Biological Habitat: Developing Living Spaces ZBIGNIEW OKSIUTA

> A fig is not a fruit but a flower garden turned inside out. It looks like a fruit. It tastes like a fruit. It occupies a fruit-shaped niche in our mental menus and in the deep structures recognized by anthropologists. Yet it is not a fruit; it is an enclosed garden, a hanging garden and one of the wonders of the world [...] A garden, on the human scale, is a population of flowers covering many square yards. The pollinators of figs are so tiny that, to them, the whole interior of the single fig might seem like a garden, though admittedly a small, cottage garden. It is planted with hundreds of miniature flowers, both male and female, each with its own diminutive parts. Moreover the fig really is an enclosed and largely self-sufficient world for the minuscule pollinators.
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> Richard Dawkins, *Climbing Mount Improbable*[1]

1 Richard Dawkins, *Climbing Mount Improbable* (New York/London: W.W. Norton, 1996), 299–300.

A system can only emerge once its borders have been defined. Evolution has developed a universal solution for a biological, liquid membrane – a film of 'skin' that separates and protects the content from the surrounding environment. In *Der Ursprung des Lebens* (*The Origin of Life*) Reinhard W. Kaplan writes, 'every organism is a unit which is demarcated from its surroundings, an individual with internal subunits going down to the molecular level. Even one-cell microbes are delimited *drops or clumps* of protoplasm which include further substructures, the so-called organelles: ribosomes, membranes and the genome, for example.'[2] In this act of demarcation, wherein a system can develop and then become an individual, lies the deciding evolutionary step. A membrane can characteristically be understood as a separation of various environments and consequently the possibility arises that, in newly created worlds, completely opposed processes such as division and synthesis could take place. Self-organization is an immanent characteristic of material, and it is thanks to the laws of the universe that such creations can come into existence of their own accord. Each process takes place in fluid media. Water is a synonym for dynamics. This malleable state of matter is the only one that allows for self-organization processes and for life as we know it. Liquid states enable processes to occur not only at the molecular level, but also at a macro scale – at the embryonic stage of the development of living organisms it liberates the foetus from the impact of gravity and allows it to develop freely. All living cells are surrounded by membranes, and, as James Lovelock writes,

2 Reinhard W. Kaplan, *Der Ursprung des Lebens. Biogenetik, ein Forschungsgebiet heutiger Naturwissenschaft* (Stuttgart: Thieme Verlag, 2nd edn 1978 [1972]), 118.

> hardly more substantial than a soap film, [a membrane] is as effective a barrier to leakage of the cell's constituents as the hull of a ship to water or the fuselage of an aircraft to the outside atmosphere. However, the watertightness of a living cell is achieved by quite different means from that of a ship's hull. The latter works mechanically and statically; the cell wall does its job by active and dynamic use of biochemical processes.[3]

3 James Lovelock, *Gaia: A New Look at Life on Earth* (Oxford: Oxford University Press, 1979), 84.

Naturally, separating oneself from the environment, creating barriers and walls, is also a central human activity. We must protect ourselves in order to survive. Clothing provides our second skin and architecture the third. From the earliest stages of human evolution, people have used – initially – biological matter to separate themselves from their surroundings and to protect themselves against a hostile environment. Like the creation of cellular membranes in biological systems, in the history of human culture the making of clothing or the construction of a roof over one's head has been a universal and primeval activity, a necessary step towards survival, existence and development. The construction of a spatial boundary between an interior and the surroundings is the basic task of architecture.[4]

4 Cf. also Zbigniew Oksiuta, *Forms, Processes, Consequences* (Białystok/Warsaw: Galeria Arsenał/Centrum Sztuki Współczesnej Zamek Ujazdowski, 2007).

