Artificial Life notes "for thought" on the exhibits of the Museo Galileo

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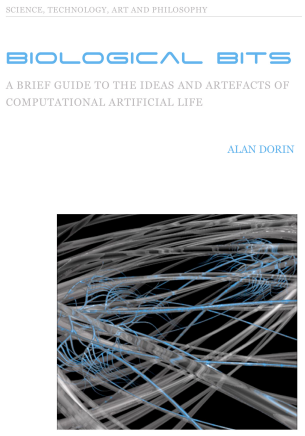
In its broadest sense, *Artificial Life* encompasses the creation of imaginary beings and the engineering of life-like artefacts. The artefacts often take the form of fine technology and may act as proxies for nature, allowing us to study or engage with biology through models. Alternatively, Artificial Life can act as an end in itself, studied only because it is intrinsically interesting. With such a wide scope, clearly the practice is interdisciplinary. Besides the biological sciences, anyone who wishes to understand Artificial Life thoroughly would benefit from an investigation of art, technology, social science and the theories, history and philosophy of these fields.



The field encompasses research and invention from the earliest existence of human-like species up until present efforts with digital technology. An easy to read, illustrated and interactive guide, *Biological Bits*, written by your lecturer, is available *free* for you to download as an iBook (Mac OSX, iPad etc.) or a PDF (all platforms, and for printing). The guide supports the notes in this document.

http://www.csse.monash.edu.au/~aland/BiologicalBits.html

Every scientist, engineer or artist approaches the world from a unique perspective, attempting to slot new experiences into their world view. The rest of this document is intended to encourage you to view artefacts and features of the natural and built environments from the perspective of an Artificial Life researcher. The idea is to "flavour" your thinking by asking how the things you encounter might be related meaningfully to the discipline. Please read (at least) chapter 1 of *Biological Bits* before you begin. This will provide the context you need.

The table on the next two pages provides a list of biological traits that many have tried to replicate technologically. Some hold recent interest only. Others are traits that have been considered essential to life since ancient times. Whenever you view a representation of life, technology or other artefact, consider this list (and try to discover elements missing from it) to reflect on how it relates to *your* understanding of biological systems, and to that of those who made it.

Some items you will find in the *Museum Galileo* in Florence are provided below the table as a starting point. Each has a backstory relating to events leading up to a point in the history of science, technology and art. Each made an impact on future developments. I have provided brief notes on the backstory for each that relates specifically to Artificial Life.

Ask me for more detail if you are interested…

*But really, **please** look at whatever interests you the most!*

Morphological traits

Form, the possession of anthropomorphic or zoomorphic form e.g. a head, face or limbs.

The *Makapansgat* pebble (manuport, c. 2.8M years BP), the *Venus of Tan-Tan* figurine (c. 500k years BP) and countless subsequent human and animal forms appearing in visual art, highlight the extent to which we judge an organism by its cover.

Physiological traits

Blood, an internally circulating liquid with animating properties.

An obvious trait with which many religions are concerned. "Be sure you do not eat the blood, because the blood is the life, and you must not eat the life with the flesh." Deut 12:23.

Breath, repeated inhalation and exhalation.

Noted repeatedly in the world's creation myths as a simple indicator of the presence of life in a body. Still used today for this purpose in medical emergencies.

Cells, tiny enclosed building blocks of multicellular organisms or complete organisms themselves.

First noted by the early microscopists in the 17th C: in cork by Hooke, and observed as Protozoa and Bacteria by Van Leeuwenhoek.

Electricity, its presence within the organism and the fact that the organism may be made to move in response to its application.

First noted by Galvani as he made severed frog's legs jump (1791). Later adopted by Shelley as the animating principle of Frankenstein's monster (1818).

Homeostasis, the maintenance of constant internal conditions in the face of external perturbation.

A concept dating back to Hippocrates (4th C BCE). The basis of current interpretations of the term may be found in Bernard (1879). The idea again found currency in 20th C Cybernetics through Ashby.

Metabolism, the set of chemical reactions that construct biomass and those that break down organic matter to produce energy and waste.

A relatively recent concept that is key to biological life as *biologists* presently think of it.

Soul, an immaterial essence contained within a material body that is responsible for animating the body.

Aet. iv. 3; Dox. 387. Anaximandros et al. "The soul is like air in its nature". The concept is at least as ancient as Anaximander (7th C BCE), but is probably much older. For instance, the ancient Egyptians had the *ka*, *ba* and *akh*, which together had similar features to what some cultures consider those of the soul.

