Chimera Obscura:
Investigations Into Non-Linear Process Towards The Design Of A Zoo

by
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AUTHOR'S DECLARATION

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners. I understand that my thesis may be made electronically available to the public.

ABSTRACT

Across diverse territories - that might otherwise be considered separate from one another - similar morphogenetic and emergent processes appear to be at play. The continuous re-inscription of the world, and its inner workings, in perceptible terms is impelled by a desire to intervene in it with greater precision and subtlety. But if emergence is already an operational force from which reality is spun, what, if any, benefit might be gained from a practice that negotiates its subject on these same terms?

The thesis departs from the premise that both the world and our cultural constructions of it are products of emergence, and thus, they may be described using a convergent set of terms. The research tests this proposition in a design for a new zoological environment. Besieged by a set of incompatible objectives, the contested territory of the traditional zoo program is approached with an ethics of emergence - one where large problems are resolved into small, knowable truths or rules. The proposed design transgresses the one-sided theatricality of the fixed perspective, frame, and stage set, reconceiving it instead as an organism in a state of dynamic equilibrium in which human visitors are active participants, thoroughly imbricated and entangled.

The work is centred on process-oriented investigations in computational environments. Through experiments with parametric modeling, object-oriented programming, and other rule-based simulations, the research delaminates the zoo complex into a series of parallel machines. Each is conceived as a rule-driven procedural sequence with its own set of inputs and outputs, which, when coupled together, form the notional feedback loops of adaptive living organisms. These processes are deployed in order to satisfy a longing for spatial conditions that are at once finite and indeterminate, both bound by gravity and disorienting, a place that is at the same time tempered and wild.

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DEDICATION

To Gertrude and Phil, and the late Istvan and Szosanna.

(...and to all the wild things in my life, past, present, and future...)

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The title of the thesis - *Chimera Obscura* - implies a hybrid cybernetic organism, part animal, part machine, one, whom, through a perverse coupling, has the capacity to reveal by way of its murky conflation. It is a sort of unity of difference; the zoo mixes not only different species but also different worlds - particularly that of the human and the animal - and it can do so only by way of architecture and its technological interventions. The zoo program's long history has been propelled by human curiosity with the Animal. Concerns about the treatment of animals as well as our cultural complicity in their internment have posed major challenges to its legitimation. Even if potential study and reverence for the natural world were enough to possibly warrant animal suffering, questions remain about which natural world it is that these reconstructions refer to. With the promise of reviving the presence of animals in our lives all but vanquished, the zoo program may still be able to facilitate meaningful and vital experiences. The question, however, is what possibility is there for the experience of the majesty and mystery of the wilderness in a space so confined, so bereft, and so neutralized?

Chimera Obscura reconceives the zoo as a living entity, one assembled like a flock; its wholeness is one of perception, and cannot be deduced from its parts in isolation. Its edges are hazy, its centre is everywhere and nowhere, it has no front or back. Its primary structural device is one of relations, a concern with the spaces between things over the things themselves. With this ambition, the intent is to create an environment that registers diversity and difference.

This thesis is not an inquiry into the ethical implications of keeping animals in captivity. In light of the contentiousness surrounding this issue, the thesis breaks the large fundamental questions down into a series of smaller ones, from which more resolute ends may be generated. It embraces a position of operating from within this very fraught territory to maximise the gains it might yield, while minimizing any of its negative consequences. It is first and foremost an architectural practice-based research, one which necessitates a healthy dose of gravity.

While the thesis is grounded in critical discourse on culture, it focuses on theories of self-organization and computation as tested through craft, not theory.

The thesis engages computation with the art of the "hack"; it operates in processes and languages on territories which it may only be loosely acquainted with. The use of computer scripting in the project evolved as its needs arose, and in this way, there may have been more efficient, clearer, and more appropriate methods than those that were employed. It purposefully crosses between exclusive territories of specialization to splice together new productive combinations. It opportunistically exploits misappropriation, abuse, and cross-contamination as co-operants in the transformation of the possible into the actualized.

WHAT THE THESIS IS

This thesis, like its subject, is a work of synthesis, an emergent phenomena whose form must be "read" out of the aggregate and broad range of overlapping concerns. It is part methodology, part design project. It ventures to bridge realms that would otherwise be mutually exclusive by literally incorporating disparate flows – embedded in information matter – into consistent planes of operation. To be absolutely clear, the thesis tests strategies by which real-life phenomena from the world is transformed into data to then be processed, translated, and finally converted into inhabitable space.

It is a response and contribution to a lineage of architectural practice concerned with generative procedures, particularly those that are autopoetic and self-organizational. The project is to be seen as marking and taking part in a recent shift that progresses beyond pure theory or experiment into scenarios of greater consequence.

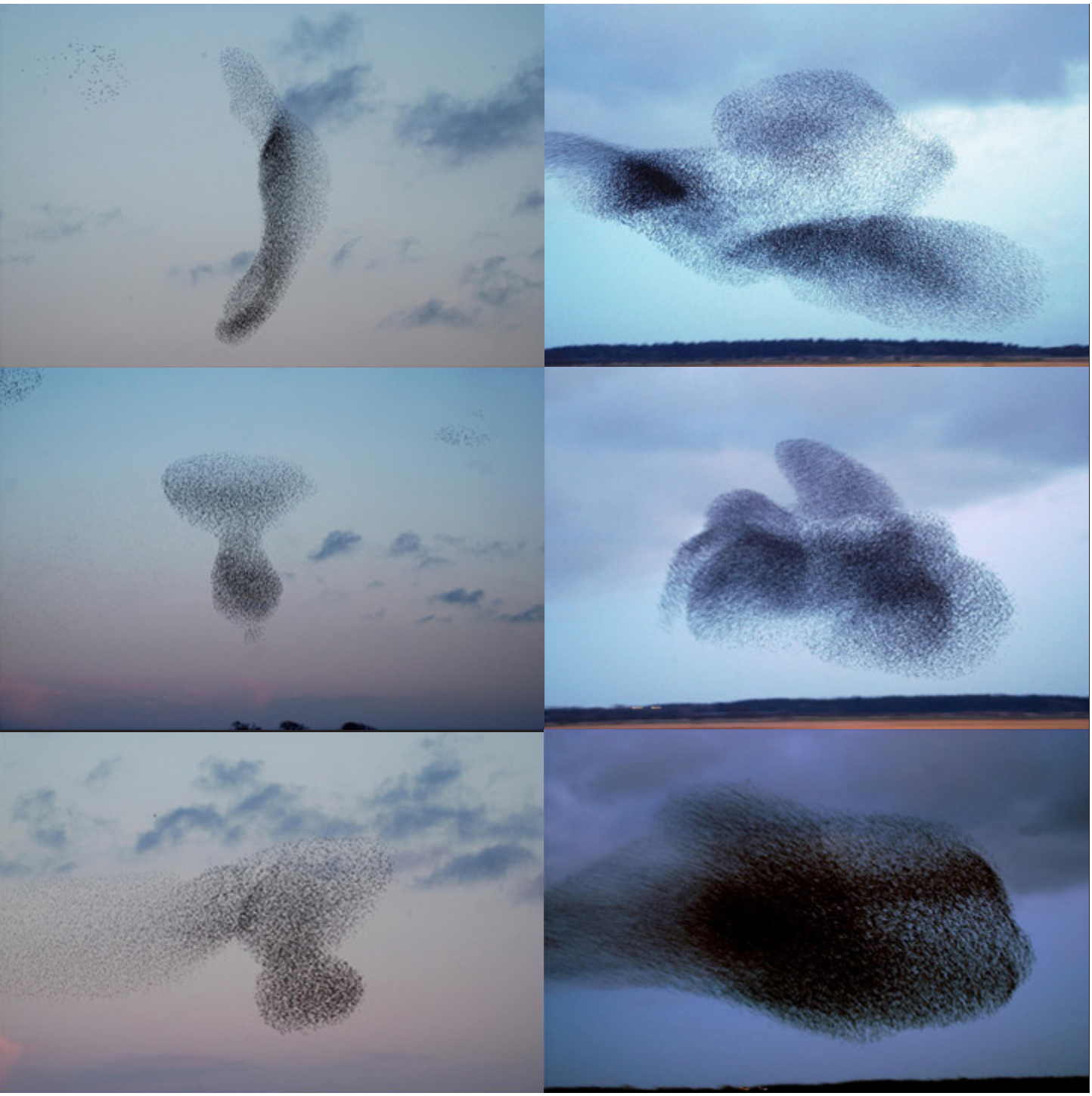
THE FORMAT OF THE THESIS

As a document, it illustrates the ideas and strategies engaged with over the course of research, to be unfolded in three parts. It begins with a chapter on its methodology, developing a framework within which the work should be viewed, and the detailing the seeds of its investigations. It is followed by a section depicting five notionally separate generative "machines" behind the design for a zoo. Each is framed by a section describing it in terms of its distinct process, sources, scripted forms, and implementation. The final chapter concludes the thesis with a drawing set of the design speculation, and a reflection upon the potential and limitations of the use of non-linear generative procedures in architectural design.

CHAPTER 1 TOWARDS A GENERAL SETTING FOR THE RESEARCH
SITUATING THE WORK

INTRODUCTION

This chapter frames the research in terms of a number of parallel investigations. It is an outline of some of the issues it contends with; those provoked both by its subject - the zoo, and the animal - and its themes - emergence, self-organization, and morphogenesis. From these theories of complexity, it segues into a discussion of technology and computational practice as media capable of simulating emergent phenomena. In the final section the thesis proposes that the grounds of the recently retired Lakeview Generating Station, in Mississauga, Ontario, be made home to a new zoo.



MORPHOGENESIS AND EMERGENCE

"THE WILL TO ANIMATION"[1]

It is otherwise with emergents, when, instead of adding measurable motion to measurable motion, or things of one kind to other individuals of their kind, there is a co-operation of things of unlike kinds. The emergent is unlike its components insofar as these are incommensurable, and it cannot be reduced to their sum or their difference.[2]

1. PIA EDNIE-BROWN. *ARCHITECTURAL DESIGN 71.2* (2001): 64.

2. G.H. LEWES, *PROBLEMS OF LIFE AND MIND (FIRST SERIES) VOL. 2* (LONDON: TRÜBNER, 1875), 412.

FIG 1.1
FLOCKING STARLINGS
EUROPEAN STARLINGS FLOCKING TO CREATE THE PHENOMENON KNOWN AS "BLACK SUN" THE PHOTO WAS TAKEN ON APRIL 5 FROM 19.30 TO 20.30 AT TØNDERMARSKEN IN DENMARK

NON-LINEAR DYNAMICS

If, as Manual De Landa contends in his *A Thousand Years of Nonlinear History*, "reality is a single matter-energy undergoing phase transitions of various kinds, with each new layer of accumulated 'stuff' simply enriching the reservoir of nonlinear dynamics and nonlinear combinatorics available for the generation of novel structures and processes." [3], then where does this leave the architect? What does this mean for the practice of architecture? If space is, by this definition, already a product of nonlinear dynamics - of contingencies within the world - the thesis asks what can be gained from taking on a position that both explicitly acknowledges these processes and seeks to operate on the system instead of its dimensions, striated and separated. It looks for the potential in reflecting on design and formative processes themselves instead of matter directly. What can this self-consciousness mean to our construction of the world, and how will it subsequently feed back on the way we lead our lives?

3. MANUEL DE LANDA, *A THOUSAND YEARS OF NONLINEAR HISTORY*. (NEW YORK: ZONE BOOKS, 1997), 21

ON EMERGENCE

Emergence is a far-reaching scientific concept, traversing scales, and even managing to conflate - and thus do away with - the dualism inherent to the nature/culture discourse; it does all this in its attempt to describe the rules or behaviours that give rise to complex adaptive systems. Its subjects are diverse, from flows in patterns of weather, to the coordinated flocking of birds, and on to the fluctuations in the stock market. It is typically characterized by the indivisibility and irreversibility of its wholes, which are arrived at only by way of the accretion of low-level rules. The ability for form [or any persistent identifiable body] to arise without the oversight or command by a single agent or "decider" has captivated scientists, designers and artists since its inception into popular consciousness in the early 90's.

Since that time, much theoretical discourse and a limited amount of practice has been directed towards its application in architecture. Countering the hylozoism[i] of the architect as auteur, in emergence architects have seen the promise of novel spatial conditions through actualizations of mass virtual forces at play including structural, environmental, and even those of culture and economics. Wrenched from the hands of the staid control of centralized regimes, architecture, it has been envisioned, might be liberated towards diverse, and indeterminate ends. And since "more is different" [4], the inclusion of a greater field of inflections might transpire an architecture embodying the pluralism of its situation.

I. RHIZOMATIC, AS IN DELEUZE & GUATTARI'S NOTION OF THE RHIZOME, AS COUNTER TO THE ORGANISATIONAL STRUCTURE OF A TREE AND ITS BRANCHES. THE RHIZOME IS AHIERARCHICAL, WITHOUT BEGININNING OR END, ENTRY OR EXIT

4. P. W. ANDERSON, "MORE IS DIFFERENT: BROKEN SYMMETRY AND THE NATURE OF THE HIERARCHICAL STRUCTURE OF SCIENCE", *SCIENCE 177* (1972): 393

While these promises may have been enough to inspire a new orientation to the world, they have come part and parcel with new demands on practice. The incorporation of a developmental time - as required by emergent processes - into architectural praxis has necessitated new practices and mediums, wherein one can now simulate the real-time feedback processes of evolution. These developments have forced us to reconsider the profession's current atomic approach to seeing and constructing the world, one which has firmly invested itself in discrete parts.

Questions still remain as to what emergence will mean to architecture in light of the fact that emergence may always be at play even when it is not explicitly stated in so many ways. This thesis tests the allegations of a new paradigm in research that suggest that there may be something legitimately novel and useful occurring when architects start to simulate natural processes as generative tools to form matter, rather than using them simply as discursive metaphors[ii]. Emergent processes, more than the optimization of component parts, are about a search for an increase in collective fitness, and their implicit correlate is that the parts become transformed in entirely novel ways in the process. Its wholes are unforeseeable through the summation of their respective contributions; and their resultant conditions, more than the performative gains they promise, generate novel ambient conditions with highly evocative capacities.

II. ARCHITECTURAL DESIGN JOURNAL (AD) HAS PUBLISHED A NUMBER OF ISSUES ON THE SUBJECT. EDITORS MICHAEL HENSEL, ACHIM MENGES, AND MICHAEL WEINSTOCK ALSO DIRECT THE EMTECH PROGRAM AT THE AA

The animal scrutinizes him across a narrow abyss of non-comprehension. This is why the man can surprise the animal. Yet the animal - even if domesticated - can also surprise the man. The man too is looking across a similar but not identical, abyss of non-comprehension. And this is so wherever he looks. He is always looking across ignorance and fear. And so, when he is being seen by the animal, he is being seen as his surroundings are seen by him. His recognition of this is what makes the look of the animal familiar. And yet the animal is distinct, and can never be confused with man. Thus, a power is ascribed to the animal comparable with human power but never coinciding with it. The animal has secrets which, unlike the secrets of caves, mountains, seas, are specifically addressed to man.[5]

5. JOHN BERGER, *ABOUT LOOKING* (NEW YORK: PANTHEON BOOKS, 1980), 5.

FIG 1.2
ZOO ENCLOSURE AS MILIEU

THE 100TH EDITION.

H. 1561.
8.

WALKING IN THE ZOO

SUNG WITH DISTINGUISHED APPLAUSE
BY
THE GREAT VANCE.

Pr 3/-

A WALK THROUGH THE ZOO.

The Stilton, sir, the cheese, the O.K. thing to do,
On Sunday afternoon, is to toddle in the Zoo.
Weekdays may do for Cads, but not for me and you,
So, dress'd right down the road, we show them who is who.
The walking in the Zoo, walking in the Zoo,
The O.K. thing on Sunday is the walking in the Zoo.
Walking in the Zoo, walking in the Zoo.
The O.K. thing on Sunday is the walking in the Zoo.

6. CHRISTOPHER PULLING, *THEY WERE SINGING AND WHAT THEY SANG ABOUT* (LONDON: GEORGE G. HARRAP & CO. LTD., 1952), 14.

Sparking outrage from the Fellows of the Zoological Society's Gardens (what would eventually become the Regent's Park Zoo in London), the colloquial term "Zoo" was coined with these lyrics toward the end of the 19th century, sung by the Victorian Music Hall Artist, Alfred Vance. This betrayal of the zoo, which had been previously legitimated as a scientific endeavour, instantaneously conjured the mass appeal that animals have historically had as objects of our curiosity; subsequently, the zoo was to be appropriated by the public as a popular destination for recreational activity.

If the very first modern zoos (early 19th century) were testaments to science's increasing reign over the natural world, so, too, were the earliest animal collections on record. As displays of power and wealth, they signalled a different sort of dominion over the natural world. Animals were returned as bounty upon conquest into foreign lands, often exchanged as gifts between rulers. As elements of one's private property, they were kept as sources of personal entertainment and symbolic resonance.[7]

7. ELIZABETH HANSON, *ANIMAL ATTRACTIONS : NATURE ON DISPLAY IN AMERICAN ZOOS* (PRINCETON, N.J: PRINCETON UNIVERSITY PRESS, 2002)

The largest private collections were typically owned by royalty, such as the one held by Louis XIV at Versailles. At these country villas, animals were routinely kept in cages set in adjoining gardens. Each specimen would be housed in their own villa decorated either with folklore related to it, or with symbols of the country of its geographical origins.. There was no effort made to intimate a likeness to the animals' native habitats, privileging neither the animal resident nor the human spectator.[8]

8. DAVID HANCOCKS, *A DIFFERENT NATURE : THE PARADOXICAL WORLD OF ZOOS AND THEIR UNCERTAIN FUTURE* (BERKELEY: UNIVERSITY OF CALIFORNIA PRESS, 2001)

FIG 1.3
POSTER ADVERTISING 'WALKING IN THE ZOO', 1871

New concerns with cataloguing and classifying the natural world emerged during the Enlightenment, first amongst doctors and pharmacists, and eventually by

European aristocrats. The animal kingdom was one branch amongst many in nature that demanded mastery. This was first made spatially manifest in the Wunderkammeren. These cabinets of curiosities lay the groundwork for what would become our Museums of Natural History, in their display of taxidermic specimens alongside shells, insects, and other exotic artefacts. The common aim of these spaces and the many scientific texts that were to follow the same pursuit - typified most famously in works by Carl Linnaeus, Charles Darwin, and Ernst Haeckel - was to bring together diverse bodies of knowledge into comprehensive systems. In them, the world was pictured for the first time as a single entity, one that cohered, was ordered, and which might be divulged of all its secrets. It also signalled, for the first time, the inherent gap between the world and its representation.[9]

9. SUZANNE MACLEOD, *RESHAPING MUSEUM SPACE: ARCHITECTURE, DESIGN, EXHIBITIONS* (NEW YORK: ROUTLEDGE, 2005), 147.

The first modern zoos began to appear alongside the industrialization and urbanization of the European continent in the early part of the 19th century. These first institutions intended to elevate the viewing of animals from the casual curiosity of roadside spectacle towards full-fledged civic institutions dedicated to research and study. Animals were to be exhibited as taxonomic specimens, one to a cage or pavilion. Inertly framed by confined enclosures, they were only moderately more lively than the taxidermic specimens typical of the panoramic tableaus at natural history museums.[10]

10. IBID., 95

From the 1960's onward, rising concerns for the natural environment and the welfare of wildlife, sparked changes in zoo design. In North America, the creation of zoos for entertainment was cast as socially unacceptable. New zoos specified that their main beneficiaries would be the animals themselves. Immersive exhibits began to appear[iv], affirming the primacy and inseparability of the relationship between species and their environment. The hope was that the animals could serve as mascots for the conservation of wild and endangered places and creatures.

IV. SEE JONES AND JONES LANDSCAPE ARCHITECTS' SEATTLE WOODLAND PARK ZOO

The zoo narrative continues to this day to be challenged and rewritten. The benefits of its purported pedagogical capacity, captive breeding programs, habitat conservation, and environmental awareness missions remain questionable when set against the real issues that confront animal welfare.

FIG 1.4
ANIMAL MARGINALIZATION

WHY LOOK AT ANIMALS

> *[…] animals are always the observed. The fact that they can observe us has lost all significance. They are objects of our ever-extending knowledge. What we know about them is an index of our power, and thus an index of what separates us from them. The more we know, the further away they are.*[11]

11. BERGER, *ABOUT LOOKING*, 16.

In his text entitled *Why Look at Animals?* John Berger writes that the marginalization of the animal took root with industrialization. What began in the Age of Reason as an attempt to uncloak the natural world of its secrets has ended with the almost complete disappearance of wildlife from our lives.

> *The zoo to which people go to meet animals, to observe them, to see them, is, in fact, a monument to the impossibility of such encounters. Modern zoos are an epitaph to a relationship which was as old as man.*[12]

12. BERGER, *ABOUT LOOKING*, 21.

Particularly endemic to the program of the zoo are questions concerning agency and to whom, precisely, it shall serve. For the purposes of the thesis, it constitutes a highly contested territory with divergent forces and ambitions competing for primacy. Attesting to its impossibility, the zoo is a place underpinned by the sublimation of life. Nowhere are the less palatable aspects of life - death, decay, predation - left bare. The wilderness inside its animals has been all but dispelled, leaving visitors wondering why the animals seem less than what they believed them to be.[13]

13. BERGER, *ABOUT LOOKING*, 28.

The thesis aims to liberate the repressed wilderness by focusing on the performative aspects of the zoo's architecture. By making the welfare of the animals a central concern, the zoo becomes an instrument for the registration of difference and diversity, a key aspect of its pedagogical intent. It posits that the zoo's program might benefit from relinquishing some of its control; control that is primarily enforced through spatial means. The design strategy is one of searching out where program is convergent, and in doing so, achieving a sort of collective gain [read:emergence]. The very qualities of the animal world that zoo visitors seek out, are the very same that are suppressed as a consequence of captivation. For animals to be furnished with environments capable of their full actualization and sustenance, and for human visitors to be held, once again, captive by an environment capable of returning their glance, the two must be imbricated in one another. The thesis proposes treat-

FIG 1.5
THE IMPOSSIBILITY OF ANIMAL ENCOUNTER

ing the diverse range of programmatic requirements, human, animal or otherwise, as if, within them, lay the seeds of the zoo's morphogenetic development.

The positioning of the animals as hypothetical clients is an amplification of the already tenuous relationship that architecture has with those it serves. In doing so, emergence, as a strategy to produce wholes from small, knowable, truths or rules, suggests a possible course of relief to a more widespread situation than just that of the immediate territory of the zoo. Furthermore in light of the fragility and inaccessibility of standards that might help inform the housing of animals in captivity the design is given a little more room to speculate on the possible worlds it might engender. [And yet, by the very same token, it has the power to cause heightened moments of anguish over the very same leaps one affords themselves.]

The thesis suggests looking at architecture as an ecological milieu in which parts must operate in interdependent and adaptive ways. It is an opportunity to construct the landscape, somewhere between the dueling opposites of the natural/artificial discourse.

The zoo forces one to negotiate issues related to the simulacrum[iii]; the constructed, camouflaged to appear as a by-product of natural, unmediated forces. Though the exhibits intend to represent animals, and their nature, there is tension between them - creatures of our curiosity as exhibited - and their genetic doubles, living uninterrupted in the wild. The question is, how can we preserve [maximize] the verisimilitude and vicissitude of life while at the same time dampening some of its range [minimize] necessitated by the artificial condition of condensed and intertwined space. [Therein lies concerns about control and to what extent we can relinquish it while still maintaining any authority.] With the zoo, the thesis imagines a return to the wild, like that of a feral animal. Somewhere between the wild and the domesticated, exists a creature acquainted with the human world, but that has an inner wilderness that can condition its visitors, just as much as they do it.