Biological polymers as construction material – form as process

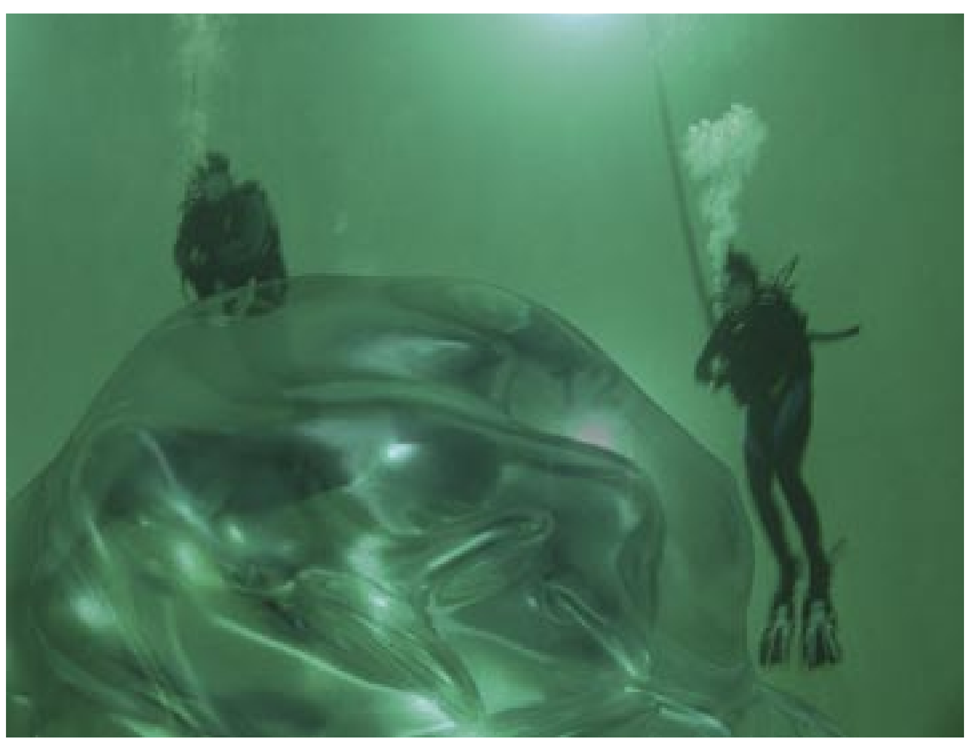
Each of the projects *Spatium Gelatum*, *Isopycnic Systems* and *Breeding Spaces* explores the possibilities of specific biological habitats. These habitats can be understood as spaces with dynamic membranes, by means of which humans, animals and plants integrate symbiotically, where the intermediary covers act as components of the living community. They protect but should be equally indivisible elements of the system's energy, material and information circulation. For my prototypes I employ biopolymers of animal and plant origin. Biological polymers are made up of chain macromolecules of natural origin: polynucleotides (DNA and RNA), polysaccharides (cellulose, starch, pectin, chitin, glycogen and agarose), polypeptides and proteins such as collagen, elastin and polyisoprene. Biopolymeric gels belong to the soft matter group, comprising so-called 'compound' or 'three-dimensional liquids' which cannot be classified as either liquids or solids. They can be soft and easy to deform (gelatine gels) or hard and fragile (agar gels). The processes that take place in biological polymers during their transition from liquid to gel to solid state are described by the theory of elasticity, formulated within the framework of physical chemistry. During the setting of a form, planes and membranes change shape and deform in a specific drama dictated by 'bending energy'. As it dries, a slice of bread always bends in the same way. The flat object arches into a double-curved, self-supporting crust (a hyperbolic paraboloid) displaying a mathematically determined geometry and considerable durability.

The aim of my research is to observe deformation processes without any prior aesthetic or formal interference. Chaotic curves and fractal deformations are the effect of precise biological self-organization processes combining the physical and chemical principles of order and beauty in the animated world. Natural constructions tend to be small scale while human structures are large scale. At the fluid molecular level, viscosity and surface tension play a primary role, while the rigid constructions of humans are primarily influenced by gravity. Humans work with the principle of adding on. Small parts are manufactured and put together to form large constructions. In a watery medium, this principle of adding on is not possible. The fluid creation of forms happens through morphogenesis *from inside* due to expansion, growth and reproduction. Right from the start, these processes depend on information which is stored in the nucleus of each cell and which determines the direction of development. At every stage of life an organism is a fully functioning perfect entity. Therefore my *Spatium Gelatum* projects study the rules for forming liquid and gelling objects from biological polymers in liquid state in order to envision architectures at any scale and to shape biological forms and objects into new habitats. *Spatium Gelatum* objects and architectures are biologically renewable. They can exist in a solid or liquid state, be soft or hard, transparent or coloured and they have different smells and flavours.