Behavioural traits

Autonomy, independence of behaviour, self-directed or self-governed response to internal and external conditions.

Life's ability to control its own behaviour, at least to an extent, is one of its more obvious characteristics (cf. Responsiveness). This self-determination carries across all of the behavioural traits tabled below and gives rise to the impression that an organism's behaviour is teleological.

Creativity, an ability to generate novelty as exhibited through problem solving, game play, art, poetry etc.

To Plato, music and painting were restricted to mimicking nature. Poetry however, was considered to be exempt from this restriction, it need not concern reality and therefore, to use our current term, it might have been considered "creative".
The mechanisation of creativity might be considered to start either with aleatory music composition (e.g. wind-chimes) or in a more complex form, with the Jacquard loom (1801).

Growth, vegetative increase in size and subsequent decay.

Aristotle, *De Anima*, (c. 4th C BCE) discusses this at length. This is perhaps one of the most difficult traits to replicate technologically unless simple expansion is considered sufficient.

It was not really until the implementation of computational developmental systems (c. 1950) that the trait could be simulated mechanically.

Intelligence, the acquisition and application of knowledge (learning), sometimes seen as a human trait exhibited through witty conversation, complex game play and similar, but also applicable more broadly to less abstract behaviours including survival, tool-making etc.

Discussed by Aristotle in *De Anima*, (c. 4th C BCE) this is difficult to replicate technologically. Nevertheless, hoax talking sculptures, manually controlled puppets and automatic clockwork oracles have given convincing impressions that may (appear to) pass Alan Turing's intelligence test (1950).

Movement, mechanical motion of body-parts.

An early trait to be technologically replicated, for instance in Egyptian articulated dolls (c. 16th C BCE) and one that has been mastered to a remarkable degree in the clockwork automata of the 18th C CE and the robots of the present day.

Navigation, self-directed movement along a route.

Animals and people navigate successfully, sometimes just to the front door of their homes, and sometimes over vast distances. An early reference to this trait's association with technology appears in the context of the self-steering Phaecian ships described by Homer (8th C BCE). There are also ancient Greek and Chinese references to magnetic and mechanical compasses.

Reproduction and replication, the ability to generate a copy of oneself, to bear offspring.

Another obvious trait that is difficult to replicate technologically although it is possible to fake it to a degree – think of Russian, nested "Matryoshka" dolls. Notably, L.S. and R. Penrose produced a neat mechanical self-replicating system using plywood (1957). Various authors since the 1940s have devised self-reproducing formal (symbolic) systems that have been realised in software.

Responsiveness, the ability to alter state in reaction to environmental perturbation and sensation.

An easy trait to mimic technologically, this has been a mainstay of the toy and automaton maker since ancient times.

Organisational traits

Emergence: (i) The ability to self-organise and self-repair as a result of emergent phenomena resulting from dynamic processes (e.g. metabolism); (ii) participation as a unit giving rise to emergent phenomena (e.g. from cells to organisms to ecosystems, from birds to flocks, from bees to colonies).

An ancient idea, possibly commencing with Aristotle. *Metaphysics*, Book H 1045a 8-10: "... the totality is not, as it were, a mere heap, but the whole is something besides the parts ...". This concept has been re-examined numerous times and retains great currency in the field of Artificial Life today.

Evolution, participation in the process of generating an adaptive lineage, possibly one of increasing complexity.

Anaximander seems to have originated the idea that existent animals and humans emerged from fish (7th C BCE)! The idea has been revised many times including in the ancient world by Empedocles and Lucretius but more recently by Hutton, E. Darwin, Lamarck, C. Darwin and Russel Wallace, leading to our modern conception of the process.

Informational traits

Communication of information between organisms.

Although it must have been obvious for millennia that animals communicate, the formalisation of this idea took place in the middle of the 20th C with the appearance of Information Theory and Cybernetics.

Processing (sensed and internalised) information about the environment in order to determine an appropriate response.

This might be encapsulated simply as "thought", an ancient idea. Evidence for thought is usually behavioural. For instance it may be assumed to have occurred when an entity appears creative, intelligent, responsive or it successfully navigates.

Storage of information about the environment within an organism.

The formalisation of this trait took place with the arrival of Information Theory and Cybernetics (mid 20th C). Evidence of its presence is usually behavioural – e.g. an organism behaves as if it has learnt something about its environment. In one sense a weathered stone has stored information about the course of water on its surface. But the stone does not actively collect nor act on this information as life may.

