Bioalloy
Designing a Cyborg's Evolutionary Future

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Bioalloy is a designed Cyborg. The project researches a possible futuristic evolutionary pathway of the living and the non-living. The project engages with the possibilities of interfacing a living system to a machine, to create an artificial life entity or a symbiotic hybrid. In the twenty first century where cybernetic entities are becoming more viable, Bioalloy predicts an evolutionary leap, exploring the possibilities of a living system interacting with a machine to create a Cyborg that will grow and nurture its own "skin" (Fig. 1). Presently, very few machines in'corp'orate any organic material.

In the future, will evolution only link the living?

Emerging from the metallic shell,
and out of the primordial ooze,
three white ossified strands,
coil, mutually embraced.

The living begins to flow,
as the bruising bleeds to red.
A slimy, soft, skin forms
as the machine courses to life.

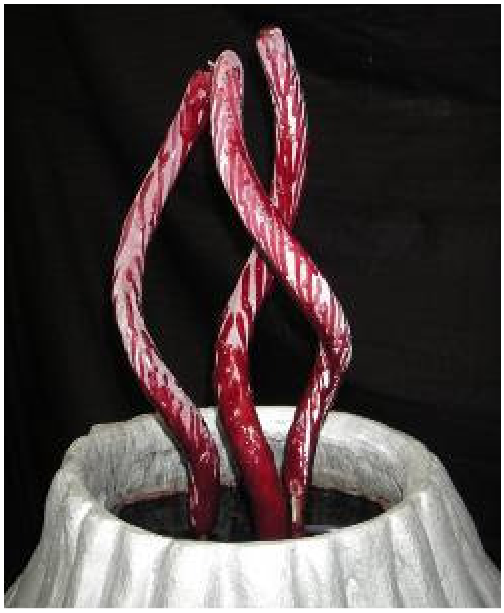

Figure 1: After several hours of a bacterial culture circulating through the ossified strands of Bioalloy, the bruising and bleeding has led to the formation of a biological skin.

Presently, the two main theories of evolution prescribe that the evolutionary development of living organisms are governed by chance variations caused by random acts of biological processes. These theories are;

- Darwin's 1859 Origin of the Species by Means of Natural Selection. Darwinian's evolutionary random biological acts have created a competition resulting in the survival of the fittest mutant. If the chance variation was advantageous in an ever changing world, the mutant would survive to fight another day. Many other variations would have been fatal.
- Symbiogenesis was originally introduced by Mereschkowsky in 1905 and further championed by Margulis in 1981. Symbiogenic's evolutionary random biological acts were the merging of two or more organisms giving rise to a chimera and survival of the new alliance. Many of these alliances would have been fatal.

Are these two theories of evolution mutually opposed to each another? Or will they again, collaborate as they have in the past in the continuing evolution of living systems? And, in the future, as the viability and availability of Cyborgian systems further increases, can these evolutionary partners again combine to link both the living and the non-living?

The cooperation of Symbiogenesis that leads to the formation of chimeras will compete successfully against natural selection and endure Darwin's survival of the fittest. The newly formed mutant will travel further on the evolutionary pathway of life, and depending on strengths or weaknesses accrued through this evolution, may or may not spawn further survival.

We would like to pose this question; (If we can be so bold as to use the human evolutionary pathway as an example to illustrate our narrative)! At an evolutionary fork in the road, early primates had to choose life's path. The human species went one way, with the remaining primates following the other route. Which of the two paths was evolutionarily most demanding?

After posing this question to many people over many years, some thought that humans had chosen the more demanding road as it was paved with guns, wars and death. Others believed that, as humans were required to work for a living rather than sit lazing in the sun eating the proverbial banana, humans must have had it harder... Most forgot to look at the bigger picture, the evolution of a species rather than individual sufferance.

Diversity is the key. As there is much more diverse primate speciation compared to the human species, the primates had a far more demanding evolutionary pathway! Primates had to adapt to their environment rather than adapting the environment to themselves! The minimal variation found in the human pathway implies that an easier evolutionary path was navigated. The remaining primates' path was paved with hardship; hence variations which occurred in the development of these species were essential for survival.

All of these random repetitive variations and adaptations have played a major part in the evolution of biological living systems. Like Erwin Schrödinger's aperiodic crystal repeating its structure as it grows, biological life resembles this repetitive nature. Repeated millions of times over millions of years, the processes of life have led to the wonderful three-dimensional patterns seen in organisms, hives, cities and planetary life as a whole (Margulis & Sagan, 1995). Will the unpredictable random repetitive nature of biological evolutionary processes play a major role in the Cyborg's evolutionary future? Where we have been is the best predictor of where we are going (Gray, 2002).

The term Cyborg was first coined by Manfred Clynes and Nathan Kline (1960) by combining the words cybernetic organism. A Cyborg is a self-regulating organism that combines the natural and the artificial together in one system. Cyborgs do not have to be part human, for any organism/system that mixes the evolved and the made, the living and the inanimate, is technically a Cyborg (Gray, 2002). Gray goes on to say 'this would include biocomputers based on organic processes, along with roaches with implants and bioengineered microbes.' This early predictor of the use of microbes in Cyborgian systems perhaps unintentionally points to yet unforeseen evolutionary possibilities.

Paul Davies in 'The Fifth Miracle' (1998) searches for the origin of life, not just; what is life! The giant leap that was made from the non-living to the living, the animation of an inert object into an autopoietic[1] being; the spark of life! Once we discover the spark, then we may be able to apply it to other systems such as Cyborgian systems to create a truly autonomous, self-maintaining and self-replicating life form.

[1] Autopoiesis coined by Chilean Biologists Humberto Maturana & Francisco Varela meaning auto (self) and poiein as in poetry (making).

The word Cyborg in recent times seems to have been hijacked by Hollywood, which has caused the public's perception of the Cyborg to be very anthropomorphic by using such stars of science fiction movies such as the Terminator trilogy (1984-2003), Star Trek series (1966-) and Bicentennial Man (1999). All of these examples are very conceptual with the Cyborg image used as a metaphor for many sociological, political and post-human paradigms. More recent novels such as Michael Crichton's Prey (2002) has moved this ontological opinion away from the human-like form to illustrate a Cyborg system that integrates bacteria and machine to produce a nanorobotic swarm camera.

Presently many realised Cyborgian systems are attempting to change this speciesist ideology by designing provocative machines that do not have any human biological substance or form. Projects such as Ken Rinaldo's (2004) Augmented Fish Reality, SymbioticA Research Group's Fish and Chips (2001) and Tsuda, et al. (2006) Robot Control: From Silicon Circuitry to Cells has all steered away from human substances and forms.

To illustrate the complexity we use forms of simplicity.

The simplistic or even primitive appearance of Bioalloy is quite deliberate, not only because of its process driven form, but it illustrates one important factor concerning evolution; start simple and progressively develop complexity. To begin with complexity may jeopardize the initiation. The commencement of biological evolution started with organisms far more primitive even than modern day microbes. With this in mind, when designing and assembling a Cyborgian System, one must initially think simplistically. Do not attempt to construct a Cyberdyne system T800, model 101 (Cameron, et al. 1984) straight off the factory floor, but keep it simple initially and gradually evolve successful iterations along the lines of the living!

Bioalloy's main non-living part can be broken into three sections; inverted fume-hood, ossified strands and barnacle, each having a vital function (Fig. 2). As the fumes emitted by Bioalloy's biologicals can become rather pungent and offensive to some, an inverted fume-hood was constructed. Initially serving as the plinth supporting Bioalloy, it's very important odour removal role became an intricate part of the system. As Cyborgian systems become more viable, they may have their own distinctive smell. The waste products that are excreted, whether gas, liquid or solid from the Cyborg will have to be dealt with. This initial Bioalloy system catered for the gas phase but liquid and solid excrement had to be removed manually.

The barnacle which houses the machinery and dams the biological soup has been shaped to honour the one creature that fascinated Charles Darwin[2]. Inside the contoured metallic shell and under the biological fluid are housed the pumps and motors that circulate this fluid around the machine. As the fluid is recycled, the barnacle acts as a receiving vessel returning the fluid from the ossified strands to the pumps. Made entirely from aluminium, the barnacle may play an important role as an electrode (and with the acidic nature of the biological fluid) in the production of electricity. It is this production of electricity that may evolve autonomy in Bioalloy. This evolutionary path may lead Bioalloy to achieve autopoiesis and be recognized as living.

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2 Bioalloy is in the form of a barnacle to emphasis the magnitude that one Chilean barnacle had on postponing the publication of the most significant book in evolutionary science. There is a story (Stott, 2003) that Charles Darwin carried a Chilean barnacle on a journey around the world, from the South American beach back to London, preserved in a jar of wine spirits. When he has finished finding homes for all the 1,529 species he has collected on the Beagle, he will return to the puzzle that the creature's strange anatomy presents; and then he will write this Chilean barnacle's evolutionary biography--a puzzle that will take him eight years to think through. Eight years, from 1846 until 1854, devoted entirely to barnacles? By 1842 Darwin had already sketched out his theory of evolution by natural selection. But he pushed it all aside, squirreling it away to work on the barnacle riddle. What was so compelling about these invertebrates that Darwin chose to postpone the completion of his major work--Origin of Species--for their sake?

One of the major hurdles of creating a Cyborgian system is that (unlike a robotic system) the living part or biological life form must maintain a certain level of hydration. Without water there is no life as we know it! Another of the barnacles functions is to separate the fluid from the electronics. This then dictates shapes and structural design to avoid the inevitable disaster if the fluid and electronics meet. Therefore some creative and improvised construction must be sought.

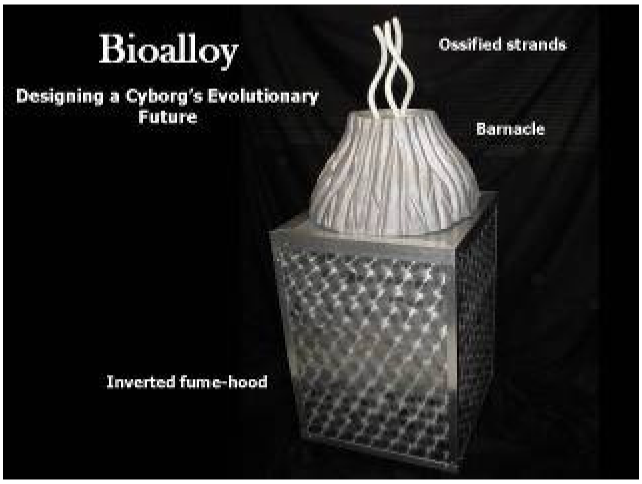

Figure 2: Bioalloy's main non-living part. The inverted fume-hood to remove Bioalloy's stink and the Barnacle shaped receptacle to dam the biological fluid. The ossified strands with their primitive shape bruise, bleed and form skin.

Bioalloy's ossified strands have following descriptors (which can be seen in figure 3);

Skeletal System;
Alloy (the combination of two or more metals) forms the major component of the non-living skeletal system of Bioalloy.

Ossification;
The ossification process coats the skeletal system in white 'bone like' cellulose.

Bruising;
Bruising begins when the red biological fluid flows through the alloy endoskeleton and impregnates the ossified coating.

Bleeding;
During the bruising process or a short time after, through small fractures in the ossified coating, the bleeding will commence. Irregular vein like patterns will form down the length of the ossified strands.

Skin Formation;
Once the biological fluid comes in contact with air a slimy, soft, skin forms.

Ageing;
As the Bioalloy matures the skin dries, darkens and wrinkles. Large fluid filled blisters give the once aesthetically pleasing (for most) white strands a more grotesque look. With age comes smell. Bioalloy is no different, with a very distinctive pungent odour that will cling and remain with by-passers.

Dietary Requirements (When Cyborg's start drinking your wine);
The diet of the biological symbiont is wine. Red wine will create a red Cyborg and white wine a white one.

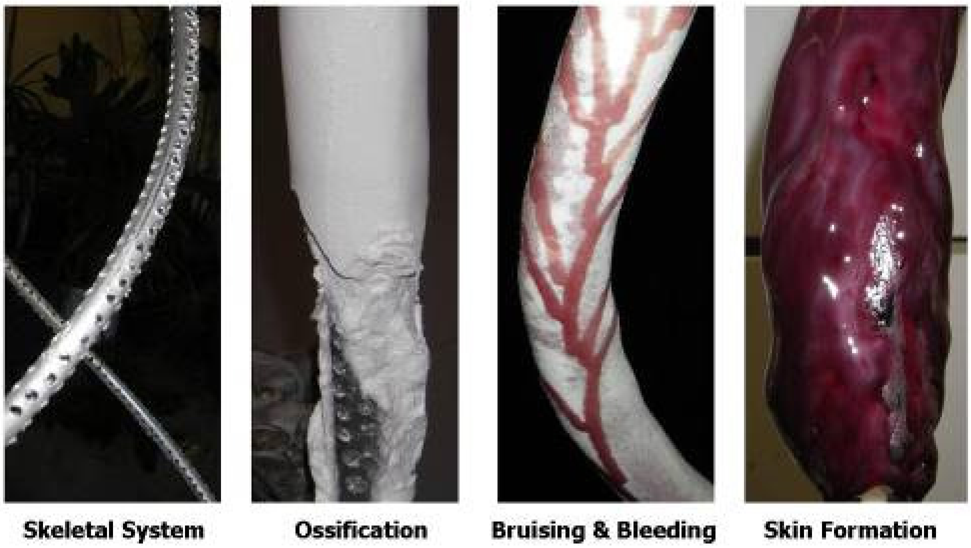

Figure 3: Descriptors given to the ossified strands. The metallic endoskeleton is ossified with cellulose. Once the machine springs to life, the biologicals bruise, bleed and finally form an outer skin over the strands.

Skin formation of Bioalloy occurs on the surface of the ossified strands (Fig. 3). The ossified strands have a primitive and simple form due to the complexity of the methodology. As the Bioalloy group has little references to other methods of ossifying the metallic endoskeleton, the shapes have be influenced and process driven. Other systems that are similar to Bioalloy's ossification are that of water purifying filter production. However due to manufacturing patents and company secrecy, the Bioalloy group was not allowed to use privileged information. 'Cellulose fibres and glue!' was the only clue we had. Therefore much research has been done on the making of the strands and future works will continue to increase the complexity of the skeletal system and constant improvement of the ossification process.

It is within the strands that interaction between the organic and inorganic takes place. The skeletal system with its inorganic metallic origins is interfaced with the organic origins of the white ossified cellulose. This cellulose has a plant origin which is interfaced with bacterial cellulose as the skin formation occurs. The skin is comprised mainly of bacterial cellulose but with a red pigmentation, gives its menacing meaty/animal organ tissue appearance. This biofilm shield (Deacon, 1996) will protect both the alloy and bacterial colony from the outside world.

The Age of the Bacteria (Gould, 1996) is now, has been in the past and probably will be in the future. These tiny primitive organisms with their immense diversification seemed to have driven evolution and controlled life. If all bacteria were to cease to exist, life as we know it would end. Symbiogenic evolution of the biological world has been dominated by bacteria. The bacteria, we believe will play a major role, not only in biological evolution but in the evolution of Cyborgian systems. Will this change the narcissistic opinion that humans have on this Gaia world and the belief that we are the sentient beings? As bacteria are the living part of Bioalloy, we will research the coming together of the living and the non-living and examine what role the bacteria will play in the Bioalloy system.

The cellulose skin that cloaks Bioalloy's ossified strands is synthesized by bacteria called *Acetobacter*[3]. Acetobacter are rod shaped bacteria, 1-4µm in size. They are aerobic (requiring oxygen) and can be found to be motile or non-motile. *Acetobacter* (commonly called 'Mother') are distinguished by their ability to convert ethanol (wine) to acetic acid (vinegar). Another feature of *Acetobacter* is the synthesis of large quantities of micro fibrils of pure cellulose. One explanation for the synthesis of this cellulose might be to keep the bacteria close to the oxygenated surface, thus forming a cellulitic raft. From an ecological view point, the Acetobacter has evolved to deal with and reduce the high alcohol and acidic environments of decaying plant material left behind by yeasts and other micro flora (VanDemark & Batzing, 1987), which can be detrimental to the remainder of us mere mortals.

Figure 4: The imperfections of Cyborgian Systems. This wound on the damaged ossified strand will eventually self heal.

As for the limitations and imperfections of the human species, it would appear that Cyborgian systems will have their own imperfections (Fig. 4). If construction of the ossified strands is flawed, the biological fluid will rip the strands apart, pressure drops and the skin formation falters. However, due to the Cyborgian System containing a living entity, the wound is self repairable; self healing. The *Acetobacter* begin to deposit their cellulose waste product, blocking the gash and preventing the flow of the biological fluid. Once the bleeding is reduced to its usual trickle, skin formation continues.

As Cyborgs are part living, are they mortals?

Bioalloy is a designed machine that in'corp'orates biological matter, researching a possible futuristic evolutionary pathway of the living and the non-living. The unpredictable random repetitive nature of biological evolutionary processes will play a major role in the Cyborg's evolutionary future. Symbiogenic theories believe that bacteria have controlled biological evolutionary processes and as Bioalloy's living part is bacterial, then will Symbiogenic theories drive the Cyborg's evolution?

In the future, evolution will link the living and the non-living!

[3] http://www.botany.utexas.edu/facstaff/facpages/mbrown

Bioalloy is an ongoing research endeavour into artistic Cyborgian systems developed in the F.N.A.S. laboratories; scientific collaborators to SymbioticA, The University of Western Australia.

Other art/science projects that the Bioalloy group are involved with can be found at;

www.bioalloy.org

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