Work with biopolymers is thus also of special interest because their density is comparable to that of water: when two liquids, which do not mix with each other, have the same or a nearly equal density and a drop of one floats inside a drop of the other, we can observe a state of relative weightlessness, of neutral buoyancy. What I call *Isopycnic Systems* (meaning 'having equal density', from the Greek *isos*, 'equal', and *pyknos*, 'density') in my work describes the aim of creating forms under water, in this neutral buoyancy

The polymer form, X-ray photo. Radiology EVK Evangelical Hospital, Cologne-Weyertal, 2007.

Photo: Birgit Vogt © Zbigniew Oksiuta & VG Bild-Kunst Bonn



Isopycnic systems (neutral buoyancy: liquid systems of equal density), 'Lane Kluski Technology' ('Poached Dumpling Technology'). Inflation of the hollows in a polymer lump floating under water, videostill, *Mesogloea*, 2003. The film was partly shot in a Neutral Buoyancy Facility, ESA European Space Agency, Cologne.

Photo: Uwe Lierman, animation: Industriesauger-TV, Cologne © Zbigniew Oksiuta & VG Bild-Kunst Bonn

phase, using liquids within liquids, with water comprising a fluid form for the floating gelling polymer mass (in a translation from the Polish, I refer to it as the 'Lane Kluski Technology' or the 'Poached Dumpling Technology'). Other liquids are injected into it to alter its shape and size and to create isomorphous spaces and interiors. By adding liquids of lower density than that of gelatine and water to the mass, it is possible to control the form's density and to maintain it in this floating state. At a practical level the isopycnic state allows the creation of a great variety of amorphous shapes which can potentially be applied to architectural scales, thus offering new possibilities for transforming amorphous forms like those generated by computer simulations.

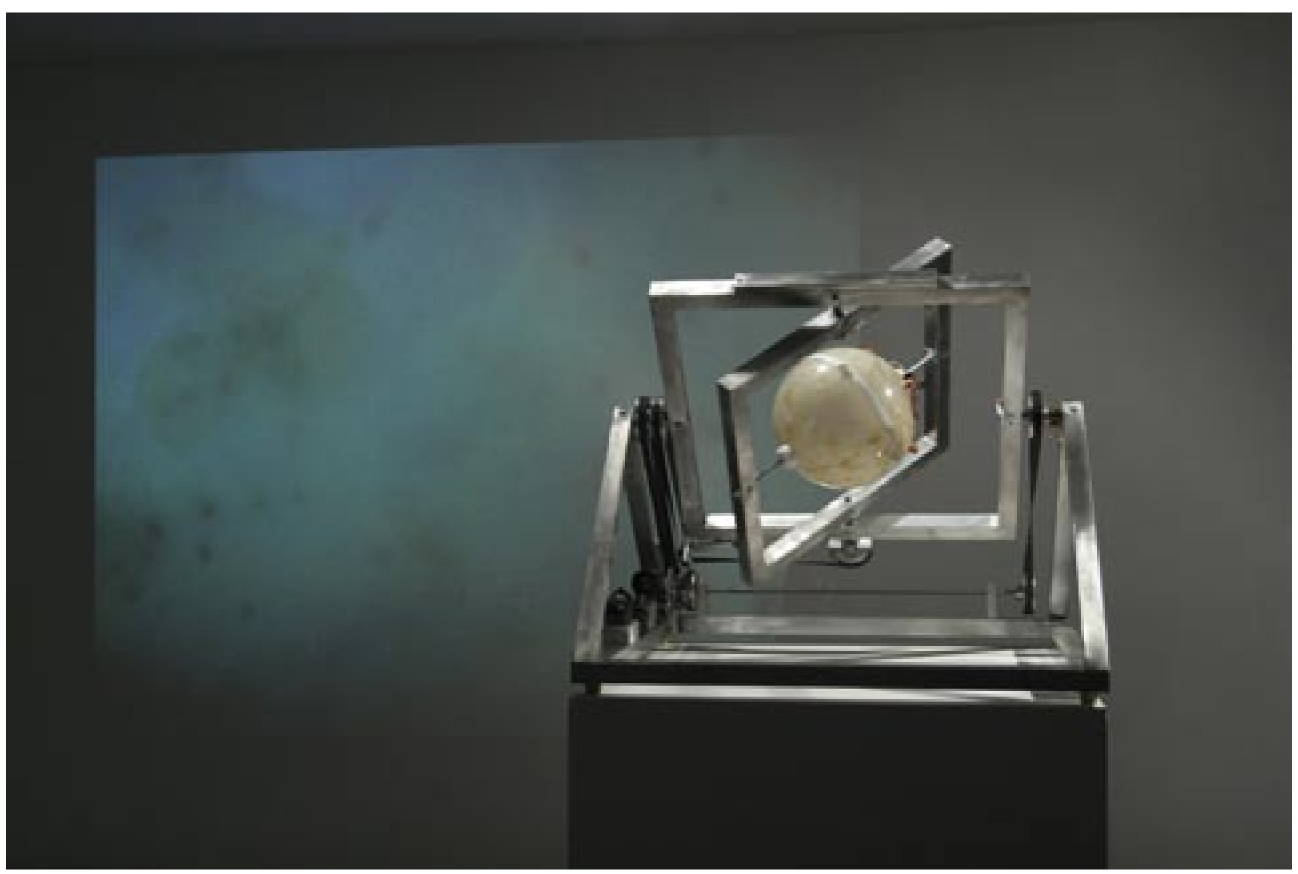
Breeding Spaces as bioreactors

The principle of molecular, dynamic membranes can also be transferred into the macrocosmic area. The basic units of living are the bubbles which surround the inner organs of higher organisms and comprise the lipid film that protect the cells. It is the skin of our bodies and the biosphere that is draped around our planet: living systems are, independent of size, surrounded by a dynamic membrane. But how are dynamic space systems, based on the universal idea of fluid membranes, created on large scales which allow the conservation and even the cultivation of organisms internally? In biological laboratory experiments flat Petri dishes made of rigid plastic are used, filled with a layer of agar upon which the perfectly enclosed microbes may be bred and observed. More sophisticated bioreactors are also made of containment material which is usually rigid – at least its containment borders are totally impermeable. Such is the principle of our technology. But why are we not considering the use of dynamic membranes here? The idea behind *Breeding Spaces* is to create a three-dimensional organic membrane, the entire interior of which constitutes a bioreactor that would still permit controlled experiments in laboratory conditions. In order to achieve this, the whole transparent research container is constructed of biopolymers, such as agar, agarose or phytogel, as a 'three-dimensional biological Petri dish'. Such sphere-shaped membranes consist of 70–98 per cent water and are filled with air. In the gelation process of this 'bubble', the agar forms stable, albeit soft and flexible, walls which rigidly isolate the interior from the outside environment. The polymer layer provides both a spatial perimeter and a nutrient medium for the micro-organisms inside and stimulates the processes taking place within the membrane.

Breeding Spaces is an attempt to generate a system in which the borderline separating the interior from the outer environment is not a foreign body, made of neutral material (such as Petri dishes or glass containers), but an immanent element of the whole structure. It is simultaneously a boundary *and* a spatial scaffold. It plays an active role in the processes inside the system, thus drawing on properties that are specific to biological membranes in living organisms. The breeding process involves injecting plant cells into the interior of a form, in this way creating a kind of *introverted biosphere*. As the cells multiply on the walls and create stable tissue, the 'bubble' itself begins to self-degrade, thus facilitating the growth of autonomous plant objects. Extending this idea further, *Breeding Spaces* could become not only spaces for breeding but breeding farms in space. Seen from a long-term perspective, the project explores the idea of such thick-fluid, three-dimensional membranes as bioreactors in the most varied surroundings: not only on the earth's surface but also under water and in outer space. The limitation which equally unites and divides each condition is the effect of gravity: normal 1 G gravity on the surface of the earth, relative weightlessness under water and 0 G in space.

← Form 090704 after several spatial invaginations and deformation. Twist, Meppen, Germany 2006.

Photo: H.W. Acquistapace © Zbigniew Oksiuta & VG Bild-Kunst Bonn



← The *Cosmic Garden* project, model, 2007. A 3D Klinostat (Random Positioning Machine), a device for simulating microgravity and studying the sensitivity of plants to the impact of gravity (geotropism). RPM dimensions: 90 x 90 x 90 cm. Bioreactor, diameter: 30 cm Installation Arsenał Gallery, Białystok, 2007

Photo Michał Strokowski © Zbigniew Oksiuta & VG Bild-Kunst Bonn

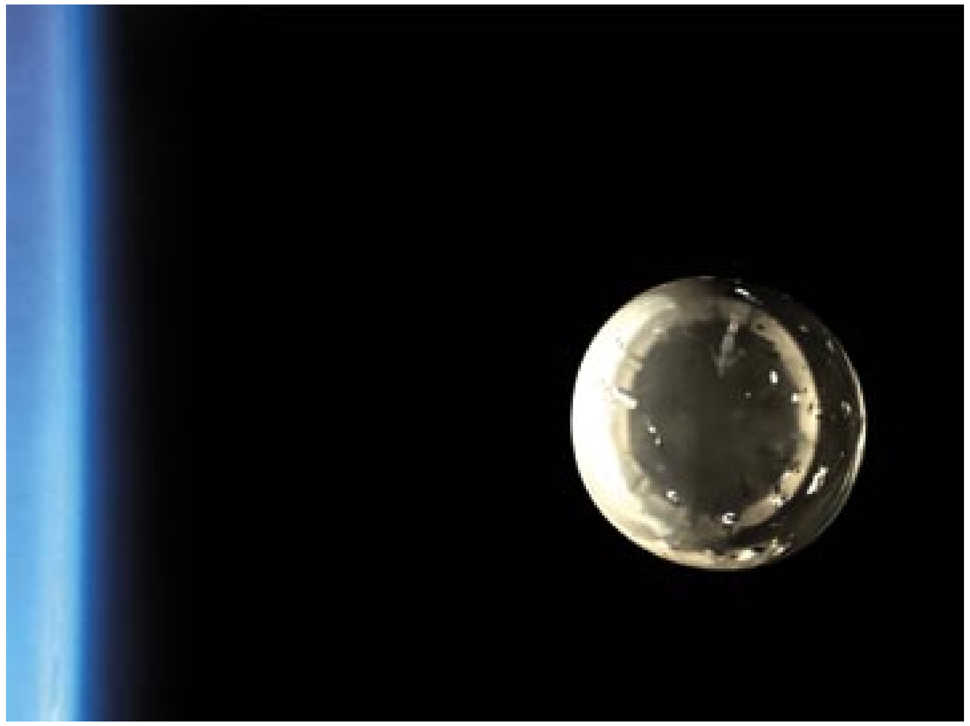
Beyond Gravity

Gravity decisively influences the manifestations of earthly technology. Humans create their static and mechanical objects according to the principles of Euclidean geometry from stiff, dead material: hardened concrete, glass, steel, ceramic. On earth we build houses and construct devices, according to the linear geometry of gravity, directed towards the inside of the globe. Construction generally requires two tools: a level line and a plumb line. The construction of fluid but stable forms with a larger, architectural scale is not possible in the earthly gravitational field. However, such objects – often designed in the virtual space of computer simulations – can exist under water or in outer space. The organisms that live in a gravitational field are themselves in a hermaphroditic condition, divided between solid and fluid material; they consist primarily *of* water and even develop, as well, particularly in the embryonic stage, *in* water. On earth, these fluid bodies are kept in form by their soft membrane, the skin, and stabilised with a skeleton. In a certain sense we can say that the phenomenon of neutral buoyancy is indeed crucial in the development of life, as the basis for its three-dimensionality. In addition, the watery medium permits the movement of molecules and the transmission of genetic, hormonal or synaptic information. Despite the fact that neutral buoyancy plays so central a role, and that it is largely used in space technology to simulate a state of weightlessness in so-called neutral buoyancy facilities, it is hardly used in the architectural creation of forms. In *Beyond Gravity* I research the possibilities of softer technologies which approximate conditions of weightlessness. Under water, employing biological polymers as construction materials makes the creation of forms by using the phenomenon of relative weightlessness possible. With the 'dead' materials available today this is unthinkable: steel is seven times heavier than water, concrete three times and glass two-and-a-half times. Only artificial materials have a density comparable to that of water. Artificial material, however, is also dead material.

At the moment, we are still sending heavy, static equipment, produced on earth under gravitational conditions, into space – an environment which is not static at all. Like the conquistadors of the past, we are attempting to erect earthly outposts. The dangers that await us there are not wild humans, exotic animals or viral illnesses but rather the deadly emptiness of a vacuum. As a result, we have set out to build solid, fortified walls there, too. However, does not living (or surviving) in the cosmos demand an entirely new habitat? In order to make survival of a biological system possible in outer space, the universal principle of a dynamic covering might present the cosmic solution, as a new biosphere, a reactor more focused on pressing ahead with the further development of existing beings than merely protecting them. The tactic of life has always been not to colonize new areas, for example, but to adjust to them and in so doing to change itself. How can such a new form of conquering be imagined? Perhaps as universal replicator DNA embedded in biological mega-incubators. Swarms of small cell-like biospheres could drift through the emptiness of the cosmos. They could be microscopic and be catapulted with natural forces into the earth's orbit. By means of the magnetic fields around our planet, electrically charged micro-organisms could overcome the earth's gravity and then die, putting the vacuum and cosmic radiation to severe tests, or else mutate to suggest new organisms in the cosmos.

Cosmic Garden

As a logical consequence, the project of a *Cosmic Garden* is thus a possibility here, a transparent polymer bubble, with a diameter of several metres and filled with air, 'poured' into outer space and, thanks to planetary rotation, having artificially created gravity. In such an isolated biosphere, plants grow and organisms, flooded by the sun, create a



The *Cosmic Garden*, 2003–2007. A liquid polymer pneu (a bubble cast) made in space as a container for breeding live organisms, videostill, *Made in Space*, 2007

Animation: André Hindenburg, Industriesauger-TV, Cologne © Zbigniew Oksiuta & VG Bild-Kunst Bonn

garden. I am already simulating each physical parameter of the project – on earth – in a 3-D *Klinostat*. This *random positioning machine* constitutes a scientific tool which researches the effect of gravitation on plant growth. Owing to rotation the tool creates a condition of weightlessness at its centre in the three-dimensional sphere, fixed in the metal frames of the *Klinostat*, as a *Breeding Space*. Depending on the speed of rotation, the tool can function either as a centrifuge or a bioreactor. It will become a model of a *Cosmic Garden*.

Since the biological membrane is a universal principle and forms the basis of each living system in the cosmos, it is conceivable in a great variety of consistencies and sizes, as a soft, gel-like or fluid object, the size of a pill, a fruit, a house or a biosphere. As a bioreactor, incubator or artificial placenta, it would become the new cradle of life and could in the future allow us to cultivate food, tools and shelters. It could even support us in settling the cosmos – it is a *life form*, thus, with a biological future.