Inheritance, the transmission of (genetic) information between organisms during reproduction

Mendel noted that parent pea plants transmitted traits to their offspring in discrete units (1865). These units were later dubbed *genes*.

Artefacts in the *Museo Galileo & Istituto e Museo di Storia della Scienza*[1]

Room I

Astrolabe

The idea that the universe, and everything in it (potentially including living things) could be understood mechanically and predicted by science and technology is embodied in the astrolabe.

Portrait of Ferdinand II de' Medici

Even a "simple" portrait is really not so simple. It resembles life in its 2D representation of 3D bodily form, its *apparent* texture, its *apparent* dress, and if "realistically" executed, its *apparent* ability to return our gaze. Patrons such as the Medici often funded inventors and artists to create their likeness, and the likeness of other living things, often in paintings, sometimes in sculptures and rarely but significantly, in mechanical technology.

Room II

Noon cannon p. 46 #3575

An important requirement for Artificial Life is the availability of a (preferably mobile) power source. The Noon Cannon demonstrates one way to convert sunlight into useable energy without solar cells.

Planetariums, armillary spheres, celestial globes (& Room XI)

For millennia the planets and stars have been counted by humanity as divine life. Like the astrolabe, armillary spheres, celestial globes, orreries and astronomical clocks demonstrate attempts to grapple with the behaviour of this known universe methodically. These devices would allow people to make predictions about behaviour, represent and organise knowledge in models, and understand observations and measurements taken of the world.

Room V

Hour glass

The hour glass has been used as a regulated power source for self-moving machines (automata) since at least Hero of Alexandria (1st C. CE). He powered his self-moving, automatic theatres using a similar device filled with grain. Water or Mercury (Quicksilver) running between closed containers via a narrow pipe or opening has also been widely used since antiquity for this purpose.

Model of the application of the pendulum to the clock (& Room VII)

The development of the pendulum clock (c. 13th C CE) was a significant moment in the history of technology. A power source (such as a descending weight or oscillating spring) could be regulated by the simple-harmonic motion of the pendulum enabling accurate timekeeping without frequent manual interventions. Clockwork also allowed for extremely sophisticated androids (automata in human form) to be developed, along with sophisticated clockwork animals. The metaphor of the mechanical clock has crept into many debates about the nature of the universe and especially biology to the extent that the French philosopher Descartes (among others) was certain that all animals were literally complex clockwork machines.

Room VI

Organum Mathematicum

The development of instruments for calculation is an important aspect of attempting to mechanise thought and behaviours associated primarily with intelligent life such as (some!) humans appear to possess. Just look at the significance of computers to many aspects of our lives today!

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[1] Reference catalogue November 2012: http://catalogue.museogalileo.it/
Online object index: http://catalogue.museogalileo.it/index/IndexObjectsInAlphabeticalOrder.html

Room VII

Armed lodestone

Lodestone is a natural magnet. In Middle English the word means 'course stone' or 'leading stone' because if allowed to swivel freely it could be used as a compass needle. This ability to move by itself, an attribute associated with living beings, was known even to the ancients.

Compound microscope, lenses (& Room IX #3247, #3797)

The development of powerful lenses and microscopes revealed to Dutch microscopist Antoni van Leeuwenhoek the presence of micro-organisms - a whole universe in a drop of water. British microscopist Robert Hooke (also famous for his work with springs) discovered tiny "cells" in cork. These discoveries revolutionised our perspective on biological life and our place in the world.

Galileo's telescopes & Sidereus Nuncius (facsimile)

Looking beyond Earth through a telescope reveals other planets to be potentially habitable. Like discovering a universe in a drop of water through a microscope, the view into the rest of the universe causes us to wonder about life beyond everyday experience. What might be the similarities and differences between us and life elsewhere? What properties of life as-we-know-it should we look for in extraterrestrial life?

Room VIII

Calculating machines

See note on *Organum Mathematicum* above.

Fountain on stand #802

This fountain has illustrations of many mythological beasts. These artificial life forms are amalgamations of the known parts of real humans, snakes, birds, goats and other creatures.

Room IX

Models of the eye #644, #2582

With an understanding of optics it became possible to explain even the first stages of sight - an otherwise miraculous occurrence that could only have been associated purely with a gift from divinity.

Wind vane #3623

A horse that moves by itself? Is it alive? Certainly the wind is at work and provides a suitable power source for automated machinery. But what of the wind? Is it alive? It was certainly represented in ancient times as having fierce human-like behaviours - ferocity, vengeance. But sometimes it was tender in its caress. It was frequently depicted in art to have a human face.