III. *SIMULACRUM*, AS IN A PORTRAYAL OR REPRESENTATION

FIG 1.6
MALAYAN TAPIR, FROM VOLKER SEDING'S *"CAPTIVE"* SERIES

THE CYBORG'S TRANSGRESSION

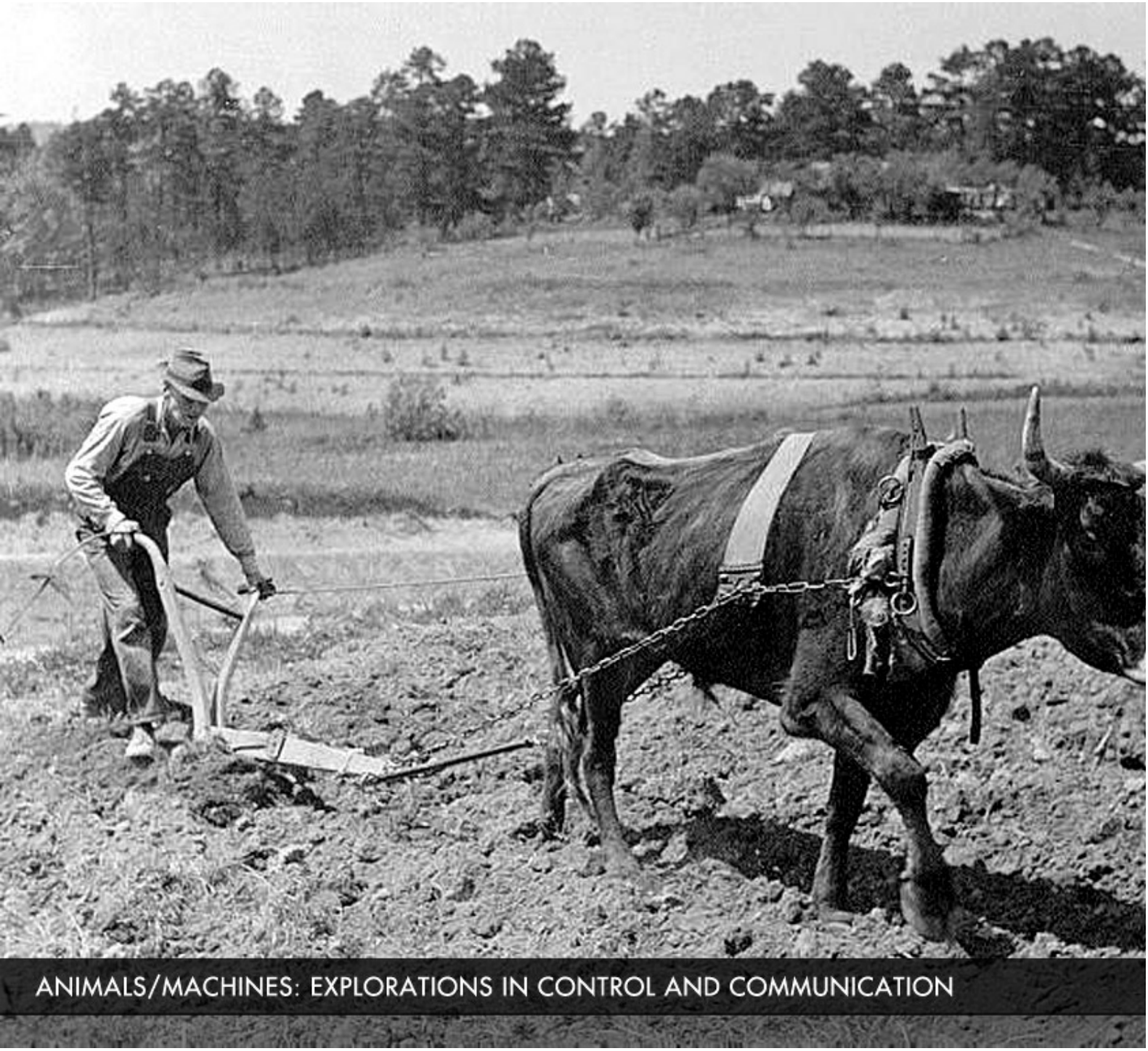
A CULTURAL PERSPECTIVE

Cyborg unities are monstrous and illegitimate; in our present political circumstances, we could hardly hope for more potent myths for resistance and recoupling.[14]

[14] DONNA HARAWAY, *SIMIANS, CYBORGS, AND WOMEN : THE REINVENTION OF NATURE* (NEW YORK: ROUTLEDGE, 1991), 154.

FIG 1.7
THE VACANTI MOUSE

FIG 1.8
STELARC, PERFORMANCE ARTIST


ANIMALS/MACHINES: EXPLORATIONS IN CONTROL AND COMMUNICATION

The territory of the zoo program, and emergence as a way of understanding complexity, should be read as foils to larger cultural concerns to which this thesis will address only obliquely.

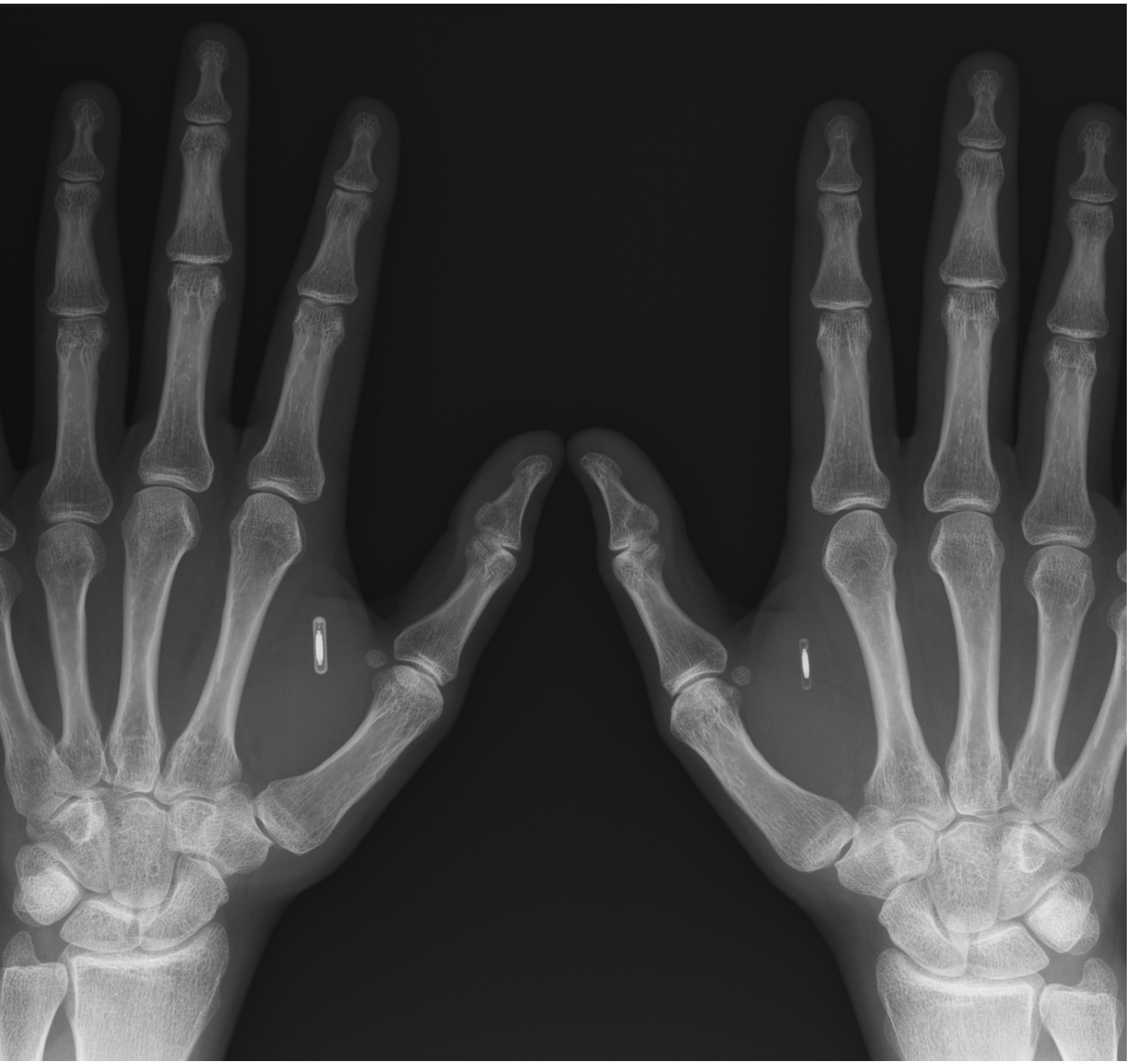
With the prospect of a design for a new zoo, a number of boundaries stand poised to be breached; universals, such as those between man and animal, and between life and technology; related to the zoo program, that between the zoo and the city, amongst distinct species or types, and between the zoo visitor and captive animal. The ambition in the proposal, and its underlying processes, is to disorder these distinct breaks, to disrupt their dualities, making it possible to see continuity and likeness across boundaries.

It is implicit, then, that the thesis is also concerned with the perception and constitution of bodies or wholes. Both the zoo program and emergence share in this preoccupation; the zoo - as a museological institution that arranges and classifies the world - and emergence - as a conceptual device for, both, perceiving, and understanding complex phenomena. Since the widespread acceptance of the Linnean system[v], zoos have prioritized taxonomic classification of the biological diversity of the world. The shared genetic traits that come to define each species - primarily manifested in visible morphological traits - confine the individual to a type, thus ignoring local particularities. From the population, it is either the statistical average that comes to define the group or that which is remarkable (largest, fastest, most ferocious) by human perception. With emergence comes an animate ("hub bub"), irresolute energy, injected into an otherwise closed, fixed unity; it describes the same organisms as an amalgam of units, the whole emerging only through their interaction. Emergence is an orientation with a distinctive rhizomatic bent. Non-linear, ahierarchical, and connective across diverse territories, it reinterprets the world as a constant becoming.

The aim of the thesis is to render the territory open to continuous re-territorialization. It intends to break down the stiff linear boundaries between worlds to reveal by registration of contiguity across distinct boundaries. The process of identification is conceived to be a continuous one; a body - human or animal - might be described

V. *SYSTEMA NATURAE*, PUBLISHED IN 1735.

FIG 1.9
AGRICULTURE WITH OXEN



in terms of assemblages of constituent parts (molecules or cells or...) persisting in time, and the same approach could hold true for populations just as it would for geological, economic, political or other processes.

POST HUMANISM & ECOLOGY

In its material and spatial portrayal of the animal kingdom as composed of atomic entities, enclosed and separated from one another by concrete walls, bars, or trenches, the zoo has done its audience a disservice. If, in ecology, Ernst Heackel first advanced the primacy of the environment in shaping the individual organism, the "umwelt" as posited by Estonian zoologist, Jakob von Uexküll, made the relationship more complex.[15] It further de-centered the world as a singular one, given to, and oriented around, the human. It describes a sort of reciprocity between body and milieu, in which the milieu is presented to each organism only insofar as its body and sensory organs are equipped to perceive it. The animal, then, does not "see" others as such, so much as elements of its environment that prompt its body into action.

15. AGAMBEN, GIORGIO, *THE OPEN : MAN AND ANIMAL* (STANFORD: STANFORD UNIVERSITY PRESS, 2004), 40.

Insofar as ecology and the umwelt explain that bodies are perpetually re-territorialized by operations of adaptation, mutualism, and coevolution, recursive reciprocal inflections such as that of the orchid and the wasp[16], illustrate models that architecture has only infrequently and casually reproduced.

16. GILLES DELEUZE, FÉLIX GUATTARI, AND BRIAN MASSUMI, *A THOUSAND PLATEAUS : CAPITALISM AND SCHIZOPHRENIA* (LONDON: CONTINUUM, 2004), 10-12.

> *Each subject spins out its relationship to certain properties of things, like the silken threads of a spider, weaving them to a firm web that supports its existence.*[17]

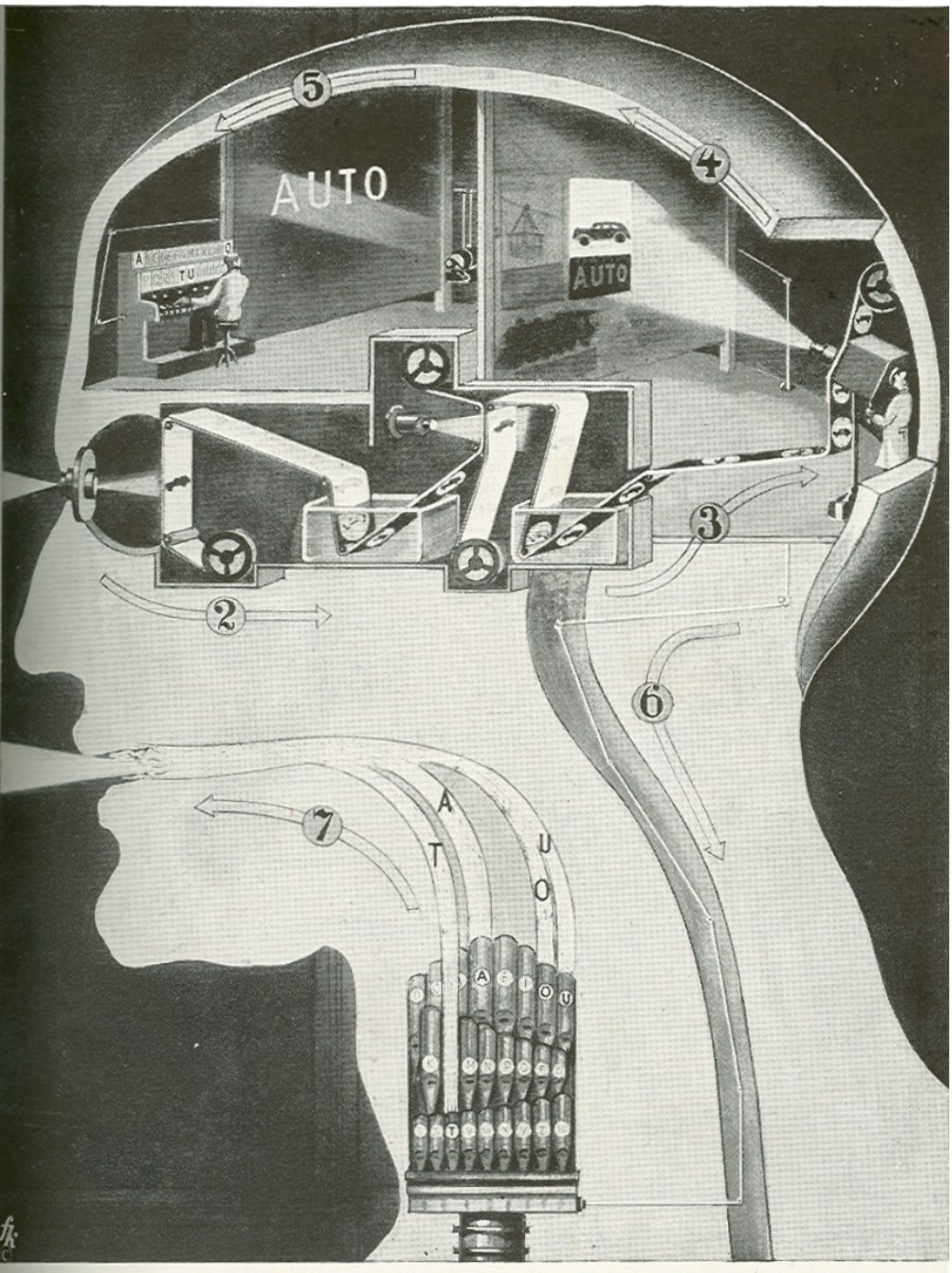
17. JAKOB VON UEXKULL, "A STROLL THROUGH THE WORLDS OF ANIMALS AND MEN: A PICTURE BOOK OF INVISIBLE WORLDS." *SEMIOTICA 89.4* (1992), ORIG. (1957): 14.

SIMULACRA

Contemporary zoos allege to transport their visitors to the alternate realities of far-off worlds. Whereas the simulacra, according to Baudrillard, threatens at every moment to replace the real – becoming corrupted, or losing its legitimacy, authenticity or depth – Deleuze counters with its validation; that "reality" is an ongoing construction, perpetually undergoing synthesis, and that it is precisely through the act of simulation that our perceptions are transformed[18]. It is the covert situation of a project within the tissues of reality by *resemblance* that bends it. It is in the 'mistakes' achieved by way of the camouflage - of the simulacrum for reality - that locates its efficacy in replacing the real. The malevolence of this surrogacy is not given by the deception itself, but by what it enables.

18. BRIAN MASSUMI, *REALER THAN REAL: THE SIMULACRUM ACCORDING TO DELEUZE AND GUATTARI* (IN COPYRIGHT, NO.1, 1987) 90-97

FIG 1.10
X-RAY OF HUMAN HANDS WITH RFID IMPLANT
IMPLANTED CAPSULE CAN REVEAL GPS LOCATION



309. This is what occurs in our head when we see an auto and say "Auto."

The question seems to be, if architecture might be considered to be a significant part of the human's milieu, as distinct from the animal, what if it were to be generated out of evolutionary processes that more closely approximated those that operate in unmediated, adaptive, and conceptually disordered ways[and at a different temporal scale]? The question of the animal, and what distinguishes man from it, are far too broad and deep to enter into here but, the thesis calls for one to step away momentarily from the humanist tradition which grants primacy to the supposed superiority of the intellect, and imagine a world generated by embedded material intelligence. In humankind's attempt to re-calibrate their environment, we might want to weigh what we forfeit in the process; in all the disease, discomfort, and suffering that we may sublimate through artifice, we are removed, too, from the depths of complexity, ambiguity, and wilderness. In the design for the zoo, the thesis imagines a position that embraces and co-opts these qualities.

> *Descartes internalized, within man, the dualism implicit in the human relation to animals. In dividing absolutely body from soul, he bequeathed the body to the laws of physics and mechanics, and, since animals were soulless, the animal was reduced to the model of a machine.*[19]

[19] BERGER, *ABOUT LOOKING*, 11.

Written almost 20 years ago, Donna Haraway's *Cyborg Manifesto* seems more prescient today than ever. In her essay, she spells out three groupings of opposites, across which border wars are enabling a new myth of the cyborg: human and animal, human-animal and machine, and the physical and non-physical. In these breakdowns, she sees a potential way out of the eternal struggles of the dualisms that attend dominance - self/other, body/mind, human/animal, public/private, man/woman, nature/culture, primitive/civilized. Cyborgs are not ruled by reproductive politics - they completely bypass the origin story in the western humanist sense - and thus do not necessitate a return to innocent wholeness. They do not seek unitary identity which gives rise to the aforementioned dualistic conception of the world. Their irony is in the potential subversion of their teleology, itself rooted in militaristic and patriarchal capitalism. On the one hand, the cyborg may be viewed as an implementation of the grid of control across the planet. But it may just as well "be about lived social and bodily realities in which people are not afraid of their joint kinship with animals and machines, not afraid of permanently partial identi-

FIG 1.11
"WHAT GOES ON IN OUR HEAD WHEN WE SEE AN AUTO AND SAY 'AUTO'", FRITZ KAHN, *DAS LEBEN DES MENCHEN*, STUTTGART, 1929

SCIENCE

MECHANICAL BRAINS

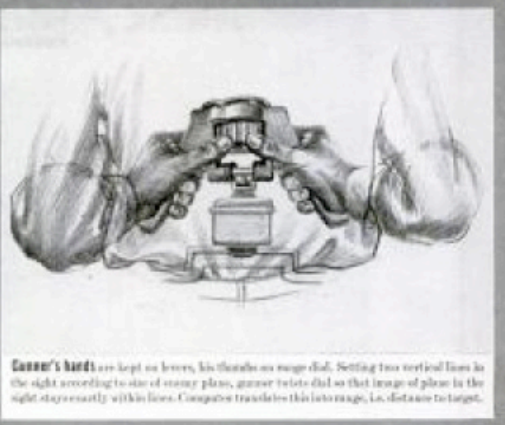
WORKING IN METAL BOXES, COMPUTING DEVICES AIM GUNS AND BOMBS WITH INHUMAN ACCURACY

A great many of the best and busiest brains fighting this war do their work not in men's heads but in metal boxes. These are mechanical brains, the useful though prosaic counterparts of the comic-strip robots that go around with stereotype joints on their legs and electric coils sticking out like hair on their steel heads. The boxed brains are computing devices which 1) take certain conditions into account, 2) go through some mechanical mathematics and 3) quickly give an answer which automatically aims a gun or directs an airplane or drops a bomb.

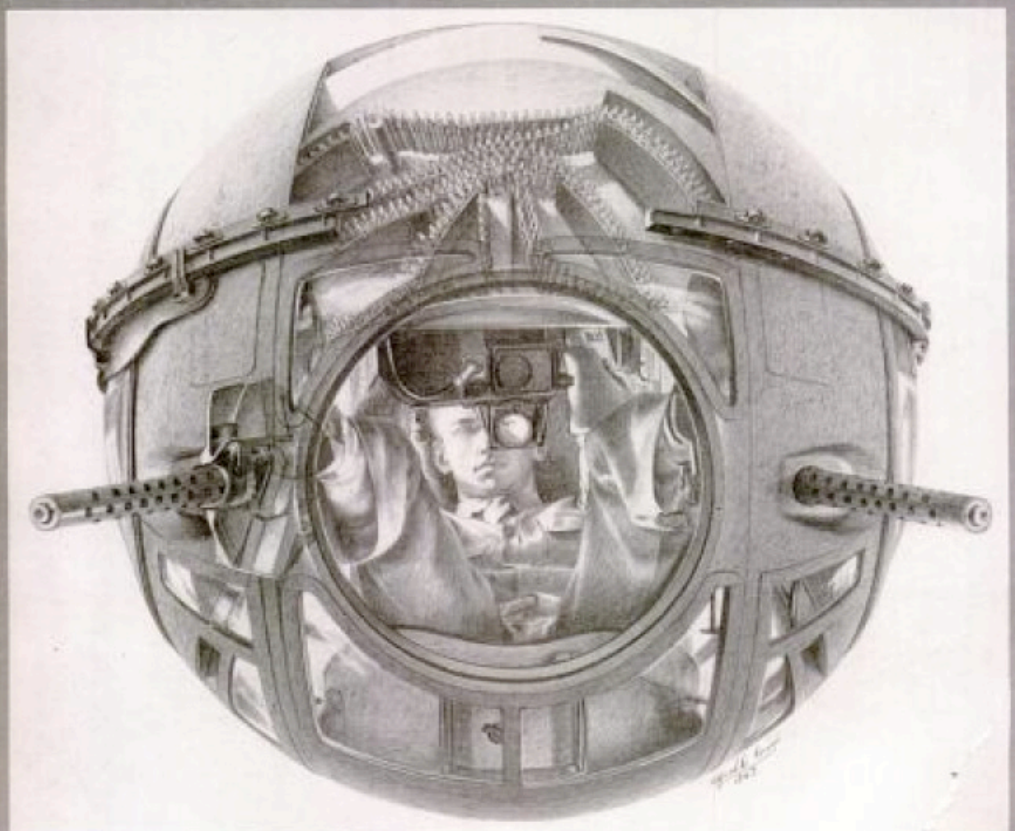
For a great many years the Sperry Gyroscope Co. of Brooklyn, N.Y. has been in the business of building mechanical brains and putting them up in metal containers. Today Sperry's business is at far-flung as the war itself. Sperry bombsights help drop bombs on our enemies. Sperry gyroscopes guide airplanes everywhere over the world. Sperry gunsights help knock enemy planes out of all the skies. Sperry control apparatus fires guns on land and sea.

One of the newer Sperry gadgets is the automatic gunsight which is used in U.S. bomber gun turrets. The way this sight and turret work is shown in the drawings on these pages. The gunner lines up his target with two vertical hairlines in the sight. The trick is to keep the enemy plane exactly framed within these lines, which are moved in or out by means of a range knob as the target approaches or recedes. As he follows the target in its course, the sight automatically makes deductions from this "tracking" process, which it translates into the relative course and speed of the target. Taking this data, the range data and other factors like the weight of .50-cal. bullets, the gears and levers and circuits that make up the mechanical brain arrive with inhuman speed at an answer. The answer is expressed at the critical moment when the gunner presses his triggers and fires his .50-cal. machine-gun at a target. The gunner's accuracy is not 100%. But it is far higher than it ever has been before in the short-lived history of combat aviation.

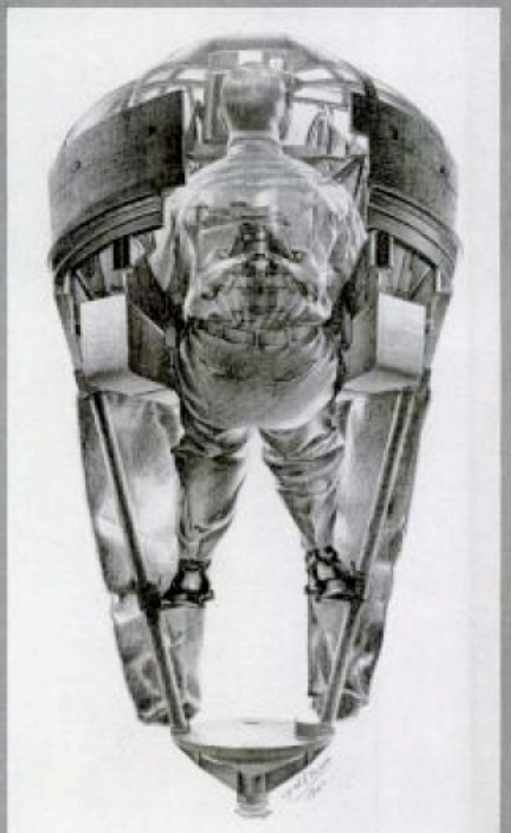
Sperry's involvement in aerial war goes back to the very beginning of war planes. The history of its development of the precision bombsight is described in the series of drawings on pages 63-64.



Gunner's hands are kept on levers, his thumbs on range dial. Setting two vertical lines in the sight according to size of enemy plane, gunner twists dial so that image of plane in the sight stays exactly within lines. Computer translates this into range, i.e. distance to target.



The ball turret underneath a big bomber operates on the same principles that govern the turret explained in detail on opposite page. Peering through his automatic computing sight, the gunner swings his turret horizontally in a complete circle and vertically from the position shown here, where guns are parallel to bottom of the plane, to position in which the guns point straight down. The bullets feed into .50-cal. guns through the system shown in cutaway part of the drawing. Electro-hydraulic mechanism of turret is made by Sperry.



Full view of turret with the gunner's body partially transparent is a composite of other drawings. Gunner never has to worry about hitting a part of own plane, such as the tail. Turret is built so that the guns automatically stop firing if they point at part of the plane.

CONTINUED ON NEXT PAGE

ties and contradictory standpoints." As illegitimate offspring, the cyborg - since their fathers are inessential - promises to be unfaithful to its origins.[20]

Taking cues from these texts, the zoo imagines, and takes pleasure in the collapse of these borders. It proposes using the program of the zoo as a re-orientation device; blurring primacy between animals and humans, and imagining machines operating as animals, and animals replacing machines, all to breakdown the body/mind split that continues to underpin domination.

20. HARAWAY, *SIMIANS, CYBORGS, AND WOMEN*, 154.

FIG 1.12
CYBERNETIC DEPICTION OF BALL TURRET, TIME MAGAZINE

The computer is being used to re-enliven old, especially mythological, animals that had begun to die in the imagination.[21]

21. CATHERINE INGRAHAM, *ARCHITECTURE, ANIMAL, HUMAN : THE ASYMMETRICAL CONDITION* (NEW YORK: ROUTLEDGE, 2006), 326.

FIG 1.13
WIM DELVOYE'S CLOACA MACHINE, 2000

Yume-Neko
夢ねこ
スマイル
あなたの気持ちにこたえてくれる…
ホワイト / ブチ黒
NEW!
あおむけにして
むねをなでてあげるとうれしがるよ♪
あたまをなでるとうれしくて
ゴロゴロのどをならしたり・・・
しっぽをふりふりするよ♪
好評
発売中!
好評
発売中!
ほっぺをなでると甘えてくるよ♪
背中をなでると
『ニャー♥』とごきげん♪
なでつづけると
気持ち良さそうに眠ってしまいます。
しっぽをつかむと怒っちゃう!
にゃん!
「夢ねこスマイル」は本物そっくりのかわいらしいペットです。

The original intention of the research was to enquire about the capacity for technique to help bridge the gap between theory and practice. Taking cues from a vast reserve of writings and practices dealing with the role of computation in progressive architectural practice - especially those that approximate natural systems - this included the acquisition of literacy in programming and writing code.

In computation, the non-linear dynamic flows of biological and other natural processes can be re-created in such a way that they operate on structural levels; shaping flows and behaviours rather than attuning to the reason of the eye. Instead of the symbolic or the narrative, both of which are employed typically from a singular perspective, the architecture may operate by a registration of a field of difference. A field condition has no singular story to tell. It is one waiting to be told, with various points of entry and exit, and different ways of reading the same material.

Catherine Ingraham [as have others] outlines the "functionalist ethic" that persists in computational work, one connected to material production in service of capital.[22] On the other hand, the computer has roots in warfare and as an instrument of political power. The computer, here, is used for the same abstraction it has afforded these regimes but it reappropriates them to subvert the orientation which views animals and the natural world as a standing material reserve.

22. INGRAHAM, *ARCHITECTURE, ANIMAL, HUMAN*,316.

The primary assumption of the thesis is that in order for emergence to act cooperatively in the design process (not discounting the latent merits of the emergence that will occur over the life of project in term of its appropriation, use, and misuse), one would have to synthesize its processes, those which involve numerous agents acting independently in time.

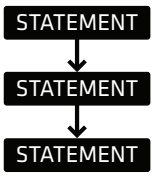
Nature produces its forms by parallel process and though architecture professes to operate in a similar way, experience in practice attests to the flimsiness of this correspondence. What one actually encounters is an overly hierarchical top-down system of discrete atomic processes. Feedback tends not to be reciprocated; it moves in one direction. The behaviour of behind-the-scenes' installations yield to the ambitions of the visual domain or vice-versa. Computers are, by definition,

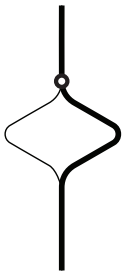
FIG 1.14
JAPANESE ROBOT CAT, SEGA TOYS, 2006

BASIC CONTROL STRUCTURES

SEQUENTIAL

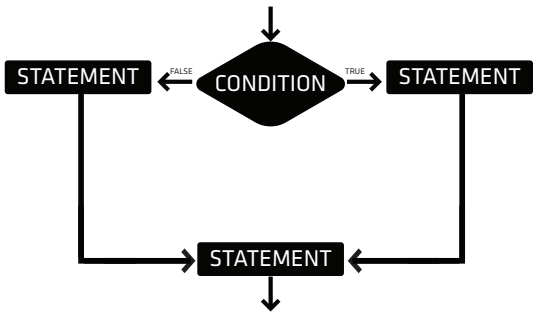
AN ORDERED LIST OF STATEMENTS





CONDITIONAL

SELECTION BETWEEN ALTERNATIVE SEQUENCES

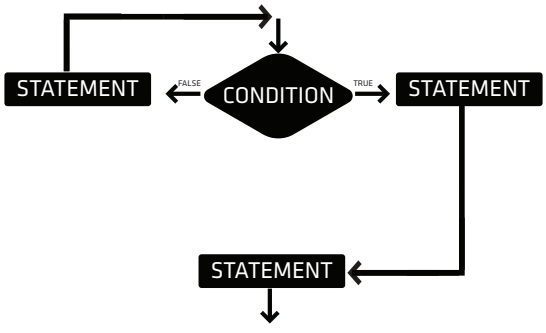


EXAMPLES:

IF THEN ELSE

ITERATIVE

SEQUENTIAL LOOP WITH CONDITIONAL STATEMENT



EXAMPLES:

FOR - A LIST OF VALUES/ARRAY
WHILE - AS LONG AS A CONDITION HOLDS TRUE
UNTIL - UNTIL A CONDITION IS REACHED

serial machines; they are only capable of processing sequential lists of procedures. Despite this fundamental structural limitation, there are mechanisms that allow for the simulation of the parallel. One is the time slicing loop; time is divided into single units that only progress after completion of an entire run of its list of procedures and subroutines. Though each pass through a script may be sequential in itself, to the computer, everything occurring within it is concurrent. The other essential mechanism is buffered storage, a reserve of memory appointed to storing processes whilst others are operating. When combined, the two allow for a single computer to behave as if it were multiple; each devoted to its own element in a program. Certain problems, like those of agent-based systems, exploit these mechanisms to examine their behaviours in ways that would be impossible to do with pen and paper.[23]

The strength of the computer is in repetitive action. It will tirelessly execute long lists of commands in fractions of the time it would take to perform by hand. With the speed afforded by computation - allowing the execution of tasks that might otherwise be deemed to be time consuming beyond feasible human persistence or devotion - also, and perhaps, more significantly, comes a qualitative change in what is possible. Additionally, their structural logic of modular subroutines eases our ability to dissect them in search of the source of qualities, be they desirable or not. Eventually, with refinement, we can build mathematical theory around these functions.

The experimentation of simulating natural processes, particularly that of Artificial Life, can be seen as a halfway point between theory and practice. Though not directly operating on matter or what we might call "reality" itself, in a surrogate environment, computational experiments allow searches and explorations within the vast realm of the possible. And still, they are rigorous if they are nothing else. There is no ambiguity about the relationship between the definition of the model and the results it will generate. These will hold as true only for the particular settings used when it is executed, and due to this required rigour, it enforces discipline. As John Holland - preeminent researcher into complex systems, and inventor of the genetic algorithm - puts it, "no amount of clever rhetoric or wishful thinking will cause a computer to deviate one iota from the consequences of the rules it embodies."[24]

23. STEVE GRAND, *CREATION : LIFE AND HOW TO MAKE IT* (CAMBRIDGE: HARVARD UNIVERSITY PRESS, 2001), 106.

24. JOHN H. HOLLAND, *EMERGENCE : FROM CHAOS TO ORDER* (READING: ADDISON-WESLEY, 1998), 121.

FIG 1.15
BASIC CONTROL STRUCTURES

BOIDS PROGRAM

initialise_positions()[i]

LOOP

draw_boids()[ii]

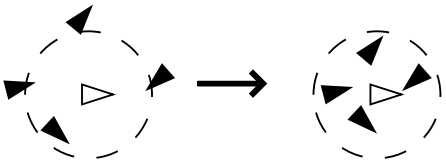
move_all_boids_to_new_positions()[iii]

END LOOP

[i] initialise_positions(): the procedure that puts all the boids at a starting position.
[ii] draw_boids(): the procedure that simply draws one 'frame' of the animation, with all the boids in their current positions.
[iii] move_all_boids_to_new_positions(): the procedure that contains the actual boids algorithm.

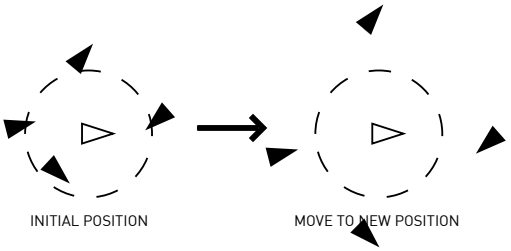
FLOCKING RULES

COHESION
RULE 1: BOIDS TRY TO FLY TOWARDS THE CENTRE OF MASS OF NEIGHBOURING BOIDS.



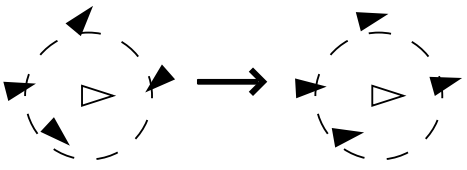
INITIAL POSITION MOVE TO NEW POSITION

SEPARATION
RULE 2: BOIDS TRY TO KEEP A SMALL DISTANCE AWAY FROM OTHER OBJECTS (INCLUDING OTHER BOIDS).



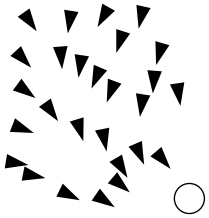
INITIAL POSITION MOVE TO NEW POSITION

ALIGNMENT
RULE 3: BOIDS TRY TO MATCH VELOCITY WITH NEAR BOIDS.

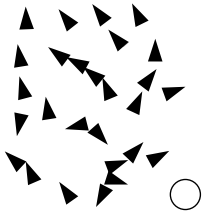


INITIAL POSITION MOVE TO NEW POSITION

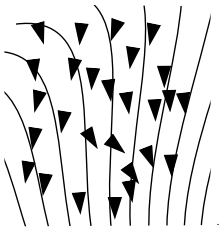
ADDITIONAL RULES



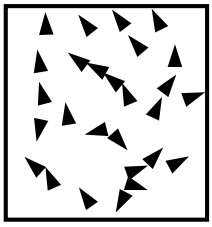
TENDENCY TOWARDS A DESTINATION



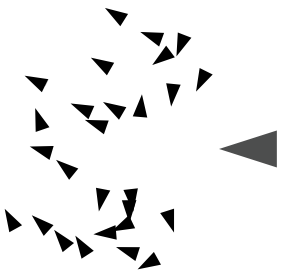
TENDENCY AWAY FROM PLACE



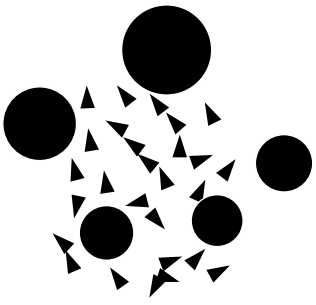
APPLICATION OF A FIELD CONDITION, LIKE WIND OR CURRENT



BOUNDING THE POSITION



SCATTERING OF A FLOCK
WHEN CONFRONTED WITH A PREDATOR



RESPONSE TO FIXED OBJECTS
PERCHING AND OBSTACLE AVOIDANCE

OOP

Object Oriented Programming (OOP) is an orientation to computer programming that instructs the behaviour of objects in genotypic code. These rules are embedded in classes, each one serving a distinct type of object. Classes are identified by names and instantiated by constructors. They can be given fields to carry variables and methods describing their behaviour in time; they are templates for indeterminate form spelling out how each object relates to its environment, and does not explicitly give form. Conceived as being separate from, but potentially responsive to, their environment, OOP is instrumental in exploring and simulating multi agent-based systems.

Multi-agent based systems provide a way to illustrate emergence; objects with simple rule sets interacting with one another to generate complex wholes. The Boids algorithm, written by Craig Reynolds, demonstrates how, given a basic class with only three simple methods – cohesion, separation, and orientation - its objects can very easily reproduce the flocking behaviours exhibited in the uncoordinated behaviour of various species.

Incidentally, many introductions to OOP concepts use analogies of zoos and animals. Structured around ideas of type and taxonomy, natural order appears to help initiates with the logic of classes, inheritance, and permutation. These examples are thoroughly imbricated with an essentialist conception of the world where "object"-ness is transcendental. Rather than viewing combination as a tactic by which to generate divergent possibilities, somehow these examples appear to miss the potential to move beyond the confines of type.

Computer based models greatly expand our opportunities for using intuition. Expanding on the informality of napkin sketches, they allow one to entertain 'what if' scenarios but allow too for the inclusion of metric details that would otherwise infringe on the immediacy of the napkin. Of course with this capacity comes a greater responsibility and need for attentiveness to only those details that matter. Too much detail defeats the purposes of the model, but this danger does not foreclose its possibilities.

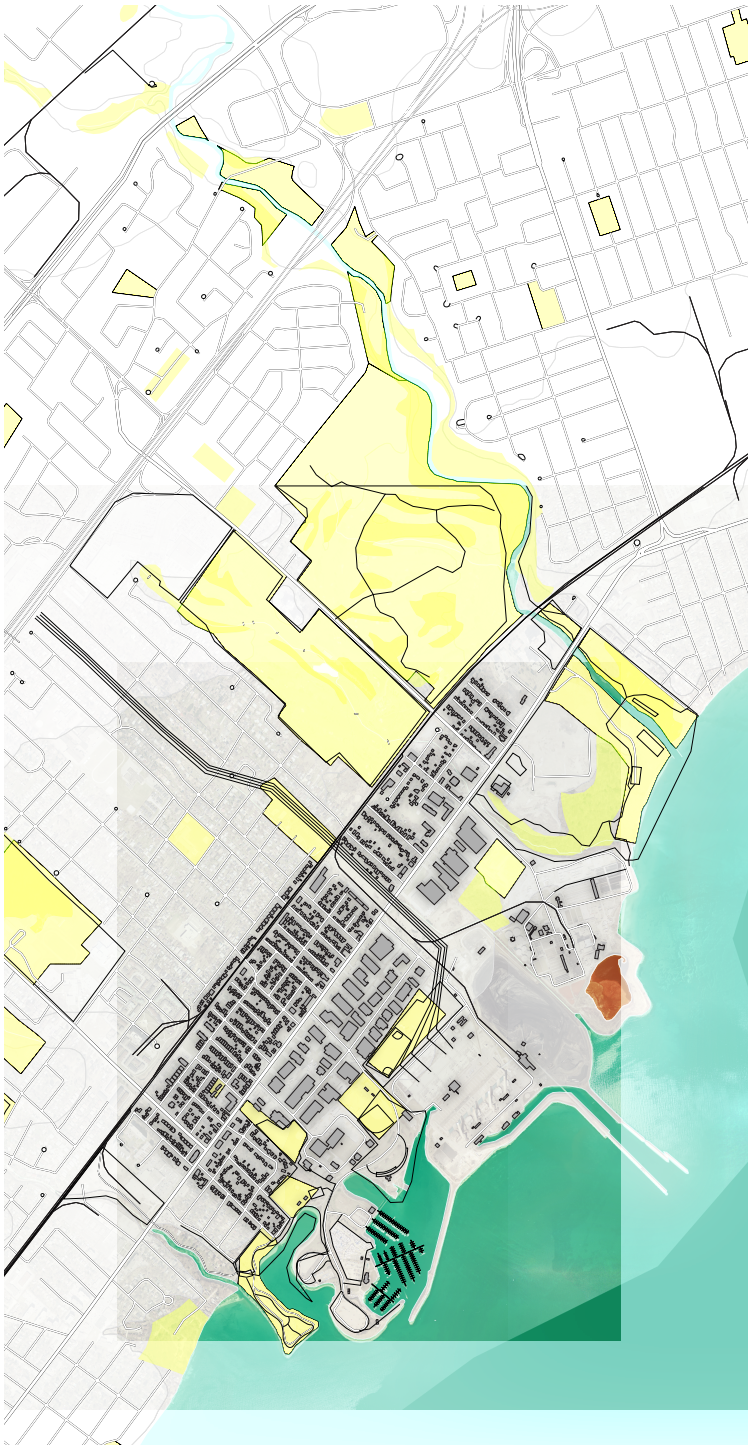
FIG 1.16
BOIDS ALGORITHM DIAGRAMS

Late twentieth-century machines have made thoroughly ambiguous the difference between natural and artificial, mind and body, self-developing and externally designed, and many other distinctions that used to apply to organisms and machines. Our machines are disturbingly lively, and we ourselves frighteningly inert.[25]

25. HARAWAY, *SIMIANS, CYBORGS, AND WOMEN*, 152.

FIG 1.17
AERIAL PHOTOGRAPH OF LAKEVIEW GS

BRADFORD
UXBRIDGE
WHITECHURCH
STOUFFVILLE
MARKHAM
BOLTON
HILL
UNIONVILLE
VAUGHAN
THORNHILL
METRO TORONTO ZOO
WOODBRIDGE
C.N.R.
PICKERING
BRAMPTON
GEORGETOWN
TORONTO
LAKEVIEW
PORT CREDIT
MISSISSAUGA
MILTON
CLARKSON
OAKVILLE
LAKE
BURLINGTON
HAMILTON
GRIMSBY
LINCOLN
ST. CATHARINES
404
407
400
409
427
QEW
403



A PROTOTYPICAL URBAN CONDITION

Zoos, by their very definition, are places not about the local, but the foreign. They house life forms alien to their context, and in so doing, they bow in varying degrees to unfamiliar pressures. Their orientation is inward, towards transporting their visitors to remote worlds with completely different landscapes. They are thus allied with the simulacra, and their relationship to their immediate context is a tenuous one. The thesis imagines the zoo as a program embodied primarily by a set of rules governing adaptive behaviour, and thus not bound to any one specific site. For the purposes of demonstration, Lakeview is used as a prototypical condition, whose situation might be well-suited to host a zoo.

GEOGRAPHY

The Lakeview area is located along the northern shores of Lake Ontario, halfway between the urban cores of Toronto and Hamilton. The area, on Mississauga's eastern border, is bound roughly by the Cooksville Creek at its western edge and the Etobicoke Creek at its eastern edge. It is just east of Port Credit and was amalgamated into the Town of Mississauga in 1968.[26]

26. HTTP://WWW.LAKEVIEWRESIDENTS.COM/

INDUSTRY

The community has deep roots in industry and the military. Its primary genus loci comes from its situation along the waterfront, outside the city, but within reach of a number of large civic centres. Its environment and scenery, however, might be viewed as the vague terrain of an environment long polluted by large industrial facilities amongst which include a large operating coal fired power plant, a waste-water sewage treatment facility, a water treatment plant as well as a significant stretch of light industrial grounds. These programs have created a disconnect from the water's edge, as well as an affront to the environment, whether in their disregard for the ambient streetscape (driven by the logistics of trailer trucks) or the smells emitting from the sewage facility.

MILITARY

But before there was industry, there was military. In fact, the area is remembered as the place where Canada's aviation history began. In the early part of the 20th century, Canada's first airport was located on what was, until the recent past, the grounds of the Lakeview Generating Station. It was there that Canada's air force was first trained in aerial warfare, and it later provided launch points for the air force's entry into WWII. An armoury, sited at the eastern end of Lakeview, served various military

FIG 1.18 ←
MAP OF SOUTHERN ONTARIO'S GOLDEN HORSESHOE

FIG 1.19 →
SITE CONTEXT

functions including weapons manufacture and storage, training and barracks. Large quantities of armament were produced at the site during the war.

PRE-COLONIALIZATION

Prior to European settlement, the land witnessed a perpetual succession of ownership with invasions and counter-invasions by numerous native groups. In time, most of the Credit Mississauga's land was lost during the Mississauga purchase but they maintained a small reserve flanking the shores of the Credit River. Industrially polluted river water caused the group illness and disease, which eventually forced them to flee these lands. In the 19th century, farm communities settled along Lakeshore road and along each of the rivers, creeks and roads it crossed. With this wave of development, the original forest cover was virtually wiped clear.[27]

27. HTTP://WWW.LAKEVIEWRESIDENTS.COM

CURRENT STATUS

Today, Lakeview is in a liminal state. A major step in the site's evolution arrived with the long-awaited demolition of the 'Four Sisters' of Lakeview Generating Station in June of 2006. The coal-fired power plant had been a landmark for the area, with each of its four smokestacks standing at almost 500 feet tall, dwarfing its neighbouring light-industrial and low-density residential sprawl. Its power supply once supplied about 17 per cent of Ontario's electricity needs.[28]

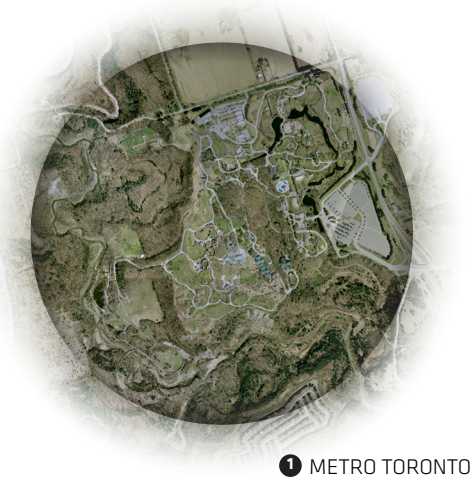
28. [BROCHURE_LAKEVIEWRETRO.PDF] [HTTP://WAPEDIA.MOBI/EN/LAKEVIEW,_MISSISSAUGA>]

Plans by the City of Mississauga are underway to revitalize nearby Marie Curtis Park at Lakeview's easternmost edge. With the remediation of contaminated soil at the former site of the Arsenal lands, the existing park space has expanded its presence westward. With the demolition of the power station, and the announcement that the Ontario government had no intentions of replacing the plant with a new gas-fired generator, much speculation on the future of the area has ensued.

A NEW DESTINATION

Amongst the visions for the now vacant Generating Station lands are a new recreational waterfront to be developed in conjunction with a larger renovation of land use from light industrial to mixed live-work spaces. The Lakeview Ratepayers Association has envisioned a scheme for the land that includes - in addition to residential, commercial, and institutional uses - a "destination" waterfront area with trails, parks, and even major tourist attractions that might include a stadium, an aquarium, and a pier with more recreational attractions such as a Ferris wheel.

FIG 1.20
VIEWS OF THE FOUR SISTERS BEING DEMOLISHED IN 2006.



1 METRO TORONTO ZOO
287 HECTARES
460 SPECIES
5000 SPECIMENS
1.2 MILLION VISITORS/YEAR

2 BRONX ZOO
107 HECTARES
5000 ANIMALS
2 MILLION VISITORS/YEAR
ARIZONA DESERT

3 SEATTLE WOODLAND PARK ZOO
92 HECTARES
1100 ANIMALS
300 SPECIES
1.1 MILLION VISITORS/YEAR
PER YEAR

4 SAN DIEGO ZOO
40 HECTARES
4000 ANIMALS
800 SPECIES
3.2 MILLION VISITORS/YEAR

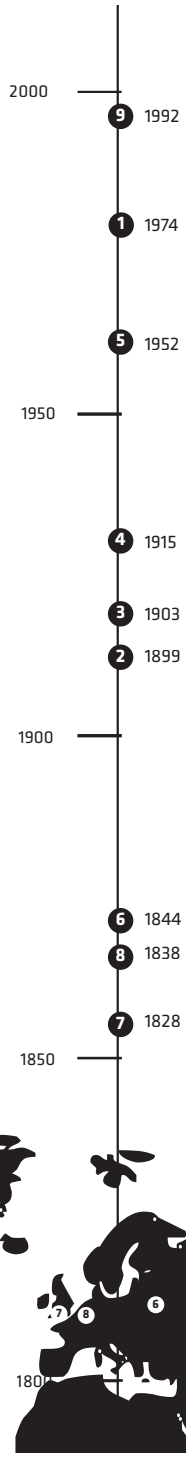
5 ARIZONA-SONORA DESERT MUSEUM
40 HECTARES
2744 ANIMALS
300 SPECIES

6 ZOOLOGISCHER GARTEN BERLIN
35 HECTARES
14,171 ANIMALS
1480 SPECIES
2.6 MILLION VISITORS/YEAR

7 LONDON REGENT'S PARK ZOO
15 HECTARES
16,802 ANIMALS
755 SPECIES

8 ARTIS ROYAL ZOO AMSTERDAM
10 HECTARES
8,236 ANIMALS
786 SPECIES

9 MONTREAL BIODOME
1 HECTARE
4,700 ANIMALS
240 SPECIES



Remarkably, during a charette process, one resident enquired into the possibility of housing a new zoo, which prompted a collage of the Metro Toronto Zoo onto the site. The single most consistent aspect of all prospective plans is centred on a renewed relationship between residents and the lake's edge.

FERTILITY

For the purposes of the thesis exploration, the site operates on a number of levels. Between its location and connectedness, existing landscape elements, available land, and adjacency to industry, a number of qualities lay in the site that identify it as an ideal prototypical condition for a zoo.

At just over 200 hectares, the site provides a generous amount of space for a zoo program while not earning the distinction – as Metro Toronto Zoo has – of being the largest zoo in the world. The first modern zoos, sited within the density of their respective urban cores, tend to be a quarter of the size at roughly 50 hectares each. Lakeview's land provides a happy medium between the gluttonous excesses of the zoo set within a pastoral landscape, and that of the oppressive enclosures of the zoo set within a dense urban core.

Partway along the Golden Horseshoe, between Hamilton and Toronto, the site is easily accessed by a population of 8 million potential visitors. It sits just south of the Lakeshore Boulevard West, a major thoroughfare, connected nearby to the Queensway Express Highway nearby. Regional rail connections are also provided for by nearby Long Branch Go Station. Local connections include Mississauga Bus routes and biking trails. The redevelopment plans for the area have also called for an extension of Toronto's Lakeshore LRT route to extend into Mississauga, which now stops nearby at Long Branch.

The site's primary distinguishing feature is its large stretch of shoreline, enabling an unmediated edge where its architecture and the surrounding landscape can be wed seamlessly together. Many of the zoo's species and exhibits require water facilities; and these installations can suggest extensions of the lake. Even before plans for the area's rejuvenation start to be put in place, the site has the seeds of several distinct landscape conditions. These latencies allow the zoo to covertly slip into place; its

FIG 1.21
ILLUSTRATION OF HISTORICAL DEVELOPMENT OF ZOOS
STUDY OF NOTABLE PRECEDENTS IN SCALE & CONTEXT ; EACH ZOO IS LOCATED GEOGRAPHICALLY AND IN TIME

body addressing its environment by amplification and extension of existing conditions.

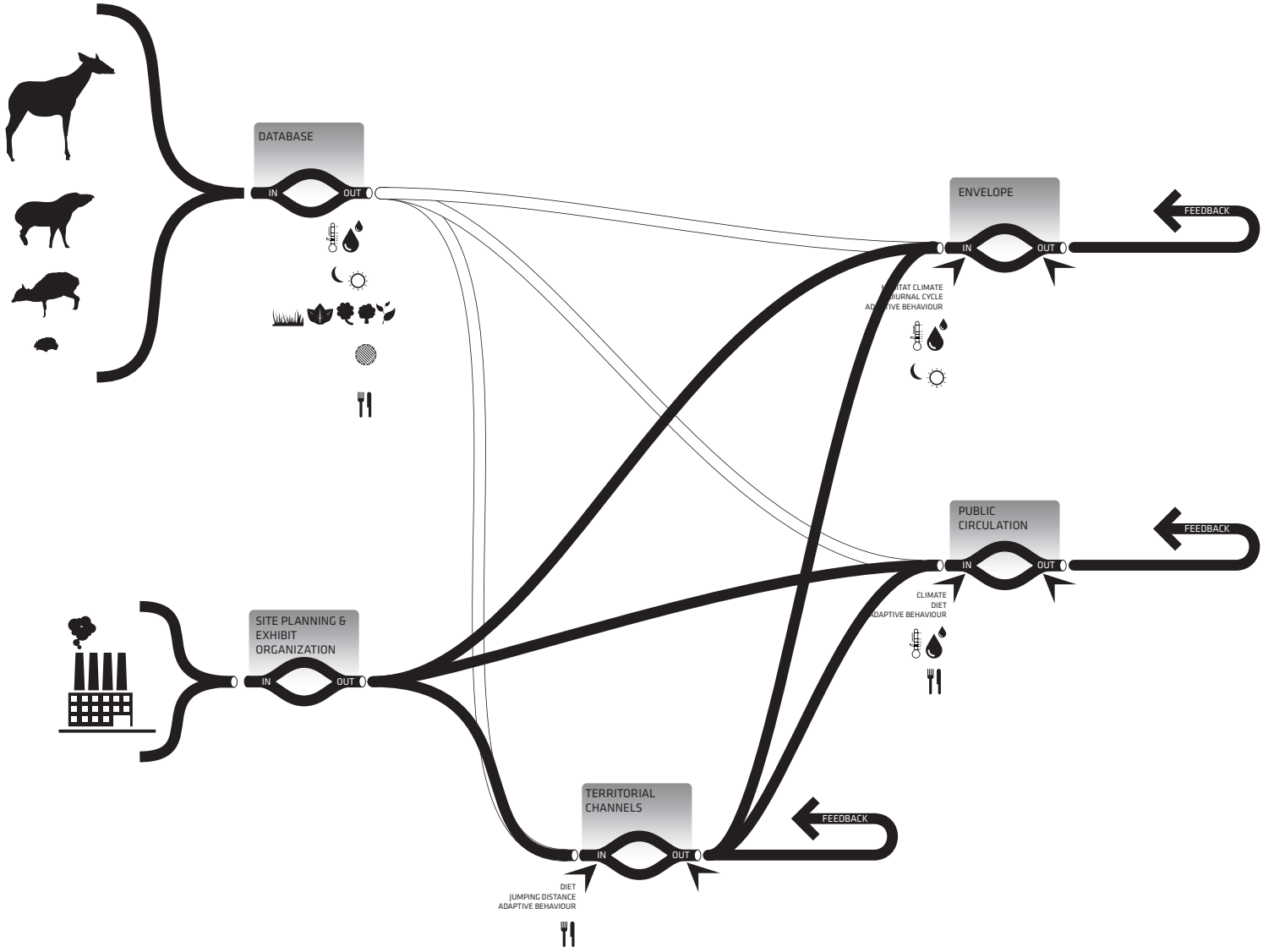
The most striking symbolic potential of the site, however, is in the now adjacent and soon to be, memory of the site's industrial and military past. This operates on two levels concurrently; on the one hand, there is the notion of the constructed landscape, a land so tampered with that it has been stripped of any possible sense of sacred ground to be preserved or reconstructed- sanctifying further manipulation, this time in pursuit of the replication of 'nature'. Concomitant is the site's place in the cultural imagination of local residents, which, due to the restricted, dangerous nature of the, now defunct, power plant, has long been uninhabited. The vacuum this has created is just the right quality to engender radical visions for the future.

With the choice of grounds retrieved from land blighted by large industry, there is also the implicit intent to superimpose the two programs - habitat/recreation & industrial - on one another. Berger has noted that the marginalization of animals appeared just as they disappeared from our daily lives, and that this coincided with the growth of industry and mechanization. In supplanting the industrial with natural living systems, the move provides for the generation of fertile, evocative imagery to spark discourse on society, and in particular, our relationship with our closest living relatives.

FIG 1.22
PANORAMA OF LAKESHORE RD.

FIG 1.23
METRO TORONTO ZOO SUPERIMPOSED ON LAKEVIEW GS.

CHAPTER 2 CONSTRUCTING THE ZOO MACHINE
AN EXPOSITION OF PROCESS


DATABASE
IN
OUT
ENVELOPE
IN
OUT
FEEDBACK
HABITAT CLIMATE
DIURNAL CYCLE
ADAPTIVE BEHAVIOUR
PUBLIC
CIRCULATION
IN
OUT
FEEDBACK
CLIMATE
DIET
ADAPTIVE BEHAVIOUR
SITE PLANNING &
EXHIBIT
ORGANIZATION
IN
OUT
TERRITORIAL
CHANNELS
IN
OUT
FEEDBACK
DIET
JUMPING DISTANCE
ADAPTIVE BEHAVIOUR

INTRODUCTION

A MEASURED LOSS OF CONTROL

An abstract machine in itself is not physical or corporeal, any more than it is semiotic; it is diagrammatic (it knows nothing of the distinctions between the artificial and the natural either). It operates by matter, not by substance; by function, not by form.[...] The abstract machine is pure Matter-Function - a diagram independent of the forms and substances, expressions and contents it will distribute.[29]

[29] DELEUZE, GUATTARI, & MASSUMI, *A THOUSAND PLATEAUS*, 141.

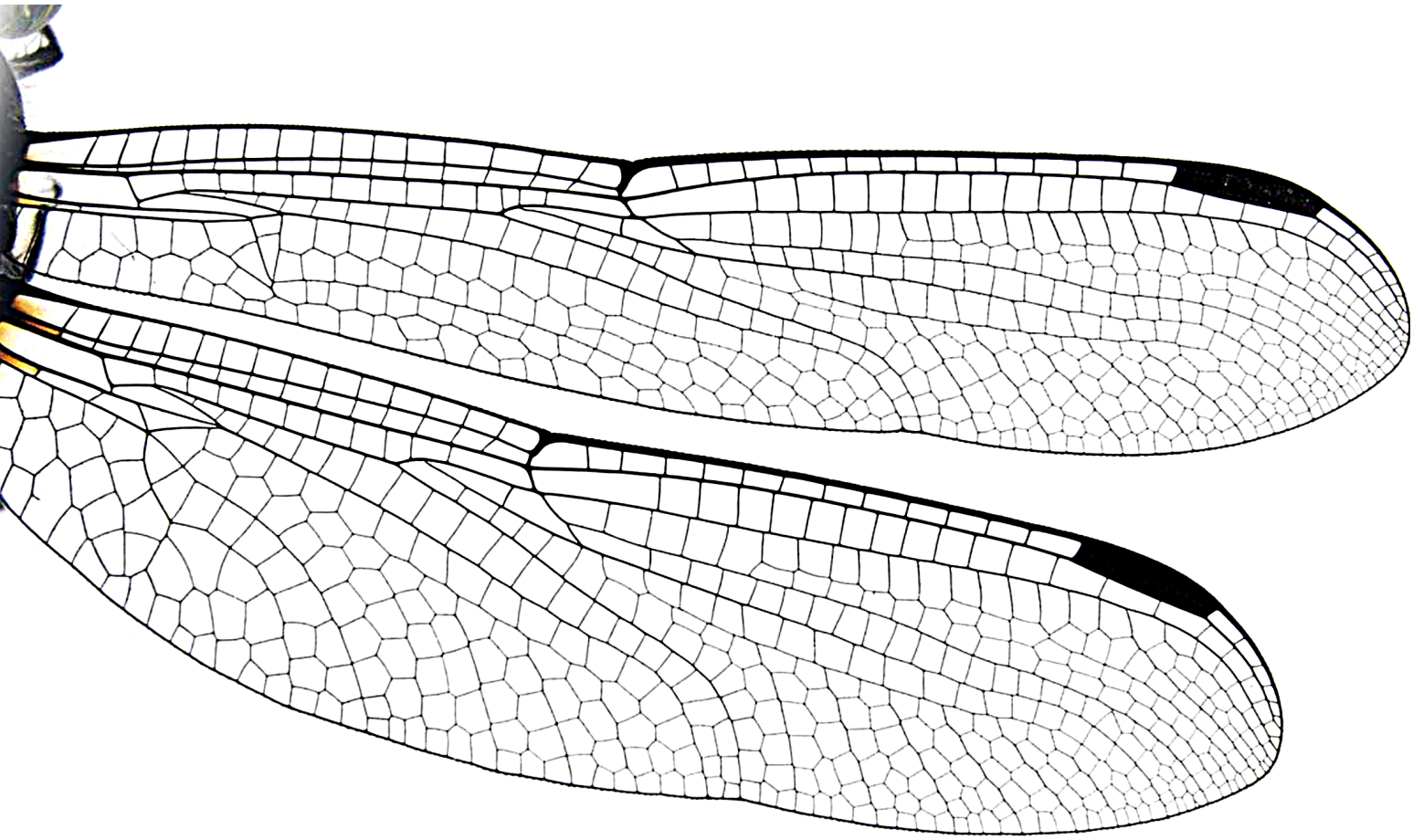
This chapter breaks down the architectural process into a series of mechanical procedures and explains each in terms of both its intent and its conscientious assembly. The separation into distinct sections, though counter to the indivisibility and simultaneity of parallel processes, serves two purposes. First, it is for the sake of clarity and economy. Second, it parallels the actual development of the project. The aggregate design of the zoo should still be considered as a single emergent product of parallel processes operating and feeding back onto each other recursively. In fact, it is this treatment of the design process - as an ecology in and of itself - that the thesis aspires to.

Each section within the chapter is dedicated to one generative or "abstract machine"[30] which has been implemented specifically as it relates to or performs for the particularities of the zoo design; but it could just as well be separated out as a so-called "design pattern" – to be re-purposed or hacked into for completely unrelated scenarios. Each has its own lineage regarding phenomena from which it has sampled, though there are reoccurring themes and overlaps amongst them. Each renders its initial assumptions open so that they may be subsequently interrogated, particularly as it might relate to decisions about composition and the order of its events.

[30] IBID., 142.

Several tropes might be recalled in this work that have become all-too familiar within contemporary cultural practice - some that may seem exhausted of potential by now - but here, nowhere is there a suggestion of uncovering untapped phenomena. These processes have not been selected for their symbolic resonance, nor for their shape as signs, but for the structural qualities they have in shaping space. The aspiration is to take explicit procedural steps that address programmatic requirements, and couple them together to produce a space that is indetermin-

FIG 2.24
PROCESSUAL OVERVIEWS

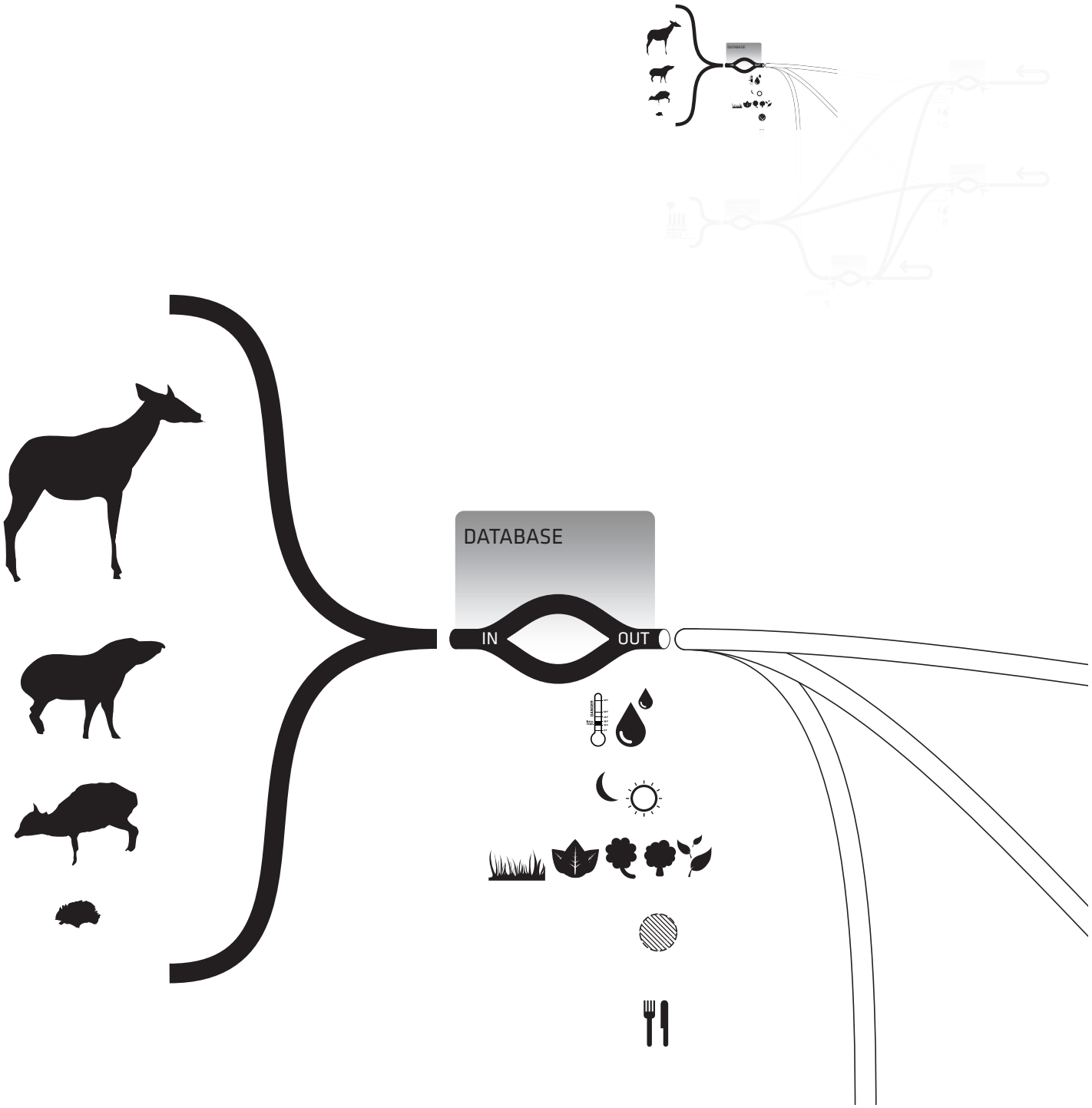


ate. The desirable spatial effects common amongst them - ambiguous boundaries, territorializing without closing off, fuzzy edges, continuous, overlapping surfaces - are imagined to be everywhere, all the time, but in different levels of intensity. The resultant atmosphere, one which the project actively cultivates and is in control of – but, of course, only to a limited degree - is one of disorientation, ambiguity, and open to continuous interpretation.

> *All the phases should be (empirical) machines in themselves. Machines connect only to each other, as molecules, which means the phases in a process need to be steps in a procedure. Finding rules. But when we use step-wise procedures does it not mean that the whole procedure is fixed in advance? Generally, 'procedure' is used in a deterministic, mechanical manner, but perhaps we should consider procedures as mechanical blocks that in themselves are straightforward and linear but that when linked can form nonlinear strings. The blocks have complex edges, multiple hinges and many ways of connecting to create a complex chain of techniques. It is path-dependent, like cooking: it works with techniques and recipes, but what actually comes out is not fully predictable.*[31]

31. LARS SPUYBROEK, *NOX : MACHINING ARCHITECTURE*, (NEW YORK: THAMES & HUDSON, 2004), 8.

FIG 2.25
DRAGONFLY WINGS


DATABASE
IN
OUT

The organizational and informational stage is material. Not immaterial as is so often put forth. It is the material potential. The material's distributed intelligence that sets the machine in motion.[32]

32. LARS SPUYBROEK, "THE STRUCTURE OF VAGUENESS", *NOX : MACHINING ARCHITECTURE* (2004): 354.

FIG 2.26
PROCESSUAL FLOWS
ANIMAL DATABASE

COMMON NAME
Okapi

SCIENTIFIC NAME
Okapia johnstoni

ORDER
Artiodactyla

CLASS
Mammalia

BODY COVER
fur

WEIGHT
550

LENGTH
98

CONTINENT
South Africa

BIOME
Tropical Rainforest

TEMPERATURE
hot

HUMIDITY
wet

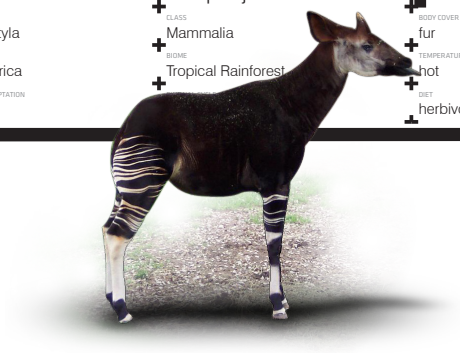
COVER
75;15;0;0;0;10

ELEMENTAL ADAPTATION
ground

DIET
herbivore

INTERACTIVITY
social

MOTILITY
sedentary



COMMON NAME
Short-Beaked Echidna

SCIENTIFIC NAME
Tachyglossus aculeatus

ORDER
Monotremata

CLASS
Mammalia

BODY COVER
fur & spines

WEIGHT
10

LENGTH
15

CONTINENT
Australia

BIOME
Forest

TEMPERATURE
temperate

HUMIDITY
mixed

COVER
15;50;0;35;0;0

ELEMENTAL ADAPTATION
underground

DIURNAL CYCLE
diurnal

DIET
insectivore

INTERACTIVITY
solitary

MOTILITY
motile

COMMON NAME
Mouse Deer

SCIENTIFIC NAME
Tragulus napu

ORDER
Artiodactyla

CLASS
Mammalia

BODY COVER
fur

WEIGHT
14

LENGTH
30

CONTINENT
Asia

BIOME
Rainforest

TEMPERATURE
hot

HUMIDITY
wet

COVER
65;15;0;5;0;15

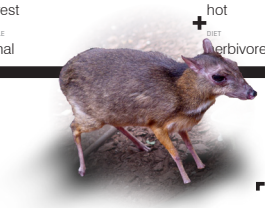
ELEMENTAL ADAPTATION
ground

DIURNAL CYCLE
nocturnal

DIET
herbivore

INTERACTIVITY
solitary

MOTILITY
sedentary



COMMON NAME
Zebra Duiker

SCIENTIFIC NAME
Cephalophus zebra

ORDER
Artiodactyla

CLASS
Mammalia

BODY COVER
fur

WEIGHT
38

LENGTH
32

CONTINENT
Africa

BIOME
Forest

TEMPERATURE
hot

HUMIDITY
mixed

COVER
75;25;0;0;0;0

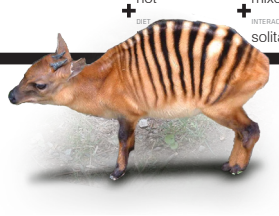
ELEMENTAL ADAPTATION
ground

DIURNAL CYCLE
diurnal

DIET

INTERACTIVITY
solitary

MOTILITY
motile



COMMON NAME
Capybara

SCIENTIFIC NAME
Capybara

ORDER
Rodentia

CLASS
Mammalia

BODY COVER
fur

WEIGHT
100

LENGTH
48

CONTINENT
South America

BIOME
Wetlands

TEMPERATURE
hot

HUMIDITY
mixed

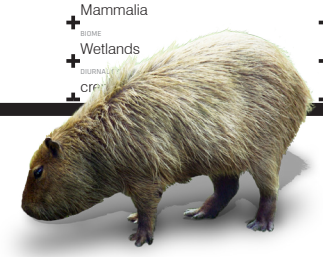
COVER
0;30;0;0;0;70

ELEMENTAL ADAPTATION
water

DIET
herbivore

INTERACTIVITY
social

MOTILITY
sedentary



COMMON NAME
Southern Tamandua

SCIENTIFIC NAME
Tamandua tetradactyla

ORDER
Pilosa

CLASS
Mammalia

BODY COVER
Fur

WEIGHT
10

LENGTH
28

CONTINENT
South America

BIOME
Rainforest

TEMPERATURE
Hot

HUMIDITY
Wet

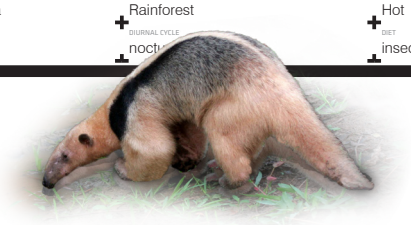
COVER
75;15;0;0;0;10

ELEMENTAL ADAPTATION
Trees

DIET
insectivore

INTERACTIVITY
solitary

MOTILITY
sedentary



This portion of the project investigates its primary subject- the wildlife to be exhibited at the zoo. Its design intends to transgress the systematic and mechanical classification of its biological specimens; in this phase, however, the process approaches its subject with just such an orientation. The intention is to transpose the world of matter and encode it into a numerical dataset. The numbers themselves are vehicles to break material out of the confines of their cultural constructions by way of abstraction. It is in this format that they are amenable to the number manipulation of computational processes. This initial section begins by detailing the process of acquiring the data, followed by its processing into seeds to instigate later generate processes. As a component of conventional architectural practice, its equivalences and correspondences opportunistically exploit its dilettante status to create a viable model to map the world.

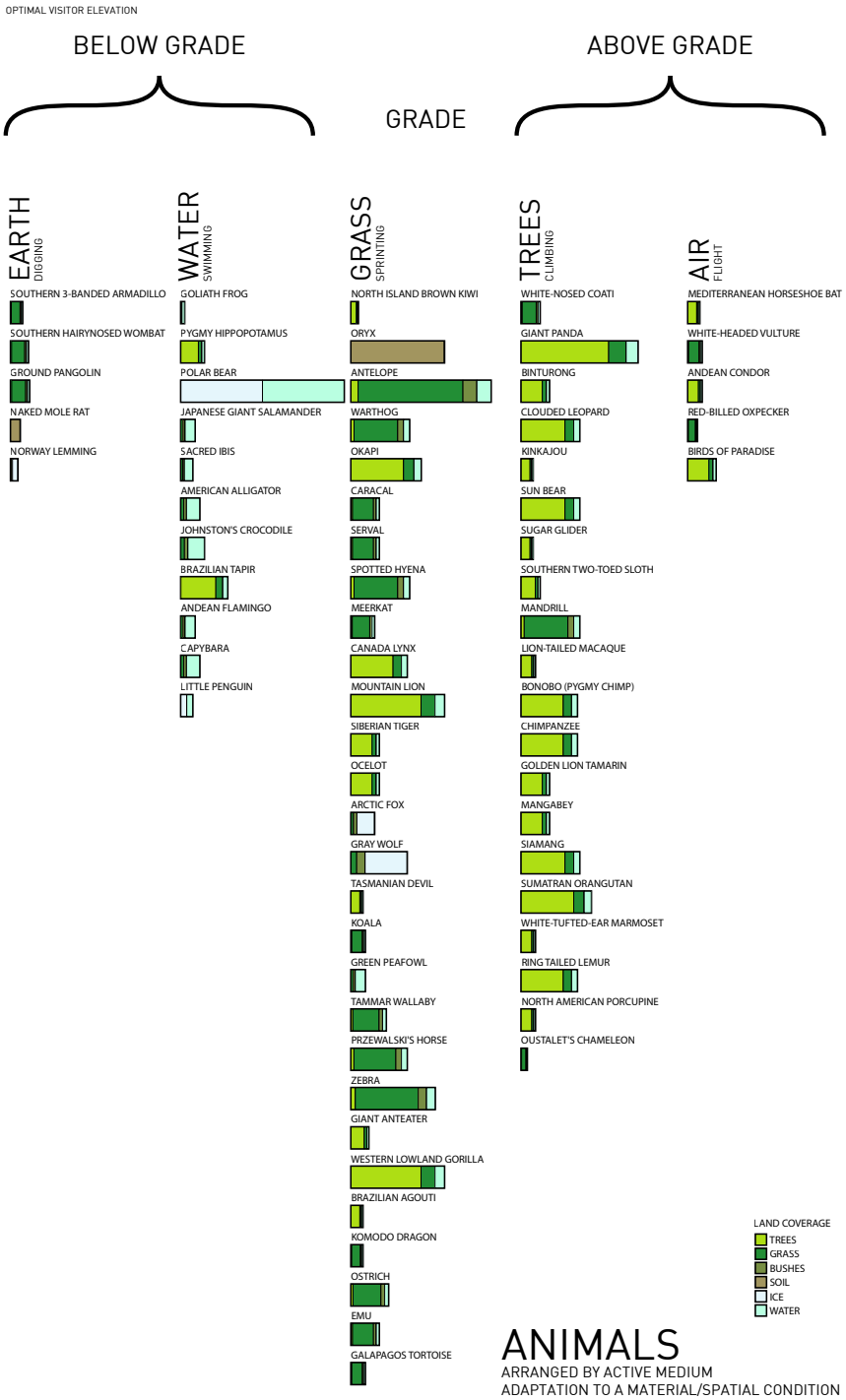
This step in the process imagines using the very logic of scientific enframing but its intent is subversion. Through its abstractions and conceptual delaminations, the model aspires to describe identity by the inclusivity of features and their combination, and thus, allowing connections and associations across boundaries that typically confine types. By capturing their essence in numerical data, the animals are conceived to be notionally liberated from the trappings of cultural packaging and open to recursive cultural reconstruction.

CHOICE OF ANIMALS

It begins with the assumption that it, like most zoos, is principally about offering its visitors views into animal worlds, the likes of which might be impossible in any other scenario. In the spirit of this zoo-going experience - and with the desire to explore overlap and combination between cultural opposites - it demands that the broadest variety of habitats and the fullest diversity of terrestrial species be accounted for. The number and diversity of species from each major terrestrial biome approximates the proportion between the amount of biomass it sustains and its surface area.

In order to affirm the zoo as a new type of chimeric entity, species have been chosen that, for different reasons, draw attention to the evolutionary production of novelty through combination and hybridization. They are selected as a function of their

FIG 2.27
MULTIPLE ANIMAL VIEWS
DIFFERENT EXHIBITION DIMENSIONS ATTACHED TO EACH ANIMAL


OPTIMAL VISITOR ELEVATION
BELOW GRADE
GRADE
ABOVE GRADE
EARTH
DIGGING
SOUTHERN 3-BANDED ARMADILLO
SOUTHERN HAIRYNOSED WOMBAT
GROUND PANGOLIN
NAKED MOLE RAT
NORWAY LEMMING
WATER
SWIMMING
GOLIATH FROG
PYGMY HIPPOPOTAMUS
POLAR BEAR
JAPANESE GIANT SALAMANDER
SACRED IBIS
AMERICAN ALLIGATOR
JOHNSTON'S CROCODILE
BRAZILIAN TAPIR
ANDEAN FLAMINGO
CAPYBARA
LITTLE PENGUIN
GRASS
SPRINTING
NORTH ISLAND BROWN KIWI
ORYX
ANTELOPE
WARTHOG
OKAPI
CARACAL
SERVAL
SPOTTED HYENA
MEERKAT
CANADA LYNX
MOUNTAIN LION
SIBERIAN TIGER
OCELOT
ARCTIC FOX
GRAY WOLF
TASMANIAN DEVIL
KOALA
GREEN PEAFOWL
TAMMAR WALLABY
PRZEWALSKI'S HORSE
ZEBRA
GIANT ANTEATER
WESTERN LOWLAND GORILLA
BRAZILIAN AGOUTI
KOMODO DRAGON
OSTRICH
EMU
GALAPAGOS TORTOISE
TREES
CLIMBING
WHITE-NOSED COATI
GIANT PANDA
BINTURONG
CLOUDED LEOPARD
KINKAJOU
SUN BEAR
SUGAR GLIDER
SOUTHERN TWO-TOED SLOTH
MANDRILL
LION-TAILED MACAQUE
BONOBO (PYGMY CHIMP)
CHIMPANZEE
GOLDEN LION TAMARIN
MANGABEY
SIAMANG
SUMATRAN ORANGUTAN
WHITE-TUFTED-EAR MARMOSET
RING TAILED LEMUR
NORTH AMERICAN PORCUPINE
OUSTALET'S CHAMELEON
AIR
FLIGHT
MEDITERRANEAN HORSESHOE BAT
WHITE-HEADED VULTURE
ANDEAN CONDOR
RED-BILLED OXPECKER
BIRDS OF PARADISE
LAND COVERAGE
TREES
GRASS
BUSHES
SOIL
ICE
WATER
ANIMALS
ARRANGED BY ACTIVE MEDIUM
ADAPTATION TO A MATERIAL/SPATIAL CONDITION

perceived capacity to undermine the cultural associations drawn between taxonomy, typically based on genetic traits, and identity, made manifest in behaviour or event. For example, where some of the largest species of the class of the feline or canine classes might typically indicate an example of an ecosystem's predatory apex, such as lions or wolves, the program instead opts for those species that are taxonomically related but may be considered to be less caricatured, such as caracals and fennet foxes. On the other hand, predatory species from classes not typically associated with such qualities are preferred, such as those belonging to amphibians or marsupials.

HYBRID TYPES

In the same spirit, species have also been given preference when they appear to lay along a morphological continuum between ends typically perceived as distinct. Examples of such species are often identified with names that compound two species such as the Mouse Deer (a very small artiodactyl), the Zebra Duiker (a bovid with striped hide), and the Golden Lion Tamarin (a primate with an elaborate mane). Likewise, nature, in its indiscriminate processes, does not "see" the borders inscribed by human geography; animals have evolved in the wild with an attunement to the particularities of their environment without respect to political boundaries. Distinct taxonomic (and genetic) types have been shown to converge through evolutionary processes on similar morphological traits corresponding to their shared ecological niches. These inherent tendencies attest to the possibility that there may be a limited reserve of operations from which nature generates its perpetual novelty. Some forms, it seems, may be better suited to deal with certain situations.

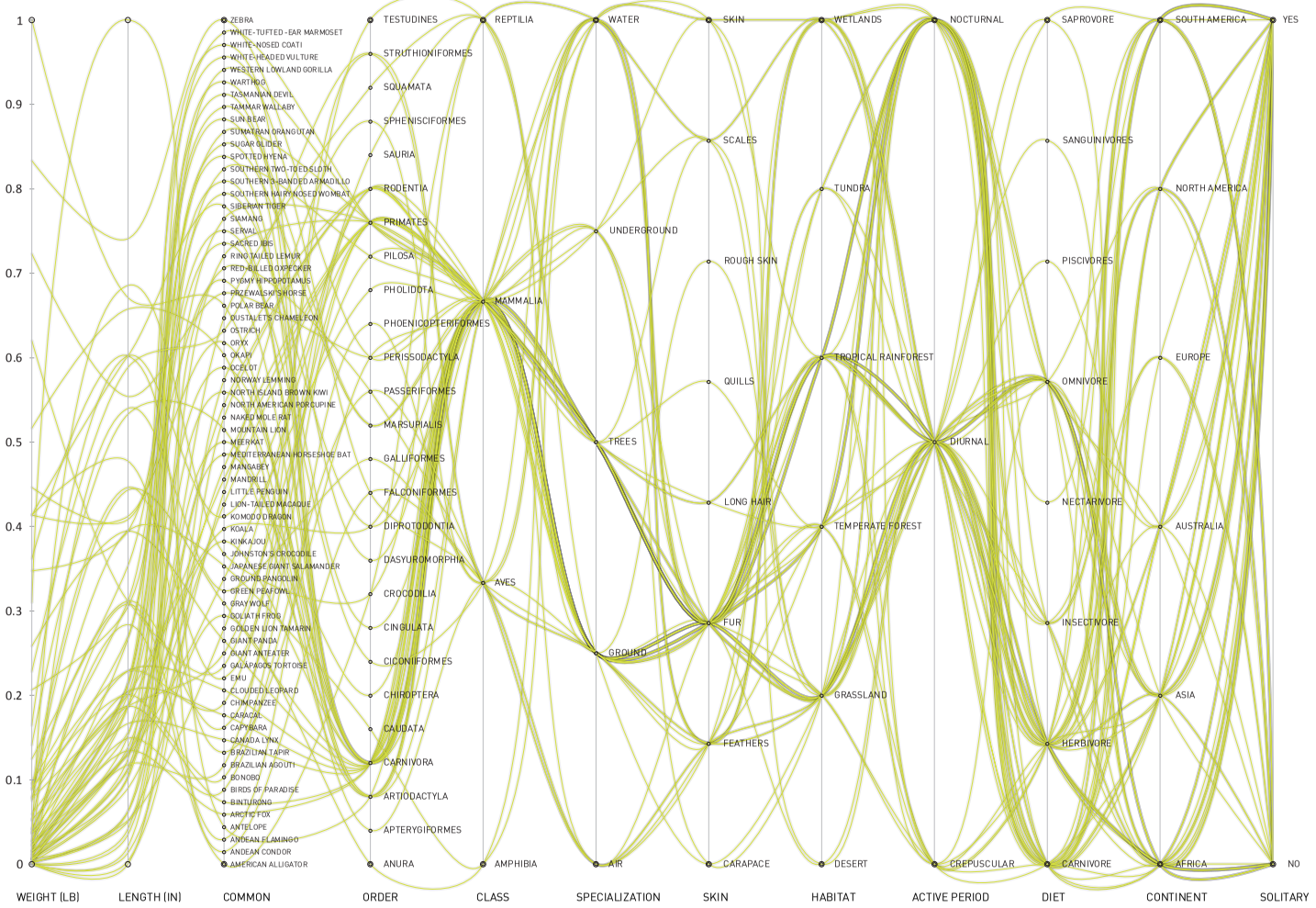
EVOLUTIONARY CONVERGENCE

ACQUIRING THE DATA

The most general information about each species is manually assembled from a variety of internet based resources. Data about each species typically summarizes its population in singular values representing the breadth of its spectrum; in the cases of body sizes, statistical averages are employed while behaviours are described in terms of one of several possible types. Standardized information about each species can be contentious and sometimes difficult to acquire. Specifications regarding holding animals in captivity are far scarcer, and the few that are published by zoological licensing bodies often do not satisfy what animal welfare advocates believe to constitute sufficient spatial parameters.

The assumptions of population are diametrically opposed to those of the typologist. The populationist stresses the uniqueness of everything in the organic world. What is true for the human species, that no two individuals are alike, is equally true for

FIG 2.28
ACTIVE MEDIUMS AND BEHAVIOURS
ADAPTATION TO MATERIAL/ SPATIAL CONDITION


1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
ZEBRA
WHITE-TUFTED-EAR MARMOSET
WHITE-NOSED COATI
WHITE-HEADED VULTURE
WESTERN LOWLAND GORILLA
WARTHOG
TASMANIAN DEVIL
TAMMAR WALLABY
SUN BEAR
SUMATRAN ORANGUTAN
SUGAR GLIDER
SPOTTED HYENA
SOUTHERN TWO-TOED SLOTH
SOUTHERN 3-BANDED ARMADILLO
SOUTHERN HAIRY-NOSED WOMBAT
SIBERIAN TIGER
SIAMANG
SERVAL
SACRED IBIS
RING-TAILED LEMUR
RED-BILLED OXPECKER
PYGMY HIPPOPOTAMUS
PRZEWALSKI'S HORSE
POLAR BEAR
OUSTALET'S CHAMELEON
OSTRICH
ORYX
OKAPI
OCELOT
NORWAY LEMMING
NORTH ISLAND BROWN KIWI
NORTH AMERICAN PORCUPINE
NAKED MOLE-RAT
MOUNTAIN LION
MEERKAT
MEDITERRANEAN HORSESHOE BAT
MANGABEY
MANDRILL
LITTLE PENGUIN
LION-TAILED MACAQUE
KOMODO DRAGON
KOALA
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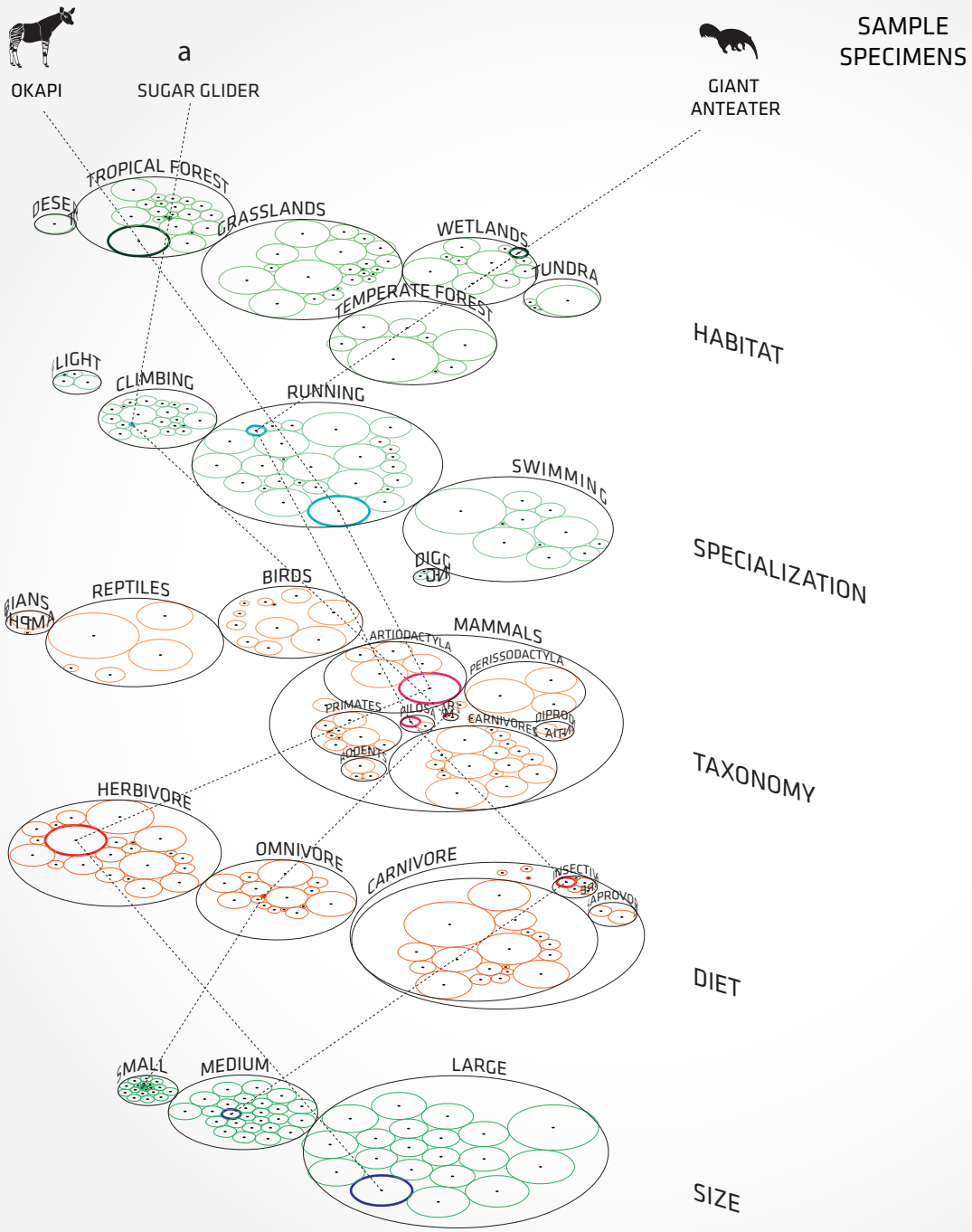
JAPANESE GIANT SALAMANDER
GROUND PANGOLIN
GREEN PEAFOWL
GRAY WOLF
GOLIATH FROG
GOLDEN LION TAMARIN
GIANT PANDA
GIANT ANTEATER
GALAPAGOS TORTOISE
EMU
CLOUDED LEOPARD
CHIMPANZEE
CARACAL
CAPYBARA
CANADA LYNX
BRAZILIAN TAPIR
BRAZILIAN AGOUTI
BONOBO
BIRDS OF PARADISE
BINTURONG
ARCTIC FOX
ANTELOPE
ANDEAN FLAMINGO
ANDEAN CONDOR
AMERICAN ALLIGATOR
TESTUDINES
STRUTHIONIFORMES
SQUAMATA
SPHENISCIFORMES
SAURIA
RODENTIA
PRIMATES
PILOSA
PHOLIDOTA
PHOENICOPTERIFORMES
PERISSODACTYLA
PASSERIFORMES
MARSUPIALIS
GALLIFORMES
FALCONIFORMES
DIPROTODONTIA
DASYUROMORPHIA
CROCODILIA
CINGULATA
CICONIIFORMES
CHIROPTERA
CAUDATA
CARNIVORA
ARTIODACTYLA
APTERYGIFORMES
ANURA
REPTILIA
MAMMALIA
AVES
AMPHIBIA
WATER
UNDERGROUND
TREES
GROUND
AIR
SKIN
SCALES
ROUGH SKIN
QUILLS
LONG HAIR
FUR
FEATHERS
CARAPACE
WETLANDS
TUNDRA
TROPICAL RAINFOREST
TEMPERATE FOREST
GRASSLAND
DESERT
NOCTURNAL
DIURNAL
CREPUSCULAR
SAPROVORE
SANGUINIVORES
PISCIVORES
OMNIVORE
NECTARIVORE
INSECTIVORE
HERBIVORE
CARNIVORE
SOUTH AMERICA
NORTH AMERICA
EUROPE
AUSTRALIA
ASIA
AFRICA
YES
NO
WEIGHT (LB)
LENGTH (IN)
COMMON
ORDER
CLASS
SPECIALIZATION
SKIN
HABITAT
ACTIVE PERIOD
DIET
CONTINENT
SOLITARY

all other species of animals and plants. [...] All organisms and organic phenomena are composed of unique features and can be described collectively only in statistical terms. Individuals, or any kind of organic entities, form populations of which we can determine the arithmetic mean and the statistics of variation. Averages are merely statistical abstractions; only the individuals of which the populations are composed have any reality. The ultimate conclusions of the population thinker and the typologist are precisely the opposite. For the typologist, the type (eidos) is real and the variation an illusion, while for the populationist the type (average) is an abstraction and only the variation is real. No two ways of looking at nature could be more different. [33]

[33] ERNST MAYR, (1970) SOURCE: HTTP://HOMEPAGES.WHICH.NET/~GK.SHERMAN/BAAAAACU.HTM

This first stage - one of acquiring and parsing the data - is about a negotiation between the individual and the collective. Perpetually under revision, and with an ever-increasing specificity, the task of amassing programmatic information underscores issues related to the fragility and limits of attempting to describe populations in terms of averages. As a mapping procedure, it contends with how much detail may be dropped and still maintain a useful resemblance to its source. It pursues the development of a model that has, at once, both better resolved correspondences to the territory it represents, and a rhizomatic disembodiment, such that it might be open to reinterpretation.

FIG 2.29
GRAPH OF COLLECTION
EACH ANIMAL IS REPRESENTED BY A BAND; EACH COLUMN IS AN INDEX OF A PARTICULAR DIMENSION


a
OKAPI
SUGAR GLIDER
GIANT ANTEATER
SAMPLE SPECIMENS
TROPICAL FOREST
GRASSLANDS
WETLANDS
TUNDRA
TEMPERATE FOREST
HABITAT
CLIMBING
RUNNING
SWIMMING
SPECIALIZATION
REPTILES
BIRDS
MAMMALS
ARTIODACTYLA
PERISSODACTYLA
PRIMATES
CARNIVORE
TAXONOMY
HERBIVORE
OMNIVORE
CARNIVORE
DIET
MEDIUM
LARGE
SIZE

THE DATABASE: A SEED

The data is intended to operate as a seed, to stimulate the adaptive response in successive layers of a generative design process; its raw information must undergo its own processing. So that it may be amenable to these processes, the data is formatted largely in terms of numerical strings in varying degrees of specificity.

Aside from the common and scientific names given to animals - already compound identities - as strings to help manage information farther along in the process, the inputs typically come in one of three primary kinds, each with increasing resolution, and less generalization. First, booleans - simple binary statements, zero or one - indicate each animal as either belonging or not. Examples of this are : social dynamics, and sedentary lifestyle. Strings or integers they represent - whole numbers - indicate attributes such as diet type, primary adaptive behaviour, climate attributes, and diurnal cycles. Floating point values are used for more precise variables, with a greater range of inputs, such as body weight, body length and enclosure areas.

COLLECTION OVERVIEW

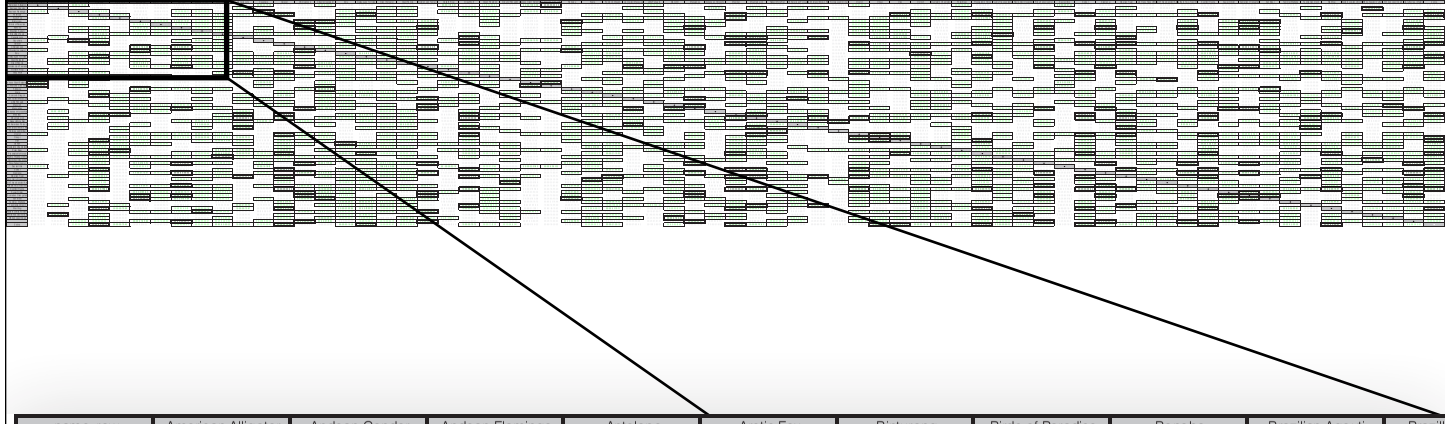
The list of selected animals is a tentative one; conceived in parallel alongside the others as a representational system, it models any species of animal through a number of key identifying values. The final list includes ninety distinct species, which represent the full breadth of animal life on the planet. The terms used to describe the species have undergone several iterations; as the model was continuously reworked as an appropriate means to act as inputs to subsequent procedures. Early versions included information such as gestations periods, as well as descriptors that were already culturally packaged types – such as named ecosystems, geographical regions - but these were later deemed to be extraneous. In order to reinforce lateral associations, compound entities were delaminated into only the most essential.

A TENTATIVE LIST

The assembly of the list was always done with the sense that at any stage during the process the specific animals as chosen could be swapped out with others or removed from the list altogether without the breakdown of the system. From the outset of the project those animals that were chosen were deemed to not be important so much as the qualities or matter that they are vehicles for. The project eschews any sense of a perfect collection of species, rather it is its ability to respond and adapt to any list thereof that is prioritized.

Early visualizations generated from the database involved processes of shuffling so as it

FIG 2.30
MOVING FROM TREE TO RHIZOME
REORGANIZATION OF THE SAME COLLECTION BY DIFFERENT CRITERIA

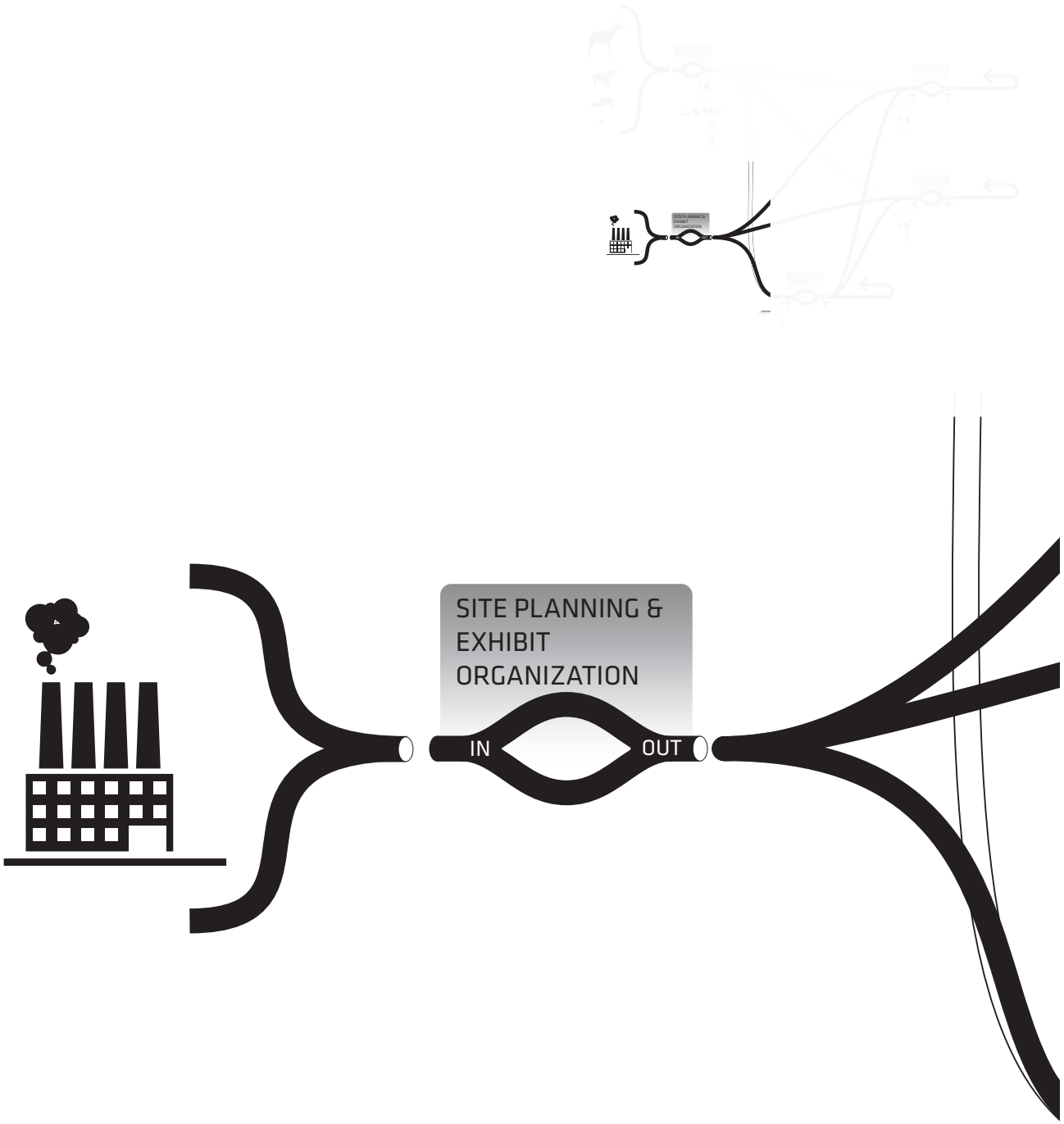


name_row	American Alligator	Andean Condor	Andean Flamingo	Antelope	Arctic Fox	Binturong	Birds of Paradise	Bonobo	Brazilian Agouti	Brazill
American Alligator	-	15-60-10-03-31	00-00-12-19-34	05-80-18-19-62	25-80-18-99-17	04-29-80-90-78	04-39-88-90-82	04-29-73-80-77	04-19-74-80-85	03-99-
Andean Condor	15-60-10-03-31	-	15-59-97-83-97	09-79-91-83-69	10-20-08-95-86	19-89-90-94-09	19-99-98-94-13	19-89-83-84-08	19-79-84-84-16	19-59-
Andean Flamingo	00-00-12-19-34	15-59-97-83-97	-	05-80-06-00-28	25-80-06-79-83	04-29-93-10-12	04-40-01-10-16	04-29-86-00-11	04-19-87-00-19	03-99-
Antelope	05-80-18-19-62	09-79-91-83-69	05-80-06-00-28	-	20-00-00-79-55	10-09-99-10-40	10-20-07-10-44	10-09-92-00-39	09-99-93-00-47	09-80-
Arctic Fox	25-80-18-99-17	10-20-08-95-86	25-80-06-79-83	20-00-00-79-55	-	30-09-99-89-95	30-20-07-89-99	30-09-92-79-94	29-99-93-80-02	29-80-
Binturong	04-29-80-90-78	19-89-90-94-09	04-29-93-10-12	10-09-99-10-40	30-09-99-89-95	-	00-10-08-00-04	00-00-07-10-01	00-10-06-09-93	00-29-
Birds of Paradise	04-39-88-90-82	19-99-98-94-13	04-40-01-10-16	10-20-07-10-44	30-20-07-89-99	00-10-08-00-04	-	00-10-15-10-05	00-20-14-09-97	00-40-
Bonobo	04-29-73-80-77	19-89-83-84-08	04-29-86-00-11	10-09-92-00-39	30-09-92-79-94	00-00-07-10-01	00-10-15-10-05	-	00-09-98-99-92	00-29-
Brazilian Agouti	04-19-74-80-85	19-79-84-84-16	04-19-87-00-19	09-99-93-00-47	29-99-93-80-02	00-10-06-09-93	00-20-14-09-97	00-09-98-99-92	-	00-19-
Brazillian Tapir	03-99-81-80-50	19-59-91-83-81	03-99-93-99-84	09-80-00-00-12	29-80-00-79-67	00-29-99-10-28	00-40-07-10-32	00-29-92-00-27	00-19-93-00-35	
Canada Lynx	15-80-18-99-20	00-20-08-95-89	15-80-06-79-86	10-00-00-79-58	09-99-99-99-97	20-09-99-89-98	20-20-07-90-02	20-09-92-79-97	19-99-93-80-05	19-80-
Capybara	00-00-25-19-34	15-59-84-83-97	00-00-13-00-00	05-79-93-00-28	25-79-93-79-83	04-30-06-10-12	04-40-14-10-16	04-29-99-00-11	04-20-00-00-19	04-00-
Caracal	05-80-18-99-24	09-79-91-04-07	05-80-06-79-90	00-00-00-79-62	19-99-99-99-93	10-09-99-90-02	10-20-07-90-06	10-09-92-80-01	09-99-93-80-09	09-80-
Chimpanzee	04-29-73-90-74	19-89-83-94-05	04-29-86-10-08	10-09-92-10-36	30-09-92-89-91	00-00-07-00-04	00-10-15-00-08	00-00-00-09-97	00-09-99-09-89	00-29-
Clouded Leopard	04-29-81-00-74	19-89-91-04-05	04-29-93-20-08	10-09-99-20-36	30-09-99-99-91	00-00-00-09-96	00-10-07-90-08	00-00-07-19-97	00-10-06-19-89	00-29-
Emu	05-80-13-09-47	09-79-96-93-84	05-80-00-90-13	00-00-05-10-15	20-00-05-89-70	10-09-94-00-25	10-20-02-00-29	10-09-86-90-24	09-99-87-90-32	09-79-
Galápagos Tortoise	05-79-98-19-34	09-80-11-83-97	05-79-86-00-00	00-00-20-00-28	20-00-20-79-83	10-09-79-10-12	10-19-87-10-16	10-09-72-00-11	09-99-73-00-19	09-79-

might enable different kinds of seeing. They are an attempt to contend with how we might look with ambivalence at the same dense world of information, and how the shifts, which inherently necessitate movement in time, might become fixed spatially. The static diagrams required a striation such that the different possible orientations would maintain their clarity. Along the vertical axis, the same collection is sorted into different groupings, each species acting as a virtual portal into a different orientation.

One attempt to model the collection consists of a pseudo-genetic code that might encompass all of its key traits, be they about morphology, habitat, or behaviour. Each species is described by a ten digit number which is generated through the concatenation of database keys. Each portion within the concatenated string designates a key trait, its number corresponding to that animal's particularity. With each animal described in part by their number, the degree of difference from one to another could be notionally described by a numerical difference between the two. The smaller the numbers are that define the relationship, the closer their similarity is. What the system allows, is an equivalence between types of similarity such that this could arise from shared behavioural trait just as much as it could come from shared habitat or morphology. The figures might be used to drive the proportional lengths of edges in a network graph, describing relatedness in spatial terms.

FIG 2.31
ANIMAL DIFFERENCE TABLES
EACH ANIMAL IS DONNED A SERIAL CODE WHICH DESCRIBES IT ACCORDING TO A NUMBER OF KEY IDENTIFIERS; THE INTERSECTION OF EVERY POSSIBLE PAIRING PRODUCES A TRAVEL-LIKE TABLE THAT ATTEMPTS TO DESCRIBE PROXIMITY


SITE PLANNING &
EXHIBIT
ORGANIZATION
IN
OUT

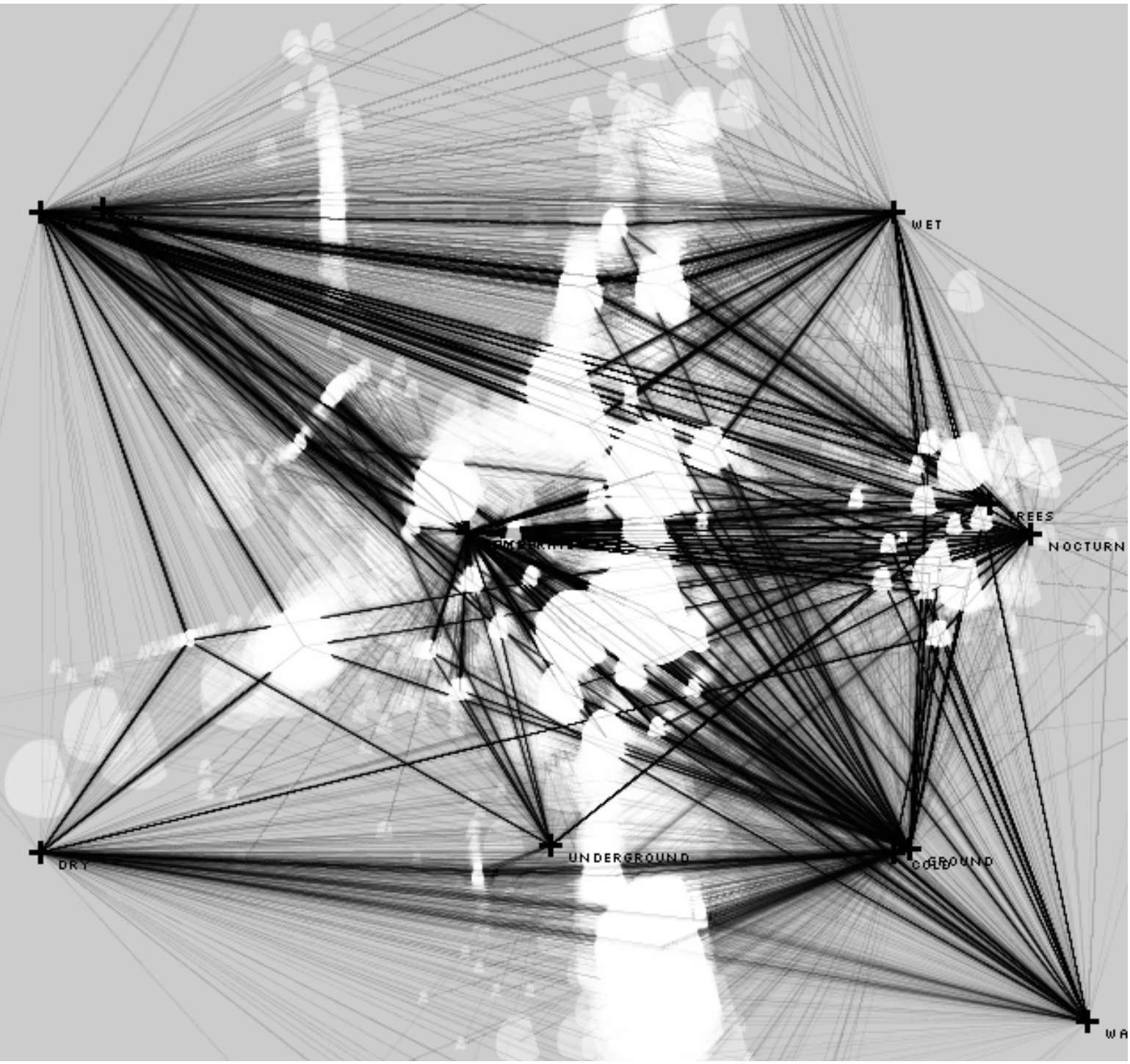
ENVIRONMENTAL CALIBRATION

SITUATING THE BODY

The challenge that the virtual poses for architecture lies more in its unform nature than its abstractness. How can the run of the unform be integrated into a process whose end is still-standing form?
The answer for many has been: topology.[34]

34. MASSUMI, BRIAN. "SENSING THE VIRTUAL, BUILDING THE INSENSIBLE." *ARCHITECTURAL DESIGN 68* (1998): 16.

FIG 2.32
PROCESSUAL FLOWS
SITE PLANNING & EXHIBITION ORGANIZATION


WET
REES
NOCTURN
DRY
UNDERGROUND
GROUND
WA

This section describes the construction of a generative machine which is tasked with the arrangement of exhibits on a site. Its point of departure are a series of landscape traits that are registered and which subsequently bear on exhibits to which they correspond. The process involves the embodiment of information from the database into agents within a simulation. Upon each run, the system generates new lists of exhibit positions.

CONTEXTUALISING THE GRAPH APPROACH

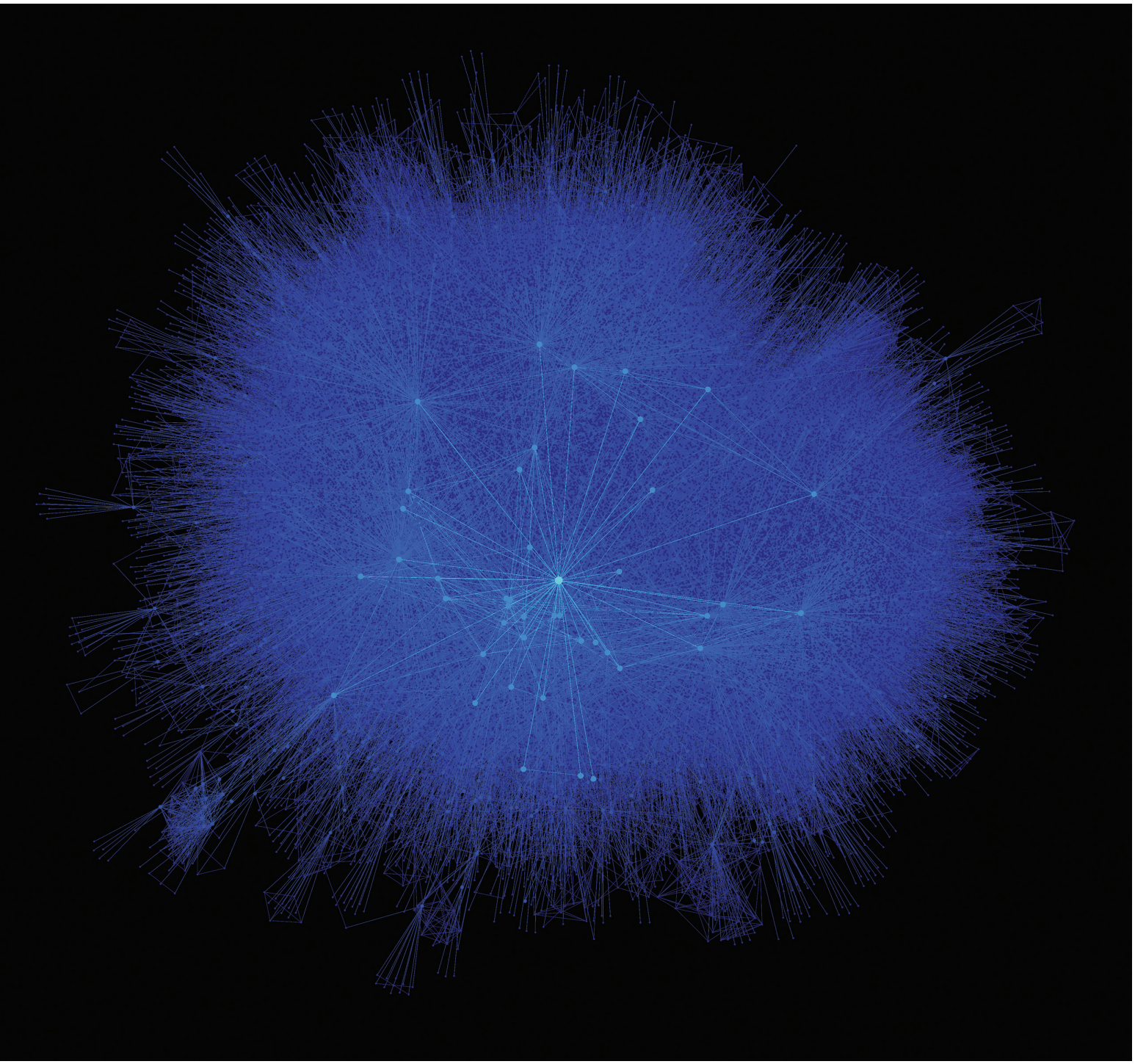
Behind this procedure, lies aspirations to both ***convey*** the restlessness of ecology as a dynamic system as well as ***perform*** as a support for multiple narratives using proximity - and landscape - as a barometer of relatedness. The collection is conceived as nothing but a topological body, underpinned, and made coherent not by shape but by the relationships or connections between points on its body.

The employed method samples from the force directed layout algorithms incorporated into interactive network graphs. These graphs work as graphic interfaces to explore vast data sets and their relationships, and have become prevalent with the rise of information technologies and genomic research. They are interactive, allowing users to shift the graph's focus by selecting nodes around which the graph will self-organize; it is in their animate behaviour that the dense virtual space of information becomes accessible. The graph's spatial metaphor is an abstraction, drawn on-screen as a network of nodes and lines. An algorithm underlying the system is embedded with the rules of Newtonian physics, whereby each body or node is impelled to move by elastic forces of springs and attractive and repellent forces of nearby particles. The system defines relationships, but not shape or form; it ensures that distances between nodes are maintained, but that their positions and movement are not made explicit. Over the course of thesis research, this particular line of inquiry started to appear in architectural research. Recent projects by thesis students at the Hyperbody Group at Delft TU[35] and research by Proxyarch[36] have used these force-directed graphs to migrate from the virtual space of information in architecture - the program - to a material one..

What this discussion is partially circling, between ideas of points and relations, non-linearity, and machines, is the concept of topology. Topology is concerned with

35. KAS OOSTERHUIS AND LUKAS FEIREISS, *THE ARCHITECTURE CO-LABORATORY : GAMESETANDMATCH II : ON COMPUTER GAMES, ADVANCED GEOMETRIES, AND DIGITAL TECHNOLOGIES* (ROTTERDAM: EPISODE PUBLISHERS, 2006).
36. WWW.PROXYARCH.COM

FIG 2.33
FORCE DIRECTED LAYOUT
TIME-ELAPSED IMAGE OF SIMULATION



the study of spatial qualities of objects which persist or remain intact even as they undergo certain kinds of transformation. These qualities are typically defined not by metric space, as in their dimensions, size or shape, but as consequences of internal relationships or connectivity. In topological space, a coffee mug is equivalent to the doughnut it can be stretched into, by transformations that do not cut or tear its surface. Objects are defined by broad sets of principles under which variants in its shape or form do not disturb its constitution.[37].

37. MANUEL DE LANDA, *INTENSIVE SCIENCE AND VIRTUAL PHILOSOPHY* (NEW YORK: CONTINUUM, 2002) 14.

FUZZINESS

Likewise, the zoo is approached as a topological entity. The locii of landscape features are conceived as notional neighbourhood or districts in space which are connected to, and inflect the positioning of the animals' exhibits. They register "rapidities and slowness" [38]. The zoo, and its identity subsist despite the variants to be actuated by the simulation of forces; an approach which allows for both indeterminacy and constraint.

38. MANUEL DE LANDA, "MATERIALITY: ANEXACT AND INTENSE", *NOX : MACHINING ARCHITECTURE* (2004): 371.

39. HTTP://WWW.RED3D.COM/CWR/BOIDS/

Like the steering based system of the Boids algorithm[39], the Force Directed Layout algorithm behind these simulations is driven by a function which accumulate the forces, given by vectors, on each time slice. Unlike Boids, which are encoded with rules that require them to seek out targeted objectives, the particles in these systems, blindly seek out moments of homeostasis. On each time-slicing loop, every particle accumulates and resolves the conflicts between opposing forces. These simulations are about describing a dynamic entity that is both one and many.

HOW THE SITE BECOMES DATA

Landscapes might be described as the physical embodiments of dynamic systems, the material residue of unorchestrated events unfolding in time. Like clouds of airborne moisture they are better described by measures of intensity than by extensivity of metric space. The site at Lakeview makes the transition into the virtual space of the simulation via spatial anchorings as approximations of spatial loci, steered by intuition. Beginning from guesses in a feed-forward operation, they exploit the metric indeterminacy of topological space. The features or qualities that these points refer to, may be either linear or with depth; the intention is not to suggest the embodiment of landscape element in a virtual point, but instead to locate the centre of a control mechanism. These controls will trigger the spatial arrangement of exhibits

FIG 2.34
VISUALIZATION OF A SOCIAL NETWORK
IMAGE BY JEFFREY HEER
HTTP://WWW.CS.BERKELEY.EDU/~JHEER/SOCIALNET/SOCIALNET_EDGES.PNG

FOREST
COLD
WETLANDS
DRY
MOUNTAIN
GRASSLANDS
HOT
WET

in order to extend existing conditions into, and through the site. The feedback received by "playing" with the positions of these anchors engenders further precision in their positioning. Like the controls of a marionette doll, it is from these initial instruments that the zoos orchestration is directed; unlike the marionette, however, the zoo does not allege to resemble behaviour or any thing that is pre-existing.

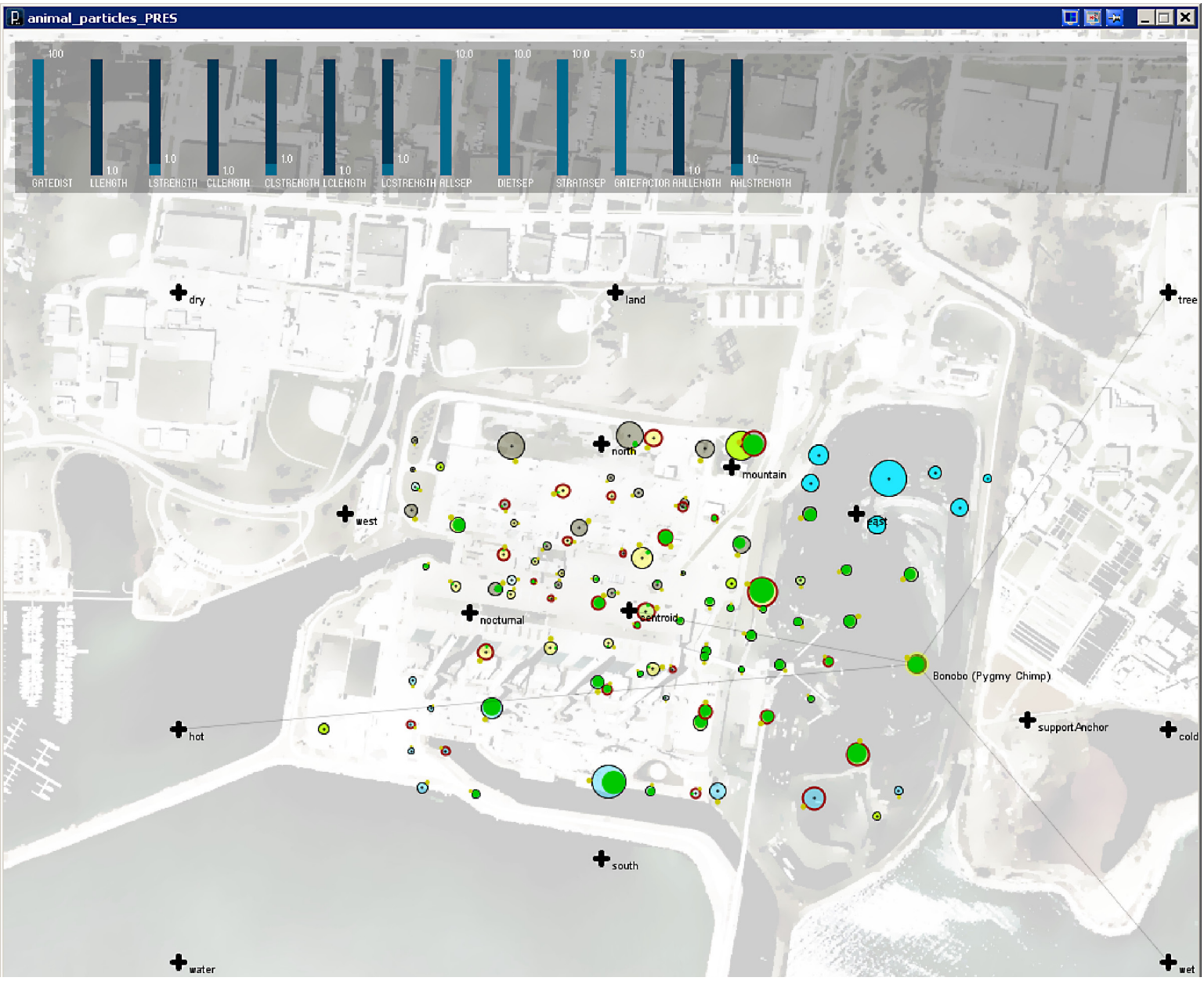
The first anchors are conceived as two axes along which the climatological qualities of temperature and humidity are charted. To the immediate north of the Lakeview GS grounds, lay playing fields that form a buffer between the zoo and the single storey light industrial land. To the West, lay a string of small parks and a marina, each of which is equipped with extensive paved parking lots. These "dry" conditions are set as counterpoint to the "wet" edge at lake-side. To the east, the wastewater treatment plant extends from Lakeshore Road to the lakefront, without interruption. "Hot" and "cold" anchors are approximately oriented to perpendicular to the moisture axis.

Following these primary anchors, landscape features are amplified upon the site. Beyond the wastewater treatment facility, on what used to be the Arsenal Lands, lies Marie Curtis Park. A "forest" anchor corresponds to an old existing woodlot within the park that migrates westward along the northern edge of wastewater treatment plant. The forested area is identified, by a survey conducted in 2003, to be containing mature Carolinian specimens of tree and ground flora, features which have become rare within Southern Ontario.[40] "Wetlands" (distinct from the "wet" indicating a humid quality) are positioned within the lake and "grasslands" within the sprawling grass lawn of the playing fields. A "mountain" anchor, bearing no resemblance to an existing feature, is positioned at the zoo's northern interface.

The anchors act as tethering devices and the system is conceived in terms of generic conditions rather than the specific ones found at Lakeview. The anchors' positions are designated explicitly but one might just as easily imagine that these positions might themselves be modified by feedback from the system. They operate to bear on the behaviour of particles representing exhibits, more than acting as precise locations; acknowledging this profane relationship, the simulation could

40. TORONTO AND REGION CONSERVATION. *ARSENAL LANDS MASTER PLAN ADDENDUM*, 2007.

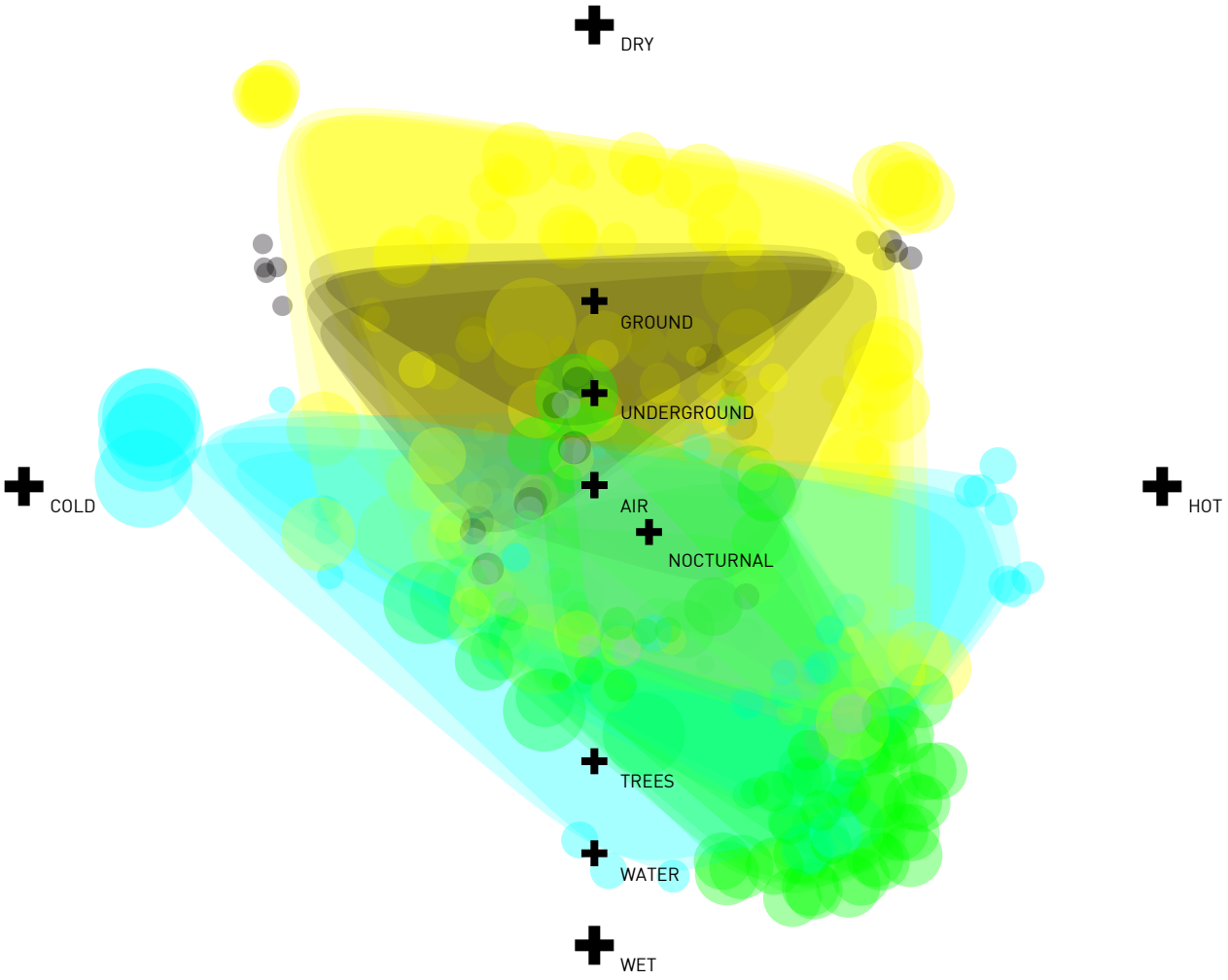
FIG 2.35
AXONOMETRIC OF SITE ATTRACTORS
EACH POINT REFERS TO A DIFFERENT DISTINCT LANDSCAPE CONDITION WHICH SUBSEQUENTLY PULLS ON CORRESPONDING EXHIBITS


animal_particles_PRES
100
GATEDIST
1.0
LLENGTH
1.0
LSTRENGTH
1.0
CLLENGTH
1.0
CLSTRENGTH
1.0
LCLENGTH
1.0
LCSTRENGTH
10.0
ALLSEP
10.0
DIETSEP
10.0
STRATASEP
5.0
GATEFACTOR
1.0
AHLLENGTH
1.0
AHLSTRENGTH
dry
land
tree
north
mountain
west
east
nocturnal
centroid
Bonobo (Pygmy Chimp)
hot
supportAnchor
cold
south
water
wet

begin to adjust these positions to suit better inter-exhibit configurations. The system is designed such that the zoo collection might be deployed on a series of different sites, with different contexts, and it would be through the anchoring mechanisms, that the program would bind to the particularities of the local.

Before digressing deeper into the mechanics of the simulation it might be wise to reaffirm that its intent is not to reproduce a behaviour seen in the animals or the different habitats themselves. This is wholly about the development of a tool, toy or machine, one to assist and augment the design process. There is nothing in it that demands to be considered as real or true, only what works spatially to varying degrees.

FIG 2.36
ANIMAL EXHIBITS
SITED WITH CLIMATIC ANCHORS


DRY
GROUND
UNDERGROUND
COLD
AIR
HOT
NOCTURNAL
TREES
WATER
WET

THE FORCE DIRECTED LAYOUT SIMULATION

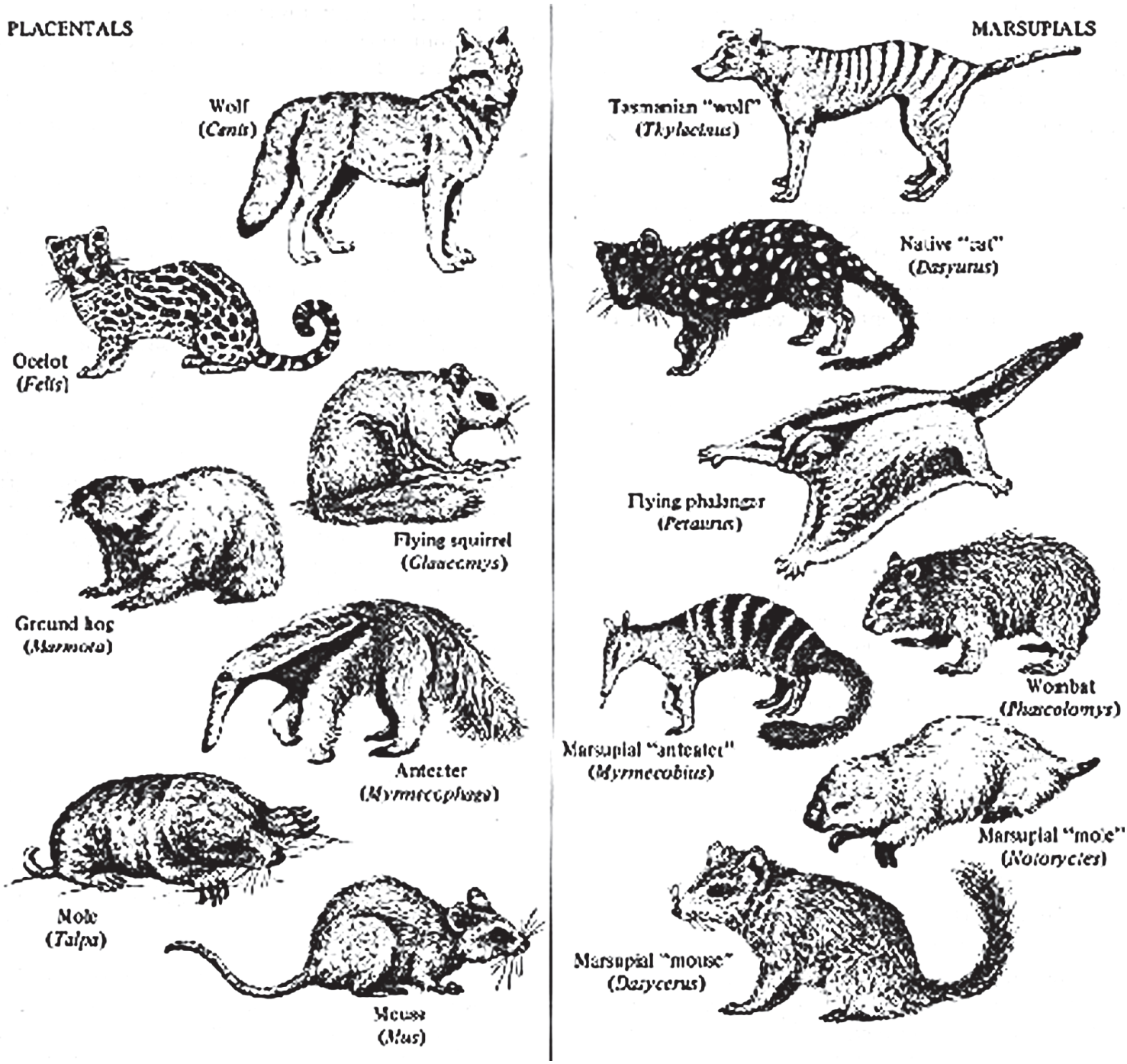
The approach to the site was developed in conjunction with the development of a particle system based simulation developed in Processing. A physics based force directed layout algorithm ensures spacing between nodes and enforce connections between them. Values are given to the edges between related objects and consequently a constellation of ideas, objects or people can be expressed as a spatial concept that is navigable. The simulation that was developed to address the site likewise intends to express the relationship between species and the landscape in terms of forces which inflect and direct each exhibit centre's position.

The final iteration of the simulation implements a version of the physics library by Jeffrey Traer[vi], modified and recompiled to improve its performance. The particle system simulates the physics of Newtonian forces where the behaviour of moving bodies is described as a function of each objects mass, and the system's gravitational forces and drag forces. The system is comprised of simple object oriented Classes defining each object's behaviour and interaction. Amongst its features, the Particle class has weight, and vector fields, and is central to the schema, as a purveyor and conductor of stable data. In physics based simulations, there is typically an attempt to embody information outside the simulated system. A Spring class enforces relationships between particles, operating like string elements. They are constructed with variables for their rest length, their strength and dampening values, all of which cumulatively bear on the qualities of this connection, ranging from springy and elastic to rigid and pole-like. Another class for attractions (and inversely repulsions) further elaborates on inter-particle relations. Along with global variables of gravity and drag, the system can be used to simulate many real life visual phenomena.

The simulation extends beyond the physics library by creating a series of new classes encapsulating its elements. Each one augments the basic system with new fields that store animal-specific information, and through its screen-drawn elements as a visual interface to the user. The visible aspect of the simulation is used primarily as a mechanism by the user to assess the functioning of the underlying processing of data.

VI. HTTP://WWW.CS.PRINCETON.EDU/~TRAER/PHYSICS/

FIG 2.37
CLIMATIC ANCHORS


PLACENTALS
Wolf
(Canis)
Ocelot
(Felis)
Flying squirrel
(Glaucomys)
Ground hog
(Marmota)
Anteater
(Myrmecophaga)
Mole
(Talpa)
Mouse
(Mus)
MARSUPIALS
Tasmanian "wolf"
(Thylacinus)
Native "cat"
(Dasyurus)
Flying phalanger
(Petaurus)
Wombat
(Phascolomys)
Marsupial "anteater"
(Myrmecobius)
Marsupial "mole"
(Notoryctes)
Marsupial "mouse"
(Dasycercus)

An Anchor class encapsulates a particle within the particle system, fixed to an explicitly given position. The initialization runs through each of the climatic ends - hot, cold, wet, dry - and creates a new anchor within the Zoo at each one's coordinates. Though early schemes aspired to have the positioning evolve over the simulations course as an adaptive element, the final version kept these positions fixed.

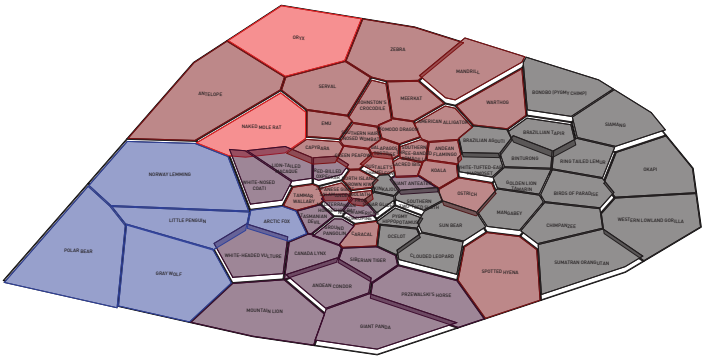
A Space class, encapsulates particles and has fields for its types, a label and its spatial properties - including area and elevation. This class is further extended through a bifurcation into Animal and Human.

The Animal class is constructed using information from the database tokenized into arguments. Along with the inherited methods and fields from the Space class, it is initialized with floats for the areas of land covers, vectors for the position of the landcovers relative to each exhibit's centre, vectors for the position of their private quarters with respect to their exhibit centres and a series of strings and booleans that describe the animal's behaviour. Depending on each Animal's perceived elemental adaptive behaviour - running, flying, climbing, swimming, digging - each is assigned an elevation with respect to the grade of the terrain. As each of these is parsed, they are also anchored to one of several landscape anchors with a Link object. Each animal is tethered to two additional anchors that correspond to their exhibit's humidity levels and temperature.

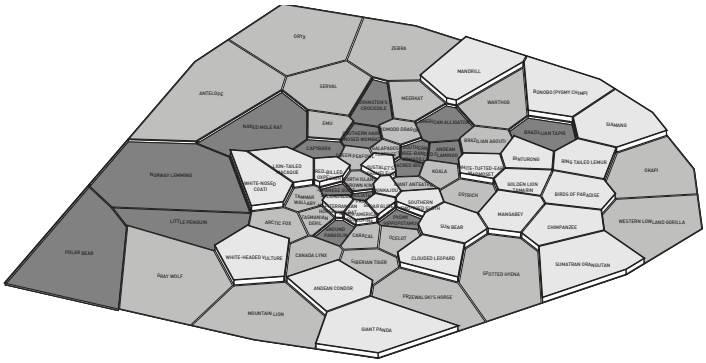
The Human class is constructed using a reduced set of arguments that in some cases include explicit positions that remain fixed over the simulation's duration. They are distinguished by a type field, identifying them as service (back of house) or public, to be inhabited and used by zoo visitors. The Human objects, by their anchors and Links, are far more restricted in their range of motion.

A Link class encapsulates the Spring class and augments it by storing the spaces it is connected to in accessible fields. Links can be created either between spaces or between spaces and anchors. They can be identified by their type and sorted into different lists to distinguish and apply modifications as is seen fit. Inter-particle links are turned on and off as particles move in and out of range of one another.

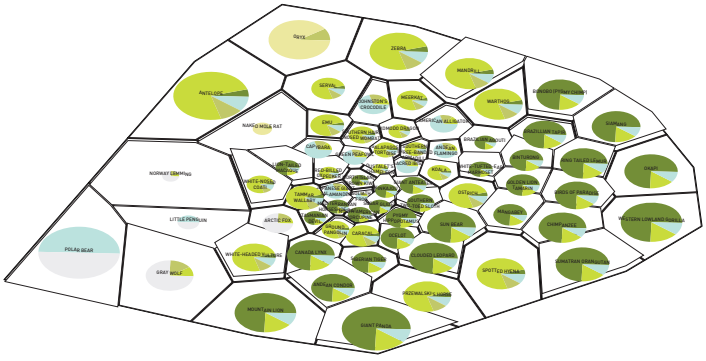
FIG 2.38
ILLUSTRATION OF EXAMPLES OF CONVERGENT EVOLUTION



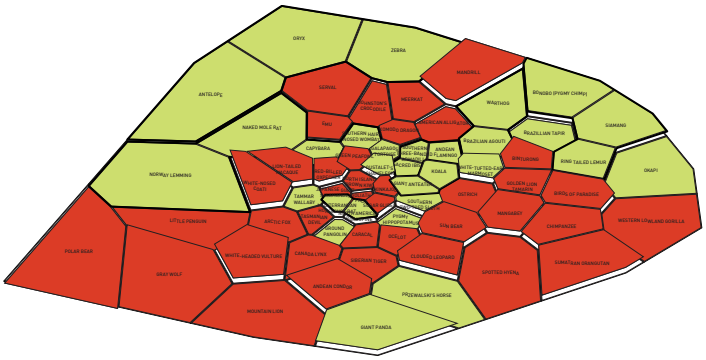
CLIMATIC SPECTRUM
TEMPERATURE AND HUMIDITY LEVELS OVERLAP TO PRODUCE
DIVERSE SET OF LOCAL ATMOSPHERIC CONDITIONS



STRATIFIED PERSPECTIVES
DIFFERING PATH ELEVATIONS FROM WHICH TO ENGAGE WITH
ANIMALS AND HABITATS, VIEW SPECIALIZED BEHAVIOURS



LAND COVER
CLOCKWISE FROM TOP: WATER, SNOW, SOIL, BRUSH, GRASS, TREES

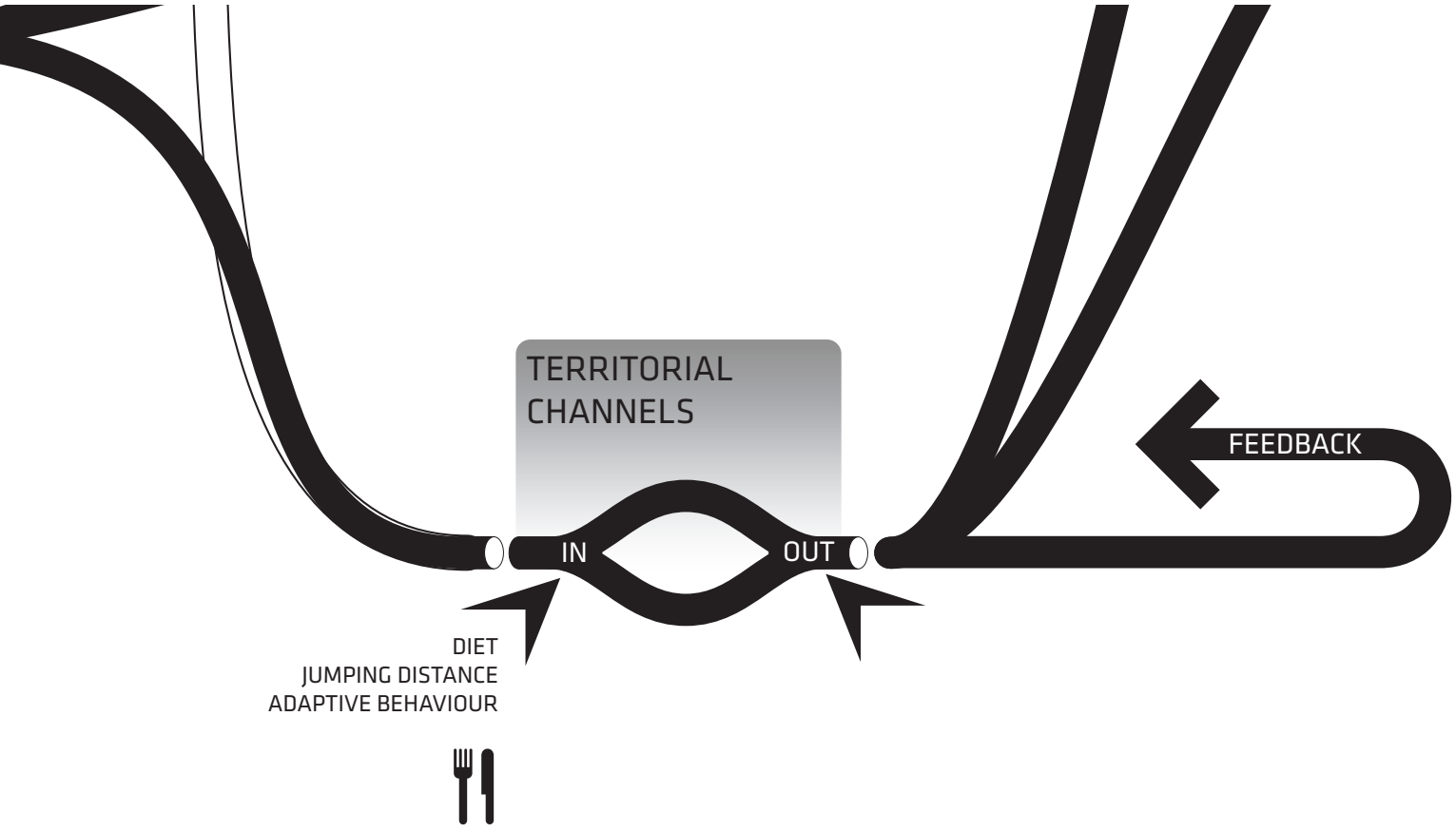


ADJACENT COMPATIBILITIES
FRIEND / FOE DISTINCTIONS, BASED ON DIET

After the simulation has been running for a period of time, movement progressively becomes dampened, and the particles will tend to settle into poised positions. Upon execution of an export function, data processed in the simulation is written to a number of text files in tab separated format.

A series of mappings generated by processing the exported data through parametric models, describe the system in terms of several identifiers, including strata, temperature and humidity, diet type, and land cover. Like the visual component of the simulation, they are used as feedback elements to assess the results of its processes.

FIG 2.39
AXONOMETRIC DIAGRAMS MAPPING EXHIBIT DISTRIBUTION
COLLECTION MAPPED ACCORDING TO SEVERAL DIMENSIONS


TERRITORIAL
CHANNELS
IN
OUT
FEEDBACK
DIET
JUMPING DISTANCE
ADAPTIVE BEHAVIOUR

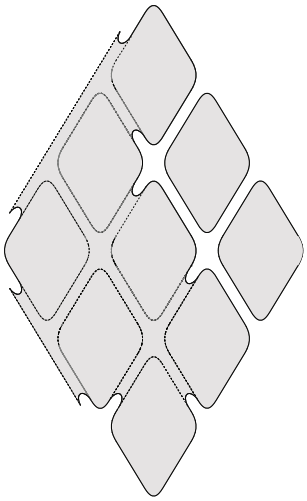
INTERNAL DIFFERENTIATION

GROUND OPERATIONS

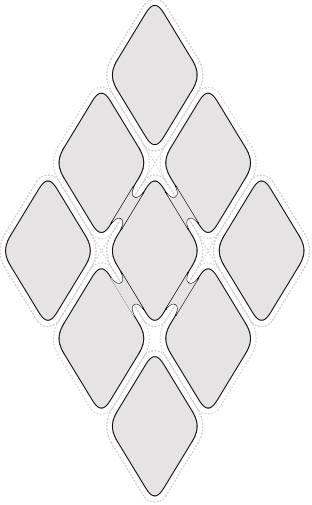
FIG 2.40
PROCESSUAL FLOWS
TERRITORIAL CHANNELS

BREACHES
DISSOLUTION OF PATHWAY AS EXHIBIT FRAME

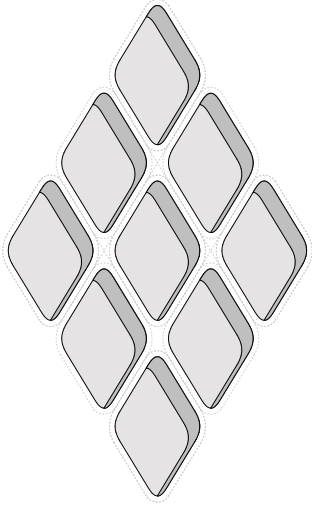
CONTAINMENT
SEPARATION OF LOTS BY WAY OF THE FRAME
OF THE VISITOR'S PATHWAY



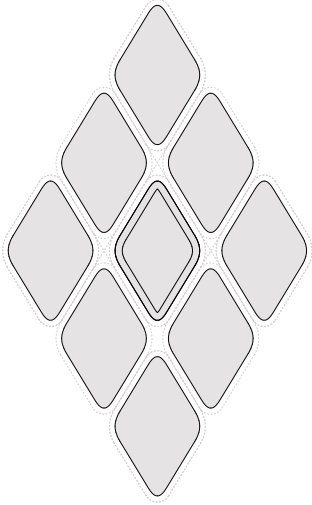
SUBMERGED PATHWAYS



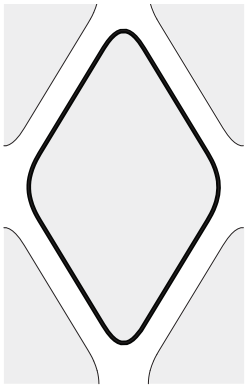
LIFT OF PATHWAYS



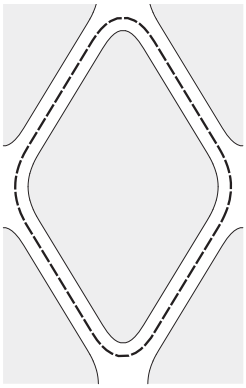
CONTINUOUS ELEVATION OF PATHWAYS



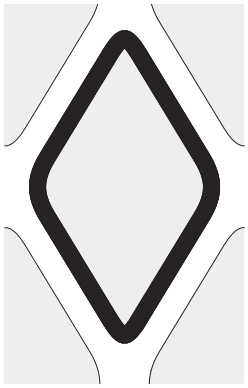
DISCRETE FRAMES



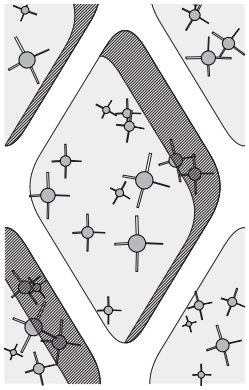
PATHWAY
GLASS, MESH, WALL



FENCING, WALL
OUT OF SIGHT - IMPERCEPTIBLE



SPATIAL DISCONTINUITY
HAHA, MOAT, ELEVATIONAL DIFFERENCE



NO SEPARATION

THE FRAME
TYPES OF SEPARATIONS BETWEEN LOTS

This section departs from the previous by transforming its generated data - particularly vectors denoting exhibit centres - into a spatial territorializing of the ground. This operation depends on distinctions made between predator and prey species in order to allocate contiguous ground surfaces, creating service corridors which allow access onto animal holding spaces.

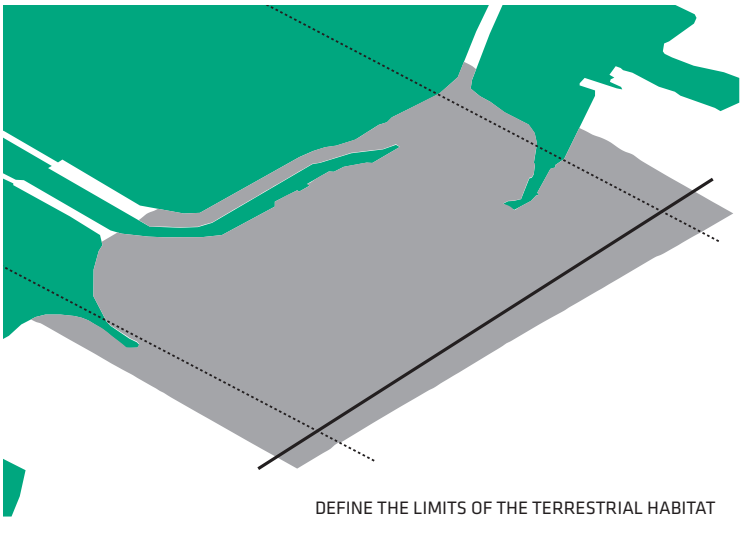
The ground is conceived as an archipelago; bodies of land connected tenuously to form a perceptible whole. Like the flocking examples too, the same body can be partitioned in a number of ways and still maintain its fidelity. Each exhibit is defined only by a concrete retaining wall and a separation by trench to its adjacent exhibit. Depending on amicability between neighbours, the void created by these channels is bridged by a light open metal grating.

The mechanism for constructing the planimetric arrangement is a two dimensional voronoi algorithm. The computational algorithm generates a tesselation of space, dividing it amongst a given set of points. The voronoi has been used formally in various research areas from geography - the computation of nearest neighbour searches and to aid in finding ideal locations for new points of distribution in a territory - to robotics - to aid the autonomous navigation around obstacles - to computer graphics - the procedural generation of natural-looking patterns like that of giraffe skins and soap bubbles.

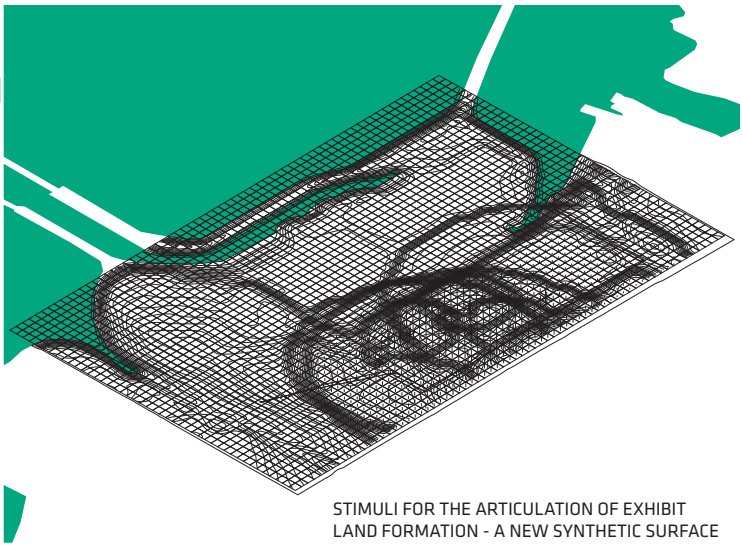
In the case of the zoo, the voronoi is a mechanism for automatically dividing space, its inputs having already been conditioned by the force directed layout. The territory is conceived as a bound whole that is internally distributed or partitioned amongst the points as given. It imagines that the zoo is in an embryonic state, the cellular division being the first stage in a series of morphogenetic developments that will continue to articulate and specialize its spatial units to suit its particular situation.

Though it may be deployed with a homogenous regularity, the perceived irregularity - characterized by varying angles of intersection of its bounding walls - reinforces the intent to create a space of disorientation and ambiguity. It does away with symmetry and orientation. Where one cell ends, the next begins, each one inflecting and

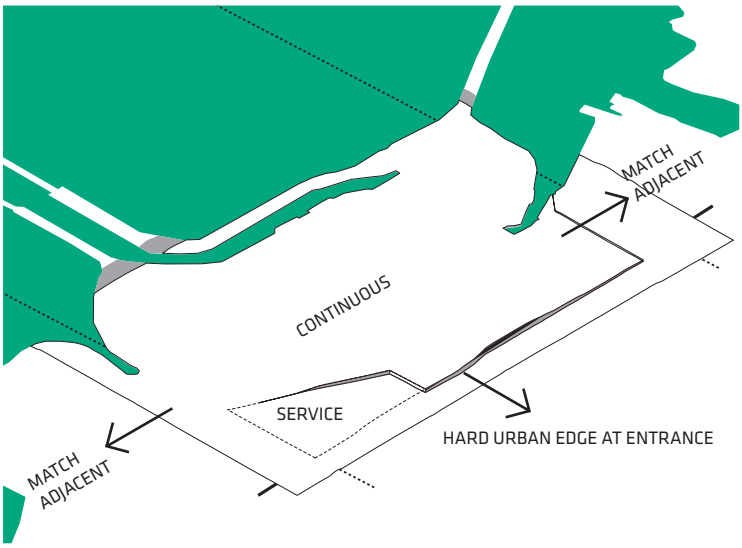
FIG 2.41
INVESTIGATIONS INTO NEIGHBOURHOODS
STUDIES OF EXHIBIT DISTRICTS AND THE POTENTIAL FOR VISITOR PATHWAYS TO ACT AS SEPARATIONS BETWEEN ANIMALS; CONTIGUOUS NEIGHBOURING EXHIBITS WOULD BE CREATED BY SEPARATING THE VISITOR PATHWAY FROM THE EXHIBIT GRADE

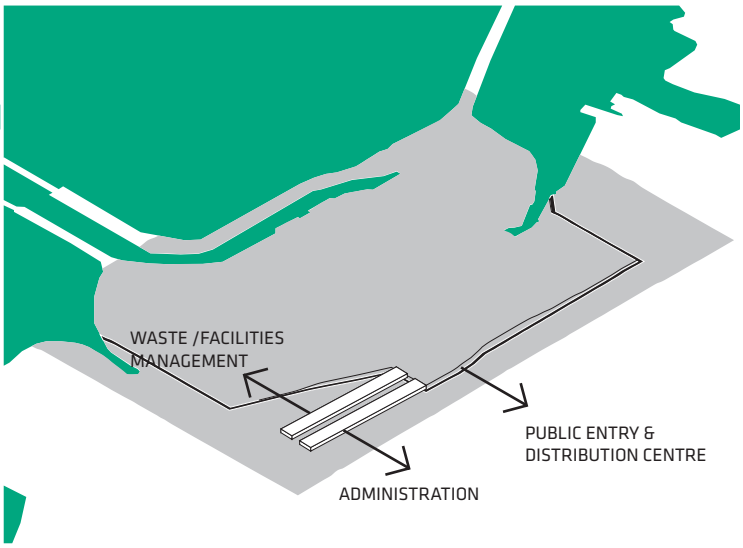


DEFINE THE LIMITS OF THE TERRESTRIAL HABITAT



STIMULI FOR THE ARTICULATION OF EXHIBIT
LAND FORMATION - A NEW SYNTHETIC SURFACE





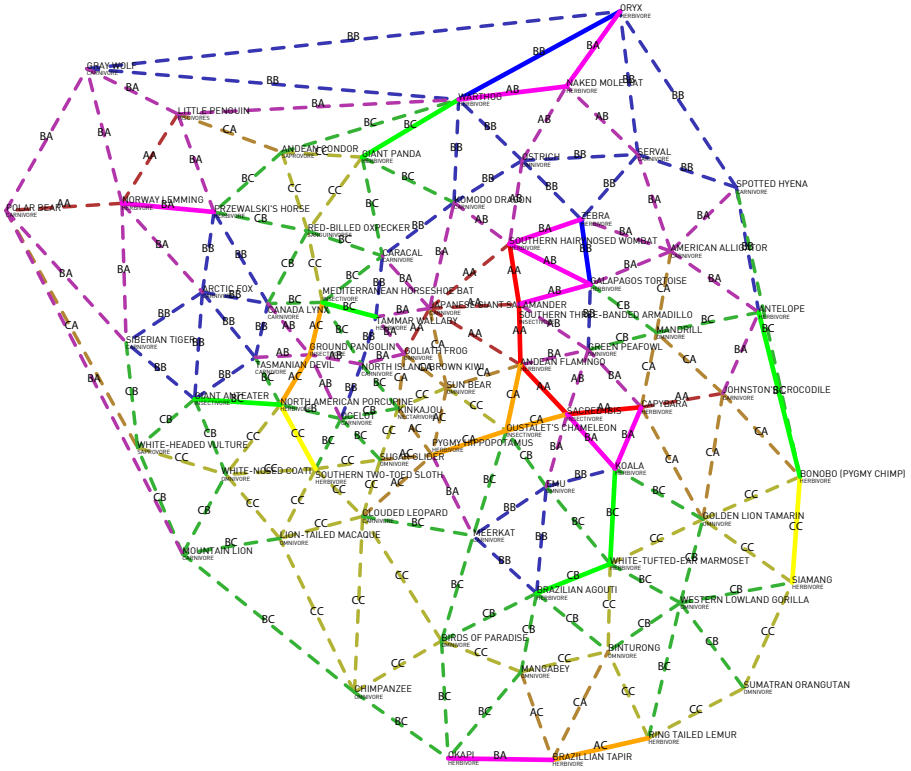
being inflected by its neighbours. As opposed to the figure/ground approach typical of zoos, this zoo is all figure, or all ground, depending on how one chooses to look at it. Delineations between species's exhibits are intended to be ambiguated, always seeking overlap where permissible. There is, consequently, no perfect vantage point from which to experience the exhibits.

The voronoi field is a homogenous one, deployed consistently across the zoo's grounds. Insofar as it is a process of division, the voronoi strategy permits further division without a loss of structural integrity. The geometry is amenable to further subdivision should further animals be inserted into the zoo. There is no direct correlation between the areas given by the animal database and the land allotted by the voronoi division scheme. The zoo is conceived as a finite piece of terrestrial real estate to be administered and distributed amongst its inhabitants. Exhibits, far exceeding the minimum space allocation given by zoo standards, can accommodate larger social groupings as well as possible subdivision, both without compromising its spatial integrity.

The zoo appropriates the landscape ha-ha, a spatial device originally used in English landscaping to conceal barriers to the movement of cattle. It was reincarnated at Carl Hagenbeck's zoo[vii] to create cages without bars for his animals. His moats were used to give the illusion of a panoramic halcyon-like scene with incompatible species living in inexplicable proximity of one another.

VII. TIERPARK HAGENBECK, HAMBURG, GERMANY, 1907

FIG 2.42
AXONOMETRIC OF GROUND OPERATIONS



FRIEND FOE

AA

BB

CC

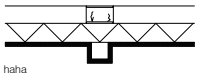
AB

AC

BC

SPATIAL DIS-CONTINUITY

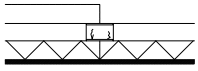
USE OF HAHAS, TRENCHES, DIFFERENCES IN ELEVATION



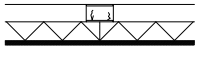
haha

PSYCHOLOGICAL/PERCEPTUAL

EXPLOITING ANIMAL'S SENSITIVITIES TO SOUND, LIGHT, MATERIAL



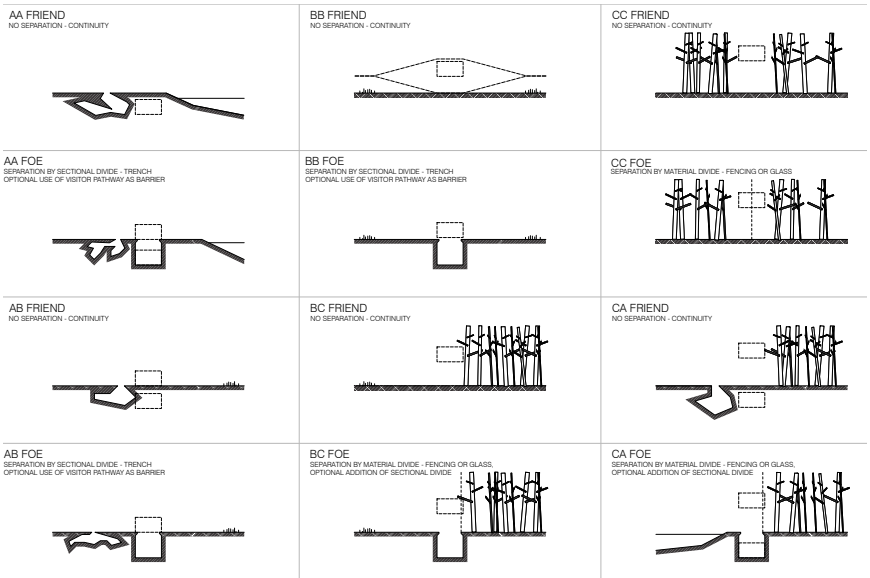
mesh/fence



mesh/fence

pathway

ANIMAL/ANIMAL SEPARATION



ANIMAL TERRITORIES

Departing from the Force Directed Layout simulation, the ground operations are triggered by the animal exhibit centres and their respective properties.

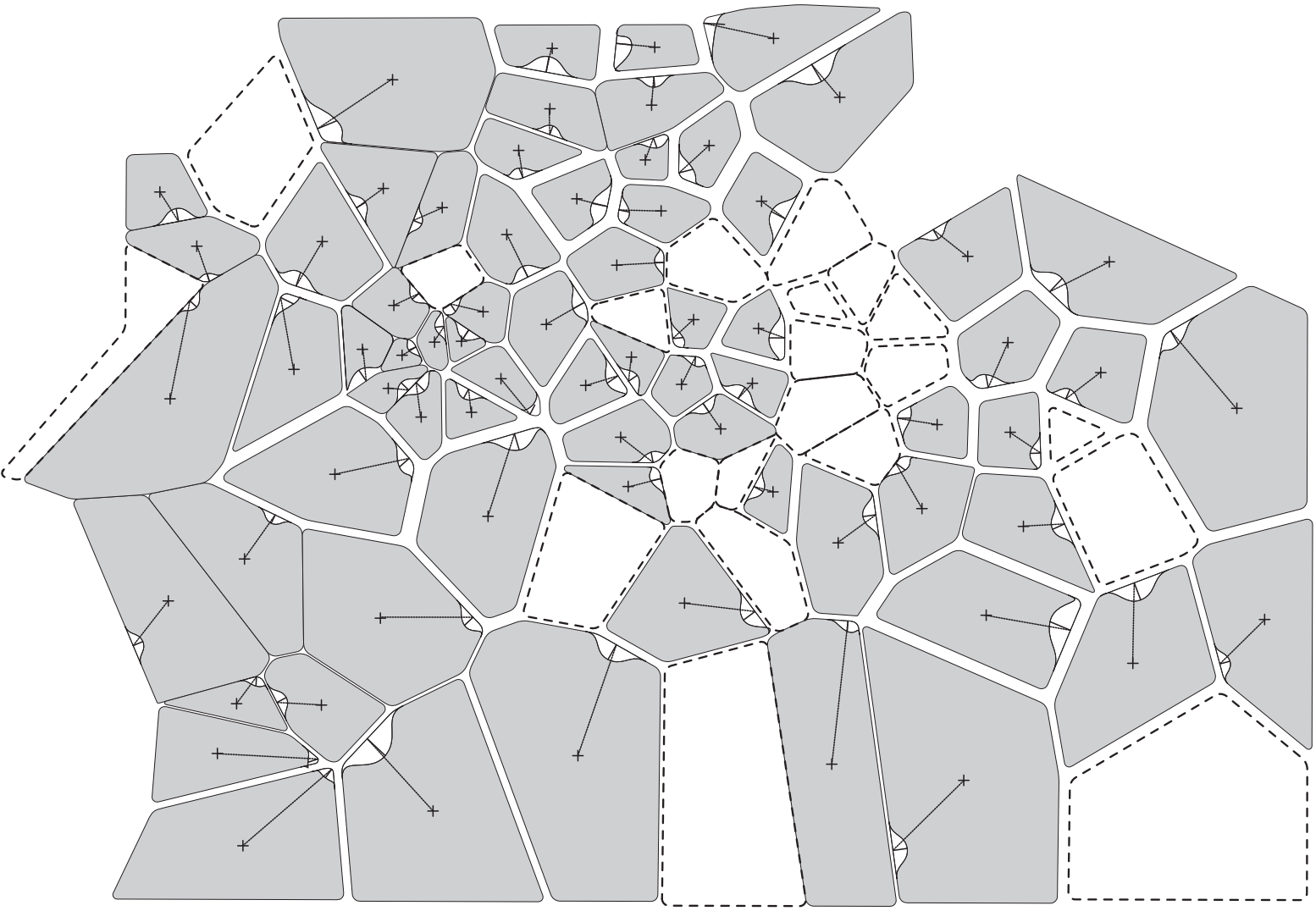
Before the ground is differentiated into enclosures, the zoo is demarcated and separated from its context by incisions in the ground. At all but its northern edges, this separation happens by way of a recess in the land or water by a concrete channel or ha-ha. These features are inserted inconspicuously to suggest continuity with its context. An "urban" edge is generated by cutting and lifting the ground; a topographical mountain oriented southward to the lake, and a glazed vertical façade oriented north towards the zoos entry point and built areas further on. Behind this glazed façade, under the lifted habitat surface, a lobby area provides meeting point, visitor orientation and other buried interpretive programs such as auditorium, and screening rooms. The land is driven by the accumulation of mountainous animals along this edge which were anchored in the force directed layout stage.

The ground, now bound, is divided by the recorded positions fed to a voronoi algorithm. Explored in several media and with different versions of the algorithm, the final version used an algorithm built into the parametric software. The basic construction of a voronoi diagram involves taking a sampling of points within a metric space and dividing it amongst them. Each point becomes bounded by a bounding wall, constructed by the perpendicular bisectors passing through the midpoints between each adjacent pairing of points. Those bisectors immediately "visible" to each point become its bounding geometry. Every point within the cell's walls are closer to its centre (sample point) than to any other in the system. In this way, voronoi can be seen to be related to the abstract machine behind other morphogenetic searches for minima like that of soap bubbles and their minimal surfaces.

The cells generated by the algorithm, are separated out into lists of "friends" and "foes", each specifying its corresponding animal's compatibility with others. Notional cell walls between adjacent friends are conceived as tenuously connected tissue, bridged with open metal grating. Around cells identified as foes, the drop in grade poses a spatial barrier to interaction.

FIG 2.43↖
EDGE CONDITIONS MAP
DIAGRAM MAPPING EACH EDGE CONDITION TO ONE OF THE SPATIAL ADJACENCY CONDITIONS

FIG 2.44←
MATRIX OF SPATIAL ADJACENCIES



ANIMAL SERVICING