Zbigniew Oksiuta *Biological Habitat*
Technical cooperation: Wolf-Peter Walter, Econtis GmbH, Emmen, Holland.
Scientific cooperation: Prof. Dr Michael Melkonian, Thomas Naumann, Dr Björn Podola, Botanical Institute, University of Cologne. Leo Leson, Ronald Zürner, Precision Mechanics Studio, Botanical Institute, University of Cologne. Jens Hauslage, Institut of Aerospace Medicine, German Aerospace Center, Cologne.
Medial cooperation: Sebastian Kaltmeyer, Martin Ziebell, André Hindenburg, Hauke Sachsenhausen, Jens Höbelheinrich Industriesauger-TV, Cologne

Light, only light JUN TAKITA

Nature inspires humans – and art is the artifice that they create. In this correlation, the natural and the artificial are not a contradiction but an inseparable tandem. They are in fact inseparable like art and science, the poetic and the rational, necessary complements to harmony. Of course, when I was a child, I marvelled mostly at natural landscapes. Having had the good fortune to live on nature's edge, I was close to rich and infinitely varied countryside: plants, tiny animals, insects. Then came the awakening to the fact that economic and urban development were fighting to take over this nature. Grey, dry concrete were to kill off all the greenery and the fauna. And most of all, the little fireflies that I loved were disappearing. But economic development and activity cannot be pronounced 'guilty', in the sense that the desire to proliferate, to reproduce, to invent and construct, it is this 'human nature' without which art would not exist. What makes these new landscapes ugly are the excesses – and the lack of creativity. How then to create a different type of landscape going beyond the nostalgia for paradise, faced with the impact of a technocratic future? Artistic action takes place where these two sides, far from requiring negotiation or confrontation, are no longer distinct, where art leads to a landscape that becomes a direct extension of the body, of my body. The landscape of a dreamt reality.

Light, only light[1] is a sculpture in the shape of my brain, made using a magnetic resonance scanner. The pictures obtained with the scanner were first restored as 3D images by computer, then turned through a fritting process into a resin form, which is then covered with a bioluminescent transgenic moss, capable of emitting light in the same way as fireflies, glow-worms and certain deepwater fish do. For this, existing laboratory techniques have to be adapted, as research scientists only handle moss the size of a Petri dish, never cultures the size of our head. Work on this unusual scale in fact considerably increases the risk of contamination from moulds that are naturally present in the air, which can eat up the moss literally overnight in the event of contamination. In the first version of *Light, only light*, the brain thus totally covered with moss would be placed in a darkroom, and its luminosity captured on camera for about ten minutes until the image gradually begins to appear on the screen. In the latest version, with the use of a transgenic moss of higher bioluminescence, it ought to be visible to the naked eye.

To be faced in this way with one's own internal cerebral organ, a replica of it really alive and perceptible thanks to the new (bio)technologies, is a singular experience that goes against conventions which hold that there is a boundary separating the inside and the outside of a body. Here the boundary is no longer a barrier. It is a set of networks, just as the mass of the brain is made up of infinitely long neural networks and millions of connections, through which stimulating environmental information is gently turned into images of the world. What I am interested in is the brain skin, with its crumpled surface and its multiple folds in which light creates a strange relief. I feel there is an analogy between the formation of this skin and the process of visual perception: the transformation of light into an image projected onto the back of our head, like the creation of a light skin. Thus the light, caught in an infinite space located between the observer and the observed object, will indeed have its shape. In *Light, only light*, rather than creating its own volume, the moss covers the surface of the support. The desire to look, and the natural desire of the growing moss to cover its brain-support, together form this skin of light. *Light, only light* is a landscape-image where the beholder is faced with his or her own image. Just as any landscape only exists when a gaze captures light, without light the beholder can see

1 **An earlier version of *Light, only light* was produced in 2004 jointly with the biologist Fabien Nogué of the INRA in Versailles, at the Station de Génétique et Amélioration des Plantes, and with the help of Professor Setsuyuki Aoki of Nagoya University, the maker of the genetically modified moss used in this work. For the *sk-interfaces* exhibition, a new moss with superior visibility qualities of luminescence is being specially developed at Leeds University's Centre for Plant Sciences, with the help of Dr Andrew C. Cuming and Yasuko Kamisugi.**