Room X

Castelli hydraulic pump (hydraulic fan) #1029

Pumps and the pressurised movement of fluids through pipes had been recognised as a property of organisms for centuries. William Harvey, first to deduce the actual circulatory movement of blood through the human body, likened the heart to a pump.

Chemistry cabinet #319, #824 …

Chemistry has its origins in alchemy. A truly ancient practice that has become more and more confused and diverse over centuries of esoteric practices – some involved creating life in a test-tube! Nevertheless, much of chemistry as it is now performed is based on techniques developed by the alchemists.

Lens-grinding lathe #3194

A machine illustrating the beginnings of industrial manufacture - the replacement of human behaviours by the activities of machines.

Wax models of birth p. 272-284

Surgeons can benefit from realistic physical models revealing the in internal workings of the human (or animal) bodies. Some of these were even dynamic - for instance blood could be made to circulate, limbs move etc.

Plate electrical machine #3766 (& Room XI)

Experiments by Luigi Galvani revealed a frog's legs could be made to jump when electricity was applied to the muscles. Perhaps electricity was the magical ingredient of life. Was it the vital spark that animated otherwise dead tissue? By applying electrical current to the bodies of the deceased perhaps the secret of life would be revealed! These experiments prompted Mary Shelley to write her famous book "Frankenstein".

The Writing hand p. 294 #3195 **Don't miss this (it is one of my favourites in this museum).**

This automaton demonstrates that the uniquely human skill of writing (and "communication") can be realised (or mimicked) in a clockwork machine. It doesn't just write gibberish but an extract from a text by the Roman poet Virgil. This invention was made by Friedrich von Knaus, who also invented the first typewriter – an android that wrote characters on a moving paper sheet in response to human input received via a keyboard.

Room XI

Hero's fountain p. 305

Hero lived in Alexandria in the 1st C. CE. He was the inventor of many "pneumatic" artificial life forms, two spectacular automatic theatres and even a *programmable* self-moving cart that mimicked the movement of beetles. This shows a recreation of an inventions he documented as part of his aim to teach the principles of the movement of air and water under pressure.

Magnetic ducks p. 309 #1213

Like the lodestone above, these ducks appear lifelike due to their ability to "self-move". (Apparently) they even bob like ducks in the water!

Room XII

Model illustrating the human arm as third-order lever p. 355 #1010

The interpretation of the body as a collection of levers and actuators allowed the principles of physics (now known as biophysics) to be applied to understand biological motion and locomotion. These same principles are used today in computer animation software.

Room XVII

Bottles and retorts p. 443+, 467

Bottles and retorts were developed by alchemists in their laboratories and remain essential containers for chemists and biological researchers today. Louis Pasteur used such vessels to convincingly disprove the hypothesis that life emerged from putrid matter. He did this by covering rotting material from external contamination (e.g. insects and bacteria) definitely disproving spontaneous generation of life (such as maggots and flies) from the bottled substances and revolutionising our understanding of disease.

Tabula affinitatum

Table showing alchemical symbols - note their association with the planets: Gold/Sol ☉ ☼; Silver/Luna ☽; Copper/Venus ♀; Iron/Mars ♂; Tin/Jupiter ♃; Mercury (quicksilver)/Mercury ☿; Lead/Saturn ♄. Apart from symbolically, how else were planets frequently represented in ancient Greece and Rome?

Room XVIII

Double-case watch, pocket watches

The possibility of miniaturising clockwork mechanisms continued to act as convincing evidence that organisms were clockwork automata with tiny gears. Many inventors especially during the 17-19th centuries in France, Switzerland and Germany, provoked discussion by presenting androids capable of writing text, drawing, playing musical instruments - even, seemingly, a top class game of chess!

Mixing faucet p. 489

This is just a humorous bathroom tap with lifelike decoration.

“Perpetual motion” clock p. 491 #713

Humans are perpetual motion machines, we wind our own springs, at least for a time. Well, so thought philosopher Julien Offray de la Mettrie. For hundreds of years inventors, engineers and watchmakers pitted themselves against friction as they attempted to make perpetual motion machines. All in vain of course. Although we learned lots about mechanics in the meantime…

Likewise, for millennia inventors have attempted to recreate life technologically. So far in vain. But we have learned, and continue to learn, a lot about biology and ourselves in the meantime!

Space for your notes, scribbles and questions: