combination of GENE, PROTEIN and metabolitic pathway data is being stored and accessed in databases available on the WWW.
It is only a short step until these databases are combined with the simulation programs mentioned above to form an integrated biological knowledge base.

I can't begin to present the rapid growth of scientific databases in biology, I will list several of the ones related to the Human Genome Project and genetic research.

PDB, 3-D biological macromolecular structure data, http://www.rcsb.org/pdb/

ExPASy Molecular Biology Server, http://www.expasy.ch/
Proteome, Inc., http://www.proteome.com/
Collection of links to various databanks, http://mbcr.bcm.tmc.edu/databases.html

Limits of human ingenuity

In order to illuminate the artificial from a different perspective let's get another view point. In the not to distant future man will make artificial living cells. Perhaps within ten years man will make the first "artificial living cell". What will the significant of this be?

Let me bring to memory another case of the artificial, once called a triumph of man over man. For years the ability to play the game of chess was one defining characteristic of mans uniqueness and intelligence. In 1997, Deep Blue, as IBM'S chess playing computer was called, beat the great Russian champion Garry Kasparov.
Ringing with the cries of a sore loser, the popular press redefines the problem in its efforts to make man the perpetual winner.
As so often the case these types of articles end with 'Machine's win hasn't proved anything'[25] or "Man is Really the Winner"[26].

This view of artificial is most prevalent in fields like Artificial Life (ALife), or Artificial Intelligence (AI).

There are numerous books and articles that expound just how artificial our society already is. The usual examples are eyeglasses, artificial limbs, and surgical implants. Other include shoes, home lighting, our homes themselves, all are brought to the forefront, showing our growing dependence on the artificial and how our lives are better through the artificial.

The traditional dependence on the use of artificial objects seems to me to be missing the point. Of course there may be a point, use is not dependency and dependency can be very far from free choice.

These things can be divided into two groups using artificial objects and
Looking at the dictionary definition again, the artificial is sometimes often implies an inferior substance or a counterfeit. There are whole cultural groups that fell that "natural vitamins" are better than synthetic ones. From a strictly scientific viewpoint this type of question comes down to "what are the differences between the natural and the synthetic object. Then it is left up to the individual's perception as far as his or her own feelings. This issue complicated by the fact that there is a whole industry whose goals is to sell "substitutes" most of which are not artificial in the sense of coping natural, but entirely new creations.

This brings us to another difficult quality of the artificial, in what degree is the artificial a copy of the natural, can the artificial every be free of our insistence of making it relative to the natural.

Only recently has the artificial fought its independence from the natural.

Both these conclusions miss the real point, that the artificial continually, one step at a time, is replacing the natural.
See the appendix for a list of Web links on the artificial.

The artificial is often put in opposition to reality. This too is an over simplification and distortion. Another common view is that we don't know reality, that we, at best, can only know the shadows of reality that our senses show us. And even here our very being, limits our ability to know reality.

This explosive developmental space combined with other practical advantages of a physical representation leads naturally to another implementation technique, robotics.

Cyberic organisms have one major advantage over the other types of organisms; the propagation of knowledge can proceed rapidly and with little cost. The period of human education is close to one third of the human life span. Artificial competitors will most likely not have this disadvantage.
This is one area where there is an urgent need for improvement and innovation in biological organisms.

Robotic and artificial

Robotic development has two very important advantages over cyberic development; the use of physical space conveniently limits the developmental space. All the constraints of the physical world are used to simplify and constrain the results of development.

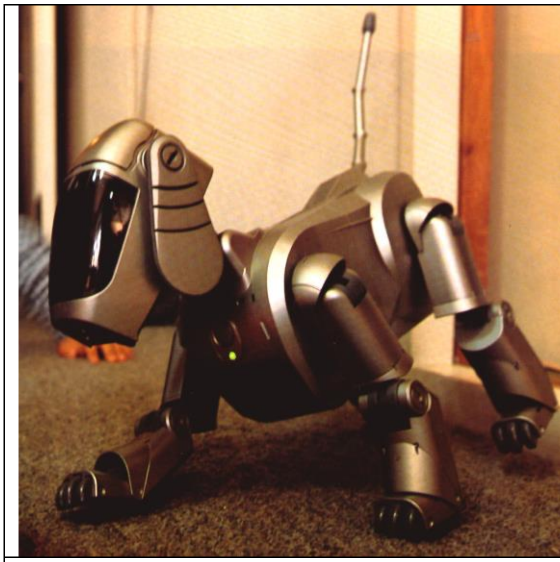
The simplest and one of the most important properties of physical space is that two things can't occupy the same space. While this is obvious, the lack of this constraint in cyberic development is a major problem. Of course the manufacture of physical representations presents its own problems. On the other hand a physical representation is easier to comprehend and has a whole range of physical uses.

As a result of the observability of robotic development I will not elaborate more on this category.

The subject of robotics is not new and has a vast literature. The most popular expressions of robotics have been in the films, Forbidden Planet, Terminator, and the most recent, Millennium Boy. These films show the dream; there is an excellent and very graphic book, which illustrates modern robotics, "**Evolution of a New Species Robo sapiens"**[27]

Let me just mention that the rapid development of robotics does represent a potential competing technology with the next to artificial forms, and natural technologies including our selves.

Today artificial synthetic creatures abound in cyberspace. Robots are moving from film into everyday life. The most recent and largest explosion of artificial animals was the gig pet craze. Giga pets were not real robots but a smart marketing of cyber pets in the form of individual lightweight and cheep "terminals" or personal digital assistants (PDAs). A somewhat more physical artificial animal abet still a robot was Sony's pet dog.



AIBO, Sony's robotic pet dog.

While these artificial companions have moved beyond science fiction and film, none of these new companions have move beyond robots.

The "robot" boy with other artificials., http://www.actiontrip.com/index.phtml

A.I.'s boy capabilities are impressive but limited, the boy is challenged. The limits in the boys capabilities help bring our own prejudices in to focus, bringing the question of empathy to the forefront, what is the limit to human empathy? Here, if we do draw a limit, it might beg the question are we human enough to be called human, are we really the “humans”. Would the rejection of “machines” offer proof that we do not define what is human.

Bicentennial Man, still looking like a robot.

Another film Bicentennial Man takes of a similar questions, in Bicentennial Man where the robot is first forced to adapt a human appearance then incorporate death in order to fulfill the demands of his surroundings. In the film, we demand death as a requirement to be human. This file is a good example of where “Artificial in its own right” lost its right to be artificial.

While the awareness of death and all its consequences, social, psychological, ecological and so on are an integral part of our existence, to make it an absolute requirement to be human is selfish and cruel. If we are to be what we think we are, human, then it will be necessary for us to learn to accept creatures whose capacities exceed our own.

I bring these issues up to contrast the limits in our behavior, if not perception, that make it difficult for us to understand the artificial from the artificials perspective.

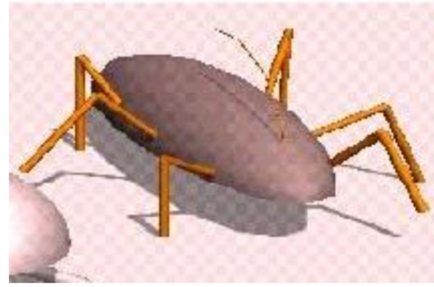
Present research in this area

One line of research is the development of Animats or cyber animals.
Animat Vision: Active Vision in Artificial Animals[28] is one site on the WWW.

Simulation, Robotics, Biology

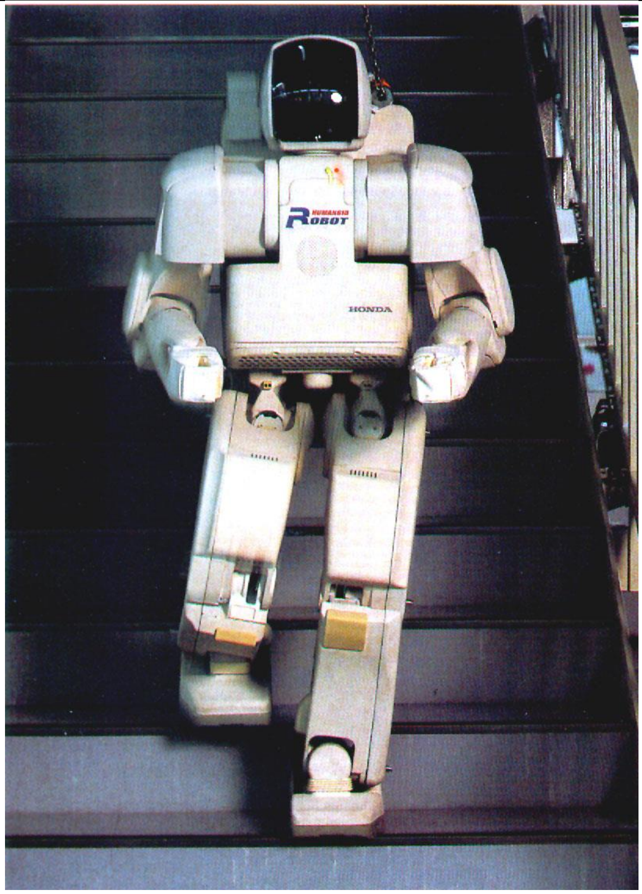
One major area of work is the simulation of insects. This work brings together to separate specialties of Robotics, simulation and biology. A brief view can be found at MIT Leg Laboratory[29]

The same research involves detailed scientific studies of cockroaches. Detailed bio and robotic engineering have followed up this collection of basic knowledge.

	
See Robo Sapiens	**Robo-Roach and the Future of Artificial Organisms**[30]

The question is which form of organism will evolve the furthest the quickest, computer simulation, artificial intelligence, and robotics? One thing is sure, if we do not develop bioengineering and genetic engineering, we will not be the winners.

While progress is being made in robotics construction of organic / synthetic / bio creatures is still far in the future.



The Honda Research Center has developed the Honda P3 as a step in developing new methods of mobility for non-organics.

It is the successful construction of non-organic creatures that makes research on organic creatures so vital.

The science of biomaterials is in its infancy and expanding rapidly.

Computational embryology

No introduction to Artificial would be complete with out at least a connection leading to **Complex Adaptive Systems** and the Santa Fe Institute[31] and Complex Systems Bibliography[32]

It is interesting that the concept of artificial intelligence seems more natural than artificial life. The very abstract nature of intelligence lends itself to the realm of the artificial. While artificial life clings to its "body" the body of life, resisting attempts to abstract it in to the world of ALife/\.

I have used the word synthetic as an alternative to artificial in order to concretize the object and station it between the artificial and the natural. Synthetic implies an embodiment that artificial does not

An Evolutionary Approach to Synthetic Biology:[33]

And another absolutely necessary reference is to Modeling of Plants and Fractals with Lindenmayer Systems[34]

I reserve the phrase ALife for the purely computational and closely akin to cyber or virtual.

I use SLife for synthetic life to describe all forms of life that depend on a physical embodiment and that are not virtual. I do not consider SLife in any substantial way different from ALife, except that it is dependent substance. This dependency offers a thin thread of connection to our own embodiment as biological life (Blife).

Anther very good Web page Visual Models of Morphogenesis:
A Guided Tour[35]
Virtual (purely computational) ALife: Hype or Science?[36]
Computational Embryology Workshop[37]
Another reference on Artificial Life: Synthetic Vs. Virtual[38]
Representations of Artificial Intelligence in Cinema[39]

While this article has concentrated on showing the acceptance and changing views toward bioengineering as shown in film there are numerous scientific articles on the coming design of artificial organisms. Reinventing the leaf[40]

Artificial in its own right

There are two avenues to approach the issues raised in this paper:

The first avenue is illustrated in a set of questions.
How will humans change themselves in order to continue to expand their abilities?
How will humans continue to expand themselves beyond themselves?
Humans have gone beyond their innate natural capabilities by extending our senses, our muscles and our minds, are we willing to change our own image of ourselves?
Can humans accept another species superior to our selves, even if we made the species ourselves?

The second avenue is to formulate the threat posed by the development of technology. Will our machines in one form or another develop beyond our own capabilities?

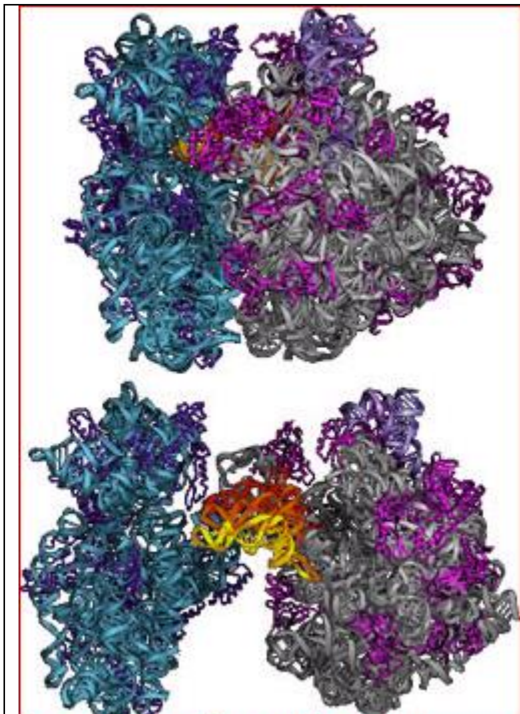
As we approach the possibility of non-organic life forms questions arise about the superiority of organic based life.

Recent developments question the superiority of organic life forms.

Assuming that an artificial mind can be built; will organic material be able to compete with non-organic materials?

First let me give some examples of where we are today.

The nano-motor was built by Ross Kelly at Boston College the chemically powered, molecular motor[41] is built of 78 atoms and works like a ratchet. There are many groups working on understanding the movement of living systems[42].
Another biological machine is the DNA computer.[43] If you want to know more about these developments search under Nanotechnology on the World Wide Web. In this paper I want to go beyond Nanotechnology and focus on biological machines.



A new view of the cell's protein factory

Protein factory reveals internal works

"The structure of one of the most fundamental biological machines was unveiled today, after investigations spanning nearly half a century. Researchers in California revealed a detailed map of the cell's protein factory, the ribosome. "

http://www.nature.com/nsu/010404/010404-1.html, and http://www.nigms.nih.gov/news/releases/noller.html

I would like to get one issue out of the way, people are not machines. Are people JUST biological machines? Are we just a collection of chemicals? NO, computers are not machines, The earth is not just a rock and a book is not just ink on paper. What is it about ink that makes letters?
People are made of biological materials, biological machines are made of biological materials, a DNA computer or a molecular motor are made of biological materials. The concept of emergence[44] has developed to help explain these phenomena.

What I am concerned with here is the use of living biological materials. The production of living tools! One of the purposes of this paper is to discuss some of the issues around biology as an engineering discipline.

A brief introduction in to the question of the Patentability of Higher Life Forms [45] is given in the footnote.

Even while all the components of cells, the biological machines we call cells, are not known, progress is being made, in understanding biological architecture and the process of construction and assembly used in cells. Biomedical Engineering is a rapidly growing field[46]. We are not JUST biological machines.

The evolution of the artificial in film

I am going to use film to show the technical advances made in recent years.

In the early nineteen hundreds robots were the cream-dela-cream of the artificial world, abet the imaginary one. These usually were of the mechanical variety. With this I mean that the construction was at the scale of the clock, i.e. metallic parts, with mechanical movement of mechanical parts.

The use of Androids came latter; Androids were still made of synthetic materials but these resembled organic materials. Only recently have artificial organisms appeared in film made of organic materials.

I could list many Science-fiction films that cover artificial creatures. Films[47] cover the gamut of Androids, Cyborgs, Robots, Creepozoids, Humanoids, Mandroid, druids, BioTech Warrior, Posthuman, Embryo and more. There are few films that have dealt with truly synthetic, bio-engineered creatures.

There were several early films that used serums or similar medical preparations to save monsterized people one was **The Wasp Woman** (1959) and another where using **royal jelly** causes every one in a family to start taking on the roles of workers and soldiers to the family mother who takes the role of a queen bee. This bring associations to the fear of having a photograph take on oneself of the fear of blood transplants in some subcultures. These fears seem to be closely related to today’s fear of creating life of the artificial.

Back in the 50’s there was a whole series of monster films, all of which used the fear of radiation and the atomic bomb as the cause of horrible monsters. In someway this fear of the atomic bomb predates the present fear of genetic engineering.

All of these films were sensationalistic and emphasized the risks and horrors of using technology. While more recent films still emphasize the risks many are now taking the technological as given and raising more ethical[48] if not philosophical issues.

In an effort to show the future I will introduce two modern films[49], where bioengineering is take for granted. Both these films have moved beyond the limitations of moralizing to directly address man relation to the new creatures.

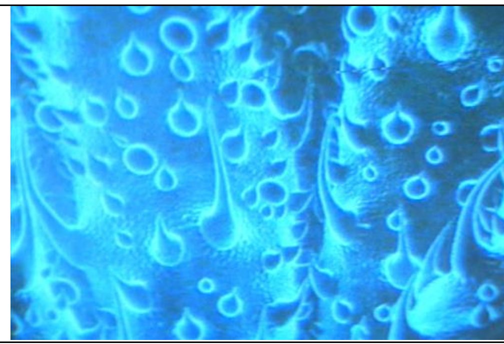
Blade Runner

While Blade Runner has been used many times to illustrate what it is to be human I will avail myself of the movie to illustrate the future of bioengineering.

There are three scenes from Blade Runner, which are particularly illustrative of the bioengineering theme.

In one scene, Decker the main character visits the Animoid bazaar. Animoid Row is a bizarre like quarter with small stalls, each of which sells artificial synthetic animals.

One scene at the bazaar has special significance. In this electron microscope view up of the artificial creature's scale there is a spectacular image of the artificial/real scale surface with its manufacturer's serial number.



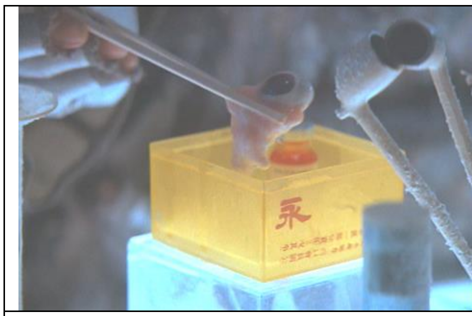
Close up electron microscope image of the artificial/synthetic animal scale[50]

While Blade Runner asks many interesting questions, it is one of the few films that show bioengineering in everyday use and is one of the best examples of bioengineering in popular culture. This scene gives some technical details of the state of bioengineering in the film.

The other scene is in the apartment of Sebastian, who is a genetic designer.
In the apartment we are introduced to several manufactured creatures. The nonchalant manner, in which these creatures occupy the apartment, is a fresh change from the moralizing and horrific nightmare visions of genophobics.

	
Scenes from Sebastian's apartment where he has several of his artificial manufactured creatures living with him	

The last scene I will present is in Chew's lab, Chew is an eye designer. Here you get another detail look at the bioengineering details.

	
In this close up you can see an artificial eye.	Here the eyes creator views his work.

Sixth Day Laws Passed

In 'The 6th Day', a man learns that cloning isn't so bad, The principle of racism can be applied to new creations as well as old. Evolution at a fast pace will be a fun ride.

Sim-Pals the future Tamagotchi

The Tamagotchi is a 'digital pet' created in 1996. Tamagotchi effect is a term that refers to the development of emotional attachment with machines or robots or even software. agents.

RE-Pet - Saving a friends life, a re-take

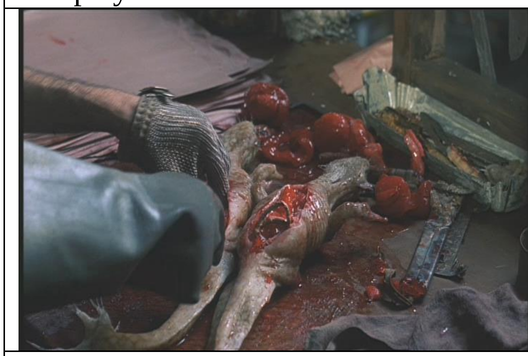
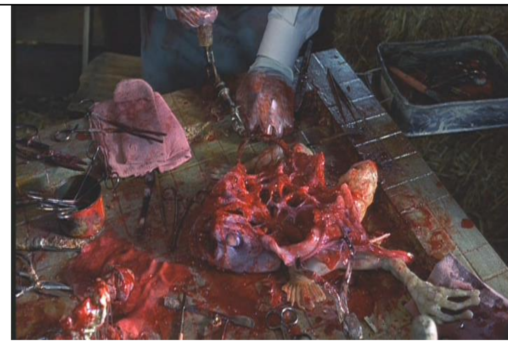
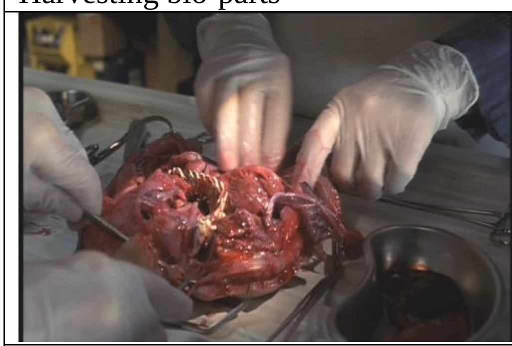
The film has a sign 'New Salmon'

As of September 2010, the FDA continues to take testimony over whether a genetically engineered salmon by **Aqua Bounty** is safe to eat, environmentally sound to raise, and whether it requires special labeling, there is a bigger question.

Existenz

This is one of the most unique film opportunities for a film presentation of bioengineering. The film is filled with scenes of bioengineered organisms and a biogame. It is also unique in that it is not preoccupied with the “digital” but an organic organ takes front seat.

	
The Bio-port, which is at the base of the spine.	The biogame is made of "metaflesh" and is a living organism that plugs directly to the player's nervous system via An "umbycord" a "bioport" which connects the bioport, which is also made of metaflesh, to the game module

	
Implanting the next generation biogame in a player	Assembling a bio-game
	
Harvesting bio-parts	Building a biogame
	
Repairing a (sick) broken biogame which is a manufactured animal	Giving medicine to a sick biogame

As you can see by these pictures this is a very unusual film. While most discussions of **Existenz** are about the existence, how real is real etc, from the perspective of this paper, the important thing is the intense use of bioorganic materials and the intense details. I know of no other film that actually shows construction using organic biomaterials.

Details of the organic games in the film are:[51]
MetaFlesh: The flesh-like material of which the game pod is constructed.
MetaFlesh Game-Pod: The game module, resembling a living kidney, started by depressing a nipple-like protuberance, causing a rhythmic, peristaltic rippling effect. The eXistenZ game-pod is basically an animal grown from fertilized amphibian eggs stuffed with synthetic DNA, a process exclusive to Antenna Research. Because it is an animal, it has a spine, bones and muscle and is susceptible to disease.

Bioport: Small, Metaflesh permanent spinal jacks positioned just above the belt-line into which the UmbyCord is plugged. The body's nervous system, metabolism and energy are the power source for the game.
UmbyCord: A split Y-shaped 12-foot connector cord resembling an umbilical cord with twisted, translucent, blue and red vein vessels running just below the surface. UmbyCords plug into ports in the back of the game-pods.
UmbyJack: The jack at the end of the UmbyCord inserted into the bioport.
Micro-pod: A miniature version of the game-pod, used to download new identities during the course of a game.
Gristle gun: A pistol made of bone and gristle, almost like the half-decayed body of a small mammal whose snout is the barrel, and whose rigid hind leg is the trigger. Instead of bullets, the gun shoots human teeth. It is designed to get past any kind of metal or synthetics detector.

Biological building, Biological cars, Biological machines?

The irony of today's world is while corporations are patenting "biological" materials the AI and related communities are discussing the rights of "created" beings.

Is a created species interior to its creators? Is a child interior to it's parents?
Will specieism join the ranks of sexism and racism?

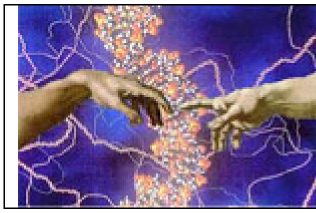
When I read statements like "Life cannot be given without freedom, whether this life is "artificial" or not.[52]" I accept the complexity of the world and sanctity of senescence. But life at its lowest level is process and organization. Like so many mysteries, it too shall be understood. It is up to us not to let understanding lead to a loss of fascination, disillusionment, or loss of beauty. I can still see the beauty of the sea, while understanding their science of waves.

The donors and recipients of organ transplants as well as prosthetics are closer to the realities of bioengineering than science fiction. Common uses of biomaterials include dentistry, orthopedic surgery, and treatment of tissue injuries.

I want to refer you Ethical Obligation To Genetic Research[53] and The Ethics of Synthetic Life Forms[54] for a short introduction to ethical issues related to synthetic beings.

Pioneering the Future

One area where bioengineering will have a great and immediate effect will be in the area of tissue engineering. In the short-term tissue engineering will revolutionize the treatment of burns, but in the long term the growth of entire organoid[55] (a hybrid organ composed of a biomaterial lattice coated with cells).

	Genetic Enhancements http://www.aleph.se/Trans/

Another area where biomaterials have and will continue to expand is the production of environmentally friendly materials that degrade and are biologically safe.
The present work on developing biomaterials for use in implants is promising. The development of sensors[56] that can smell is an active area of research. A related area is the direct interfacing of electronic signals and nerve cells. The first use of this technology is for treatment or assistance in nerve damage to the eyes or severed nerves.

While researching this paper I came across a new term “Transgenic Animals”. These animals could be used for production of food, medicine as well as organs.

It is important defend the freedom to innovate[57]. Defending the right to create using biological materials[58] is basic to this paper.

I hope that people fears will not block the path for the trailblazers[59].

Many of the discussion related to genetic research, Transgenic Animals, and the use of biological materials reminds me of the Dark Ages, when doctors were generally forbidden to perform dissection[60], Genetic manipulation is biology’s last taboo[61].

Another relevant background subject is the Turning test[62]. In AI and ALife the Turing test is often as a measure to answer the question “Can machines think?” The discussion of sentience beings is beyond this paper I just want to point out that philosophical discussions in area of what is considered sentient, conclude with compassion or empathy being the final Occam’s razor.

Paranoia in the Age of Simulation, Taking control

In the book “Do androids dream of electric sheep”, through the help of a simple and universally available and used machine it is possible to dial-in any desired emotion. A warning label is attached, warning the users to be particularly careful when they select depressing modes, since there is a risk that these modes will lead to a selection of even more depressing modes with a possible risk for a deadly outcome.

Here again is a case where “artificial” is judged as inferior to “natural” While a mechanical device in this case, it has an obvious parallel with drug use. Would our society ban the use of a “mood machine” would its use be considered a drug?

There is an apocalyptic strain running through some of the post-human literature. This view expounds the thesis that a future ecological disaster provides an environment where post-humanoid i.e. artificial humans are better suited than the “fragile” older model.

I would like to propose that the creation of new beings could be as attractive as the creation of a new architecture. The creation of “never before created creatures” is as creative as writing a sonata and can be as rewarding if we don’t let our fears get the best of us.

Spirituality

Spirituality is often reserved for human souls. Humans have denied the soul of other humans before on the alter of conquest. To deny created beings a soul is just as capricious. We may be afraid that our creations may be more human than human to coin a phrase.

Carved in granite above the door at the bioengineering college was the phrase “You can't say whether it works until it "speaks" to you!”

The article “The Golden Road To Unlimited Totalitarianism”[63] you can read phrases like “There is little clean air left, almost no pure water, and Frankenfood genes are jumping the fences all over the planet... The scientific establishment has decided once-for-all that it has the inalienable right to own life and death and all natural processes in between. While the human race is too busy earning a living to worry about anything else, scientists are, as we know, quietly patenting human genes.”

I recommend this article, as an example of what we must deal with if the science of the artificial is to reach it’s potential.
In order to help those people who feel lost and frightened by the future it is important to support them with a Future-Creative Policy which will relieve their fears and help them see change for what it really is.

> 'What is a human being, then?'
> 'A seed.'
> 'A... seed?'
> 'An acorn that is unafraid to destroy itself in growing into a tree'
>
> *David Zindell, The Broken God*

As we approach biology’s last taboo, I hope we can handle it better than the Dark Ages did.

The Culture of the Artificial

Richard Dawkin’s[64] Extended Phenotype raises many interesting questions, but I want to take this a step further. When humans wear glasses, replace their joints, or transplant a heart, these are our we are extending our phenotype.

Let me bring in another parallel with nature to show why our inventions are part of our phenotype.

In computer science there has been a great deal of research on “autonomous agents”. Computer scientists in their efforts to understand organization have come to study self-organization and the patterns it forms. This research has a parallel in the study of societies and the social sciences. Just as the biological sciences have their favorite “organisms” to study a specific biological phenomena, the social sciences and the computer sciences have chosen insect societies to study “colony organization”. These “agent based studies” are based on the interaction of individual agents, be they insects, computer programs or human beings.

The collective behavior in biological systems extends the study of “organization” from the cellular level to the level of societies. Today these phenomena are studied as “emergent properties of the system”.

Are wasp nests part of the wasp? Is a bee’s nest part of a bee? Is the great barrier reef an individual?

Scott Turner[65] in The Extended Organism: The Physiology of animal-Built Structures gives a good argument for the extended Phenotype beyond the individual animal.

Where does the individual end?

There is a continuous usage of “organization” through all levels of living things, from the organelles[66], to cities.

I read once “that to look at an animal was to see the world it evolved in, that every living thing was a representation, a mirror of its environment.”

So as our knowledge increases we slowly come to realize how much we see reality through ourselves, just how much all our thoughts and we are a product of our environment. The very fact that we see time as we do is totally dependent on our life span.

The Nordic Committee on Bioethics has release a report of Transgenic animals - why? The report on the uses of transgenic animals and the ethical questions that have been raised. Nord 1998:508, ISBN 92-893-0154-6 pp 82

In conclusion

In conclusion the artificial is the “natural follow” up to the natural not a continuation! The artificial will be different, no inferior, not missing, and different, with its own problems, insufficiencies and advantages.

“Artificial in its own right” refers to the creation and burgeoning of artificial organisms. This includes everything from microbes to post humans.

The time when the measure of all things was “being natural” is history. The hegemony the “positive value of natural” is now a burden on our culture. If humans are to survive we must now build our future on the artificial.
Evolution is no longer in the hands of nature[67] taking thousands or millions of years; today evolution is part of our culture and proceeding on the human time or post-human timescale.

The living world can be divided into three groups, the biological, the non-organic and the organic. Biological organisms will not be able to keep up with the other two groups, if they are not made aware of the competition.
The rate of change is constantly increasing and it is approaching a rate that exceeds the capacity of humans and their institutions. If humans are to continue to be viable, then genetic engineering is required.
While the use of nano-scale technology may help, the knowledge of our own construction is necessary if we are to compete.

Artificial life is life which itself evolves at an accelerated rate due to the impact of culture. This is independent of the material or direct human involvement.

I have used film to show examples of future creatures and their place in society of the tomorrow.

The time is past when as Protagoras’ said, "Man is the measure of all things; of what is, that it is; of what is not, that it is not."[68] The naive acceptance of anthropocentrism as providing the horizon is no longer tenable. The days of Frankenstein are past, the future belongs to Frankenstein.

It is absolutely necessary that we develop bioengineering and genetic engineering science and technology if the organic creatures are going to compete with the non-organic creatures.
It is important defend the freedom to innovate[69]. Defending the right to create using biological materials[70] is basic to this paper.

As we approach the possibility of non-organic life forms questions arise about the superiority of organic based life.

How will humans change themselves in order to continue to expand their abilities?
Humans have gone beyond their innate natural capabilities by extending our senses, our muscles and our minds, are we willing to change our own image of ourselves?
Can humans accept another species superior to our selves, even if we made the species ourselves?
How will humans continue to expand themselves beyond themselves?

I would like to propose that the creation of new beings could be as attractive as the creation of a new architecture. The creation of “never before created creatures” is as creative as writing a sonata and can be as rewarding if we don't let our fears get the best of us.

Author's note

On a personal note, this paper was partially motivated by a question posed to me several years ago, What right to you have to decide for future generations? I don't think there are simple answers; I think we should preserver the bio-enormous diversity that exists today and at the same time I believe new creatures will emerge.

The subject of this paper has covered several disciplines and at various degrees, please excuse the sometimes-varying levels of detail. I would like to thank, Dale Peters for giving me the opportunity to express my ideas and for his kind permission to allow me to expand on the original research project paper format.

Appendix

Conferences

ICCS International Conference on Complex Systems,
http://necsi.org/events/iccs/iccscover.html
ICSB International Conference on Systems Biology, http://www.icsb2001.org/
IPCAT International Workshop on Information Processing in Cells and Tissues,http://www.etro.vub.ac.be/Research/LAMI/Research%20Topics/evol/ipcat/welcome.html
ISMB International Conference on Intelligent Systems for Molecular Biology,
http://www.ismb02.org/
PSB Pacific Symposium on Biocomputing, http://psb.stanford.edu/
RECOMB International Conference on Research in Computational Molecular Biology,
http://www.erpland.org/recomb/

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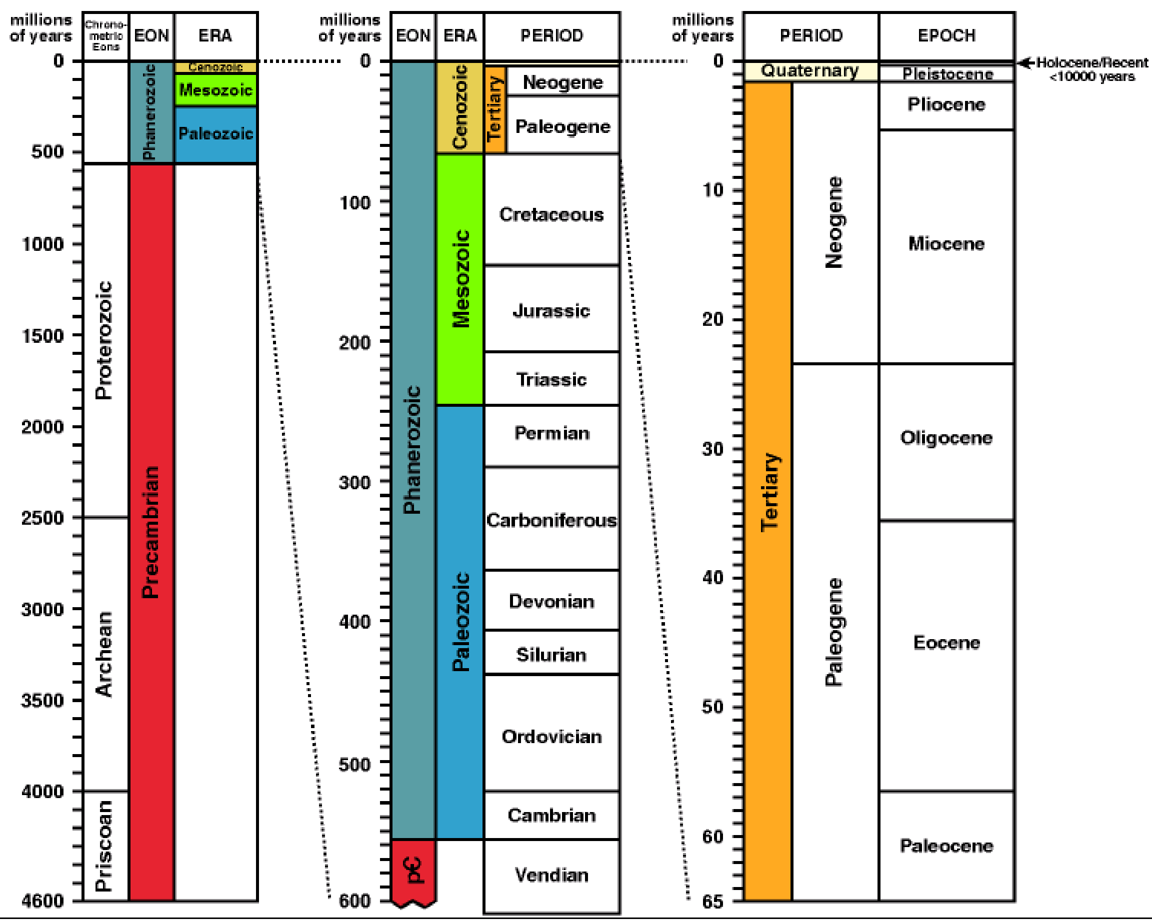
Geological Time Scale



http://www.geo.ucalgary.ca/~macrae/timescale/timescale.html

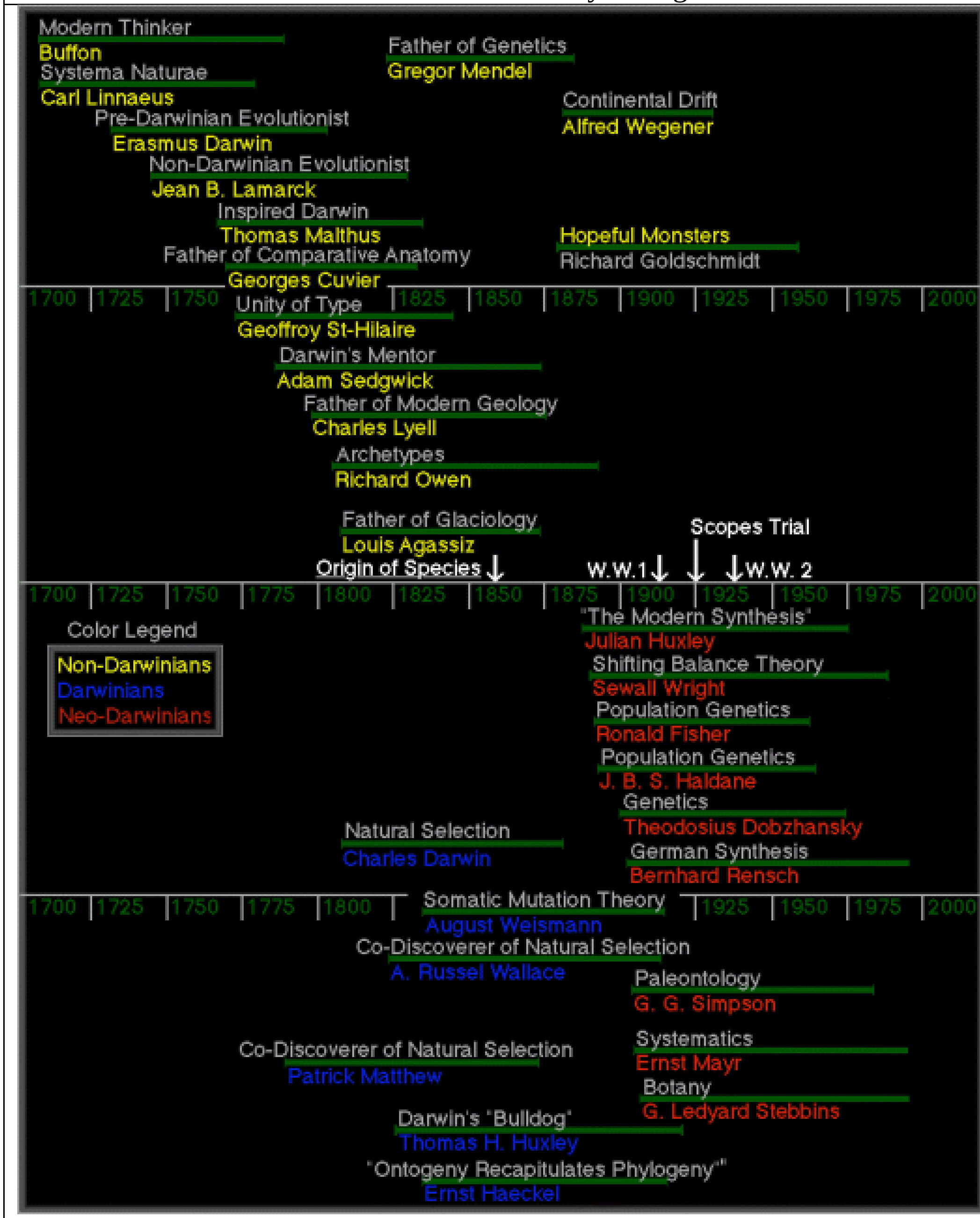
Evolutionary Timeline	
Time (Myr ago)	Event
4600	Formation of the approximately homogeneous solid Earth by planetesimal accretion
4300	Melting of the Earth due to radioactive and gravitational heating which leads to its differentiated interior structure as well as outgassing of molecules such as water, methane, ammonia, hydrogen, nitrogen, and carbon dioxide
4300	Atmospheric water is photodissociated by ultraviolet light to give oxygen atoms which are incorporated into an ozone layer and hydrogen molecules which escape

	into space
4000	Bombardment of the Earth by planetesimals stops
3800	The Earth's crust solidifies--formation of the oldest rocks found on Earth
3800	Condensation of atmospheric water into oceans
3500-2800	Prokaryotic cell organisms develop
3500-2800	Beginning of photosynthesis by blue-green algae which releases oxygen molecules into the atmosphere and steadily works to strengthen the ozone layer and change the Earth's chemically reducing atmosphere into a chemically oxidizing one
2400	Rise in the concentration of oxygen molecules stops the deposition of uraninites (since they are soluble when combined with oxygen) and starts the deposition of banded iron formations
2000	The Oklo natural fission reactor in Gabon goes into operation
1600	The last reserves of reduced iron are used up by the increasing atmospheric oxygen--last banded iron formations
1500	Eukaryotic cell organisms develop
1500-600	Rise of multicellular organisms
580-545	Fossils of Ediacaran organisms are made
545	Cambrian explosion of hard-bodied organisms
528-526	Fossilization of the Chengjiang site
517-515	Fossilization of the Burgess Shale
500-450	Rise of the fish--first vertebrates
430	Waxy coated algae begin to live on land
420	Millipedes have evolved--first land animals
375	The Appalachian mountains are formed via a plate tectonic collision between North America, Africa, and Europe
375	Appearance of primitive sharks
350-300	Rise of the amphibians
350	Primitive insects have evolved
350	Primitive ferns evolve--first plants with roots
300-200	Rise of the reptiles
300	Winged insects have evolved
280	Beetles and weevils have evolved
250	Permian period mass extinction
230	Roaches and termites have evolved
225	Modern ferns have evolved
225	Bees have evolved
200	Pangaea starts to break apart
200	Primitive crocodiles have evolved
200	Appearance of mammals
145	Archaeopteryx walks the Earth
136	Primitive kangaroos have evolved
100	Primitive cranes have evolved
90	Modern sharks have evolved
65	K-T Boundary--extinction of the dinosaurs and beginning of the reign of mammals
60	Rats, mice, and squirrels have evolved
60	Herons and storks have evolved

55	Rabbits and hares have evolved
50	Primitive monkeys have evolved
28	Koalas have evolved
20	Parrots and pigeons have evolved
20-12	The chimpanzee and hominid lines evolve
10-4	Ramapithecus exist
4	Development of hominid bipedalism
4-1	Australopithecus exist
3.5	The Australopithecus Lucy walks the Earth
2	Widespread use of stone tools
2-0.01	Most recent ice age
1.6-0.2	Homo erectus exist
1-0.5	Homo erectus tames fire
0.3	Geminga supernova explosion at a distance of roughly 60 pc--roughly as bright as the Moon
0.2-0.03	Homo sapiens neanderthalensis exist
0.05-0	Homo sapiens sapiens exist
0.04-0.012	Homo sapiens sapiens enter Australia from southeastern Asia and North America from northeastern Asia
0.025-0.01	Most recent glaciation--an ice sheet covers much of the northern United States
0.02	Homo sapiens sapiens paint the Altamira Cave
0.012	Homo sapiens sapiens have domesticated dogs in Kirkuk, Iraq
0.01	First permanent Homo sapiens sapiens settlements
0.01	Homo sapiens sapiens learn to use fire to cast copper and harden pottery
0.006	Writing is developed in Sumeria
Modified from Evolutionary Timeline[1] http://www.talkorigins.org/origins/geo_timeline.html	

[1] Evolutionary Timeline http://www.talkorigins.org/origins/geo_timeline.html

Timeline of Evolutionary Thought



Derived from: Timeline of Evolutionary Thought[71]
http://www.ucmp.berkeley.edu/history/evotmline.html

Time Line of Genetics	
1750 B.C.	The Sumerians brew beer.
500 B.C.	The Chinese use moldy soybean curds as an antibiotic to treat boils.
100	Powdered chrysanthemum is used in China as an insecticide.
1590	The microscope is invented by Janssen.

1663	Cells are first described by Hooke.
1675	Leeuwenhoek discovers bacteria.
1797	Jenner inoculates a child with a viral vaccine to protect him from smallpox.
1830	Proteins are discovered.
1833	The first enzymes are isolated.
1855	The Escherichia coli (E. Coli) bacterium is discovered. It later becomes a major research, development and production tool for biotechnology.
1863	Mendel, in his study of peas, discovers that traits are transmitted from parents to progeny by discrete, independent units, later called genes. His observations laid the groundwork for the field of genetics.
1869	Miescher discovers DNA in the sperm of trout.
1877	A technique for staining and identifying bacteria is developed by Koch.
1878	The first centrifuge is developed by Laval.
1879	Fleming discovers chromatin, the rod-like structures inside the cell nucleus that later came to be called chromosomes . In Michigan, Darwin devotee William James Beal makes the first clinically controlled crosses of corn in search of colossal yields.
1900	Drosophila (fruit flies) used in early studies of genes.
1902	The term "immunology" first appears.
1906	The term "genetics" is introduced.
1911	The first cancer-causing virus is discovered by Rous.
1914	Bacteria are used to treat sewage for the first time in Manchester, England.
1915	Phages, or bacterial viruses, are discovered.
1919	The word "biotechnology" is first used by a Hungarian agricultural engineer.
1920	The human growth hormone is discovered by Evans and Long.
1928	Fleming discovers penicillin, the first antibiotic.
1938	The term "molecular biology" is coined.
1940	American Oswald Avery demonstrates that DNA is the "transforming factor" and is the material of genes.
1941	The term "genetic engineering" is first used by Danish microbiologist A. Jost in a lecture on sexual reproduction in yeast at the technical Institute in Lwow, Poland.
1942	The electron microscope is used to identify and characterize a bacteriophage - a virus that infects bacteria.
1944	Waksman isolates streptomycin, an effective antibiotic for TB.
1946	Discovery that genetic material from different viruses can be combined to form a new type of virus, an example of genetic recombination.
1947	McClintock discovers transposable elements, or "jumping genes," in corn.
1949	Pauling shows that sickle cell anemia is a "molecular disease" resulting from a mutation in the protein molecule hemoglobin.
1950	Artificial insemination of livestock using frozen semen (a longtime dream of farmers) is successfully accomplished.
1953	Nature publishes James Watson's and Francis Crick's manuscript describing the double helical structure of DNA, which marks the beginning of the modern era of genetics.
1954	Cell-culturing techniques are developed.
1955	An enzyme involved in the synthesis of a nucleic acid is isolated for the first

	time.
1956	The fermentation process is perfected in Japan. Kornberg discovers the enzyme DNA polymerase I, leading to an understanding of how DNA is replicated.
1958	Sickle cell anemia is shown to occur due to a change of a single amino acid.
1959	Systemic fungicides are developed. The steps in protein biosynthesis are delineated.
1960	Exploiting base pairing, hybrid DNA-RNA molecules are created. Messenger RNA is discovered.
1964	The International Rice Research Institute in the Philippines starts the Green Revolution with new strains of rice that double the yield of previous strains if given sufficient fertilizer.
1965	Harris and Watkins successfully fuse mouse and human cells.
1966	The genetic code is cracked, demonstrating that a sequence of three nucleotide bases (a condon) determines each of 20 amino acids.
1967	The first automatic protein sequencer is perfected.
1969	An enzyme is synthesized in vitro for the first time.
1970	Specific restriction nucleases are identified, opening the way for gene cloning . First complete synthesis of a gene.
1971	Discovery of restriction enzymes that cut and splice genetic material.
1972	The DNA composition of humans is discovered to be 99 percent similar to that of chimpanzees and gorillas . Initial work with embryo transfer.
1973	Stanley Cohen and Herbert Boyer perfect genetic engineering techniques to cut and paste DNA (using restriction enzymes and ligases) and reproduce the new DNA in bacteria.
1974	The National Institutes of Health forms a Recombinant DNA Advisory Committee to oversee recombinant genetic research.
1975	Asilomar Conference (moratorium on genetic engineering research). The first monoclonal antibodies are produced.
1976	The tools of recombinant DNA are first applied to a human inherited disorder . Molecular hybridization is used for the prenatal diagnosis of alpha thalassemia . Yeast genes are expressed in E. coli bacteria . DNA sequencing discovered; first working synthetic gene.
1977	First expression of human gene in bacteria . Methods for reading DNA sequence using electrophoresis are discovered.
1978	High-level structure of virus first identified . Recombinant human insulin first produced . North Carolina scientists show it is possible to introduce specific mutations at specific sites in a DNA molecule.
1979	Human growth hormone first synthesized.
1980	The U.S. Supreme Court, in the landmark case Diamond v. Chakrabarty, approves the principle of patenting genetically engineered life forms, which allows the Exxon oil company to patent an oil-eating microorganism . The U.S. patent for gene cloning is awarded to Cohen and Boyer . The first gene-synthesizing machines are developed . Researchers successfully introduce a human gene - one that codes for the protein interferon - into a bacterium.
1981	Scientists at Ohio University produce the first transgenic animals by transferring genes from other animals into mice . Chinese scientist become

	the first to clone a fish - a golden carp.
1982	Applied Biosystems, Inc., introduces the first commercial gas phase protein sequencer, dramatically reducing the amount of protein sample needed for sequencing.
1983	The Polymerase Chain Reaction (PCR) technique is conceived. PCR, which uses heat and enzymes to make unlimited copies of genes and gene fragments, later becomes a major tool in biotech research and product development worldwide . The first genetic transformation of plant cells by TI plasmids is performed . The first artificial chromosome is synthesized . The first genetic markers for specific inherited diseases are found.
1984	The DNA fingerprinting technique is developed . The first genetically engineered vaccine is developed . The entire genome of the HIV virus is cloned and sequenced.
1985	Genetic marking found for kidney disease and cystic fibrosis.Genetic fingerprinting enters the courtroom. Genetically engineered plants resistant to insects, viruses and bacteria are field tested for the first time . The NIH approves guidelines for performing experiments in gene therapy on humans.
1986	University of California, Berkeley chemist describes how to combine antibodies and enzymes (abzymes) to create pharmaceuticals . The first field tests of genetically engineered plants (tobacco) are conducted . The Environmental Protection Agency approves the release of the first genetically engineered crop - gene-altered tobacco plants.
1987	First field trials of a genetically altered bacterium . Frostban, a genetically altered bacterium that inhibits frost formation on crop plants, is field tested on strawberry and potato plants in California, the first authorized outdoor tests of an engineered bacterium.
1988	A patent for a process to make bleach-resistant protease enzymes to use in detergents is awarded . Congress funds the Human Genome Project, a massive effort to map and sequence the human genetic code as well as the genomes of other species.
1989	First field trial of a recombinant viral crop protectant.
1990	Chy-Max(tm), an artificially produced form of chymosin, an enzyme for cheese-making is introduced. It is the first product of recombinant DNA technology in the U.S. food supply . Human Genome Project - an international effort to map all of the genes in the human body - is launched . The first federally approved gene therapy treatment is performed successfully on a 4-year-old girl suffering from an immune disorder . The first successful field trial of genetically engineered cotton plants is conducted. The plants had been engineered to withstand use of the herbicide Bromoxynil . The first transgenic dairy cow - used to produce human milk proteins for infant formula - is created.
1992	American and British scientists unveil a technique for testing embryos in vitro for genetic abnormalities such as cystic fibrosis and hemophilia.
1993	The FDA declares that genetically engineered foods are "not inherently dangerous" and do not require special regulation . The Biotechnology Industry Organization (BIO) is created by merging two smaller trade associations.

1994	The FLAVRSAVR(tm) tomato - the first genetically engineered whole food approved by the FDA is on the market . The first breast cancer gene is discovered . Approval of genetically engineered version of human DNAase, which breaks down protein accumulation in the lungs of CF patients.
1995	The first baboon-to-human bone marrow transplant is performed on an AIDS patient . The first full gene sequence of a living organism other than a virus is completed for the bacterium Hemophilus influenzae . Gene therapy, immune system modulation and genetically engineered antibodies enter the clinics in the war against cancer.
1996	The discovery of a gene associated with Parkinson's disease provides an important new avenue of research into the cause and potential treatment of the debilitating neurological ailment.
1997	Scottish scientists report cloning a sheep, named Dolly, using DNA from adult sheep cells . A group of Oregon researchers claims to have cloned two Rhesus monkeys . A new DNA technique combines PCR, DNA chips and a computer program providing a new tool in the search for disease-causing genes.
1998	The first complete animal genome for the elegans worm is sequenced . A rough draft of the human genome map is produced, showing the locations of more than 30,000 genes .
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Words of our time

If you find this and related topics interesting, search for the following phrases on the WWW.
Artificial Anthropology, Artificial Cells, Artificial Computation Agents, Computer Based, Artificial Creatures, Artificial Ecologies, Artificial Intelligence, Artificial Photosynthesis, Artificial Reality, Artificial Self-Replication, Artificial Synthetic, Bio-Inspired Hardware Systems, Biological Computation Agents, Androids, Biomedical Engineering. Computational Anthropology, Computational Autopoiesis, Computational Biology. Computational Cell Biology, Computational Embryology, Computational Evolution, Computational Intelligence, Computational Life, Computational Morphogenesis, Computational Neuroethology, Computational Neuroscience Computational Psychologists, Computational Social Science, Computational World, Cyborgization, Digital Evolution, DNA Computers, Evolvable Hardware, Hierarchical Complexity, Hybrid Computation Agents, Cyborgs, Mathematical Biology, Nanotechnology, Posthuman, Robotics, Synthetic Actors, Synthetic Behavioral Ecology, Synthetic Biology, Synthetic Brain, Synthetic Environments, Synthetic Mind, Synthetic Psychology, Tissue Engineering, Transhumanism, Virtual Cell, Virtual Reality

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End Notes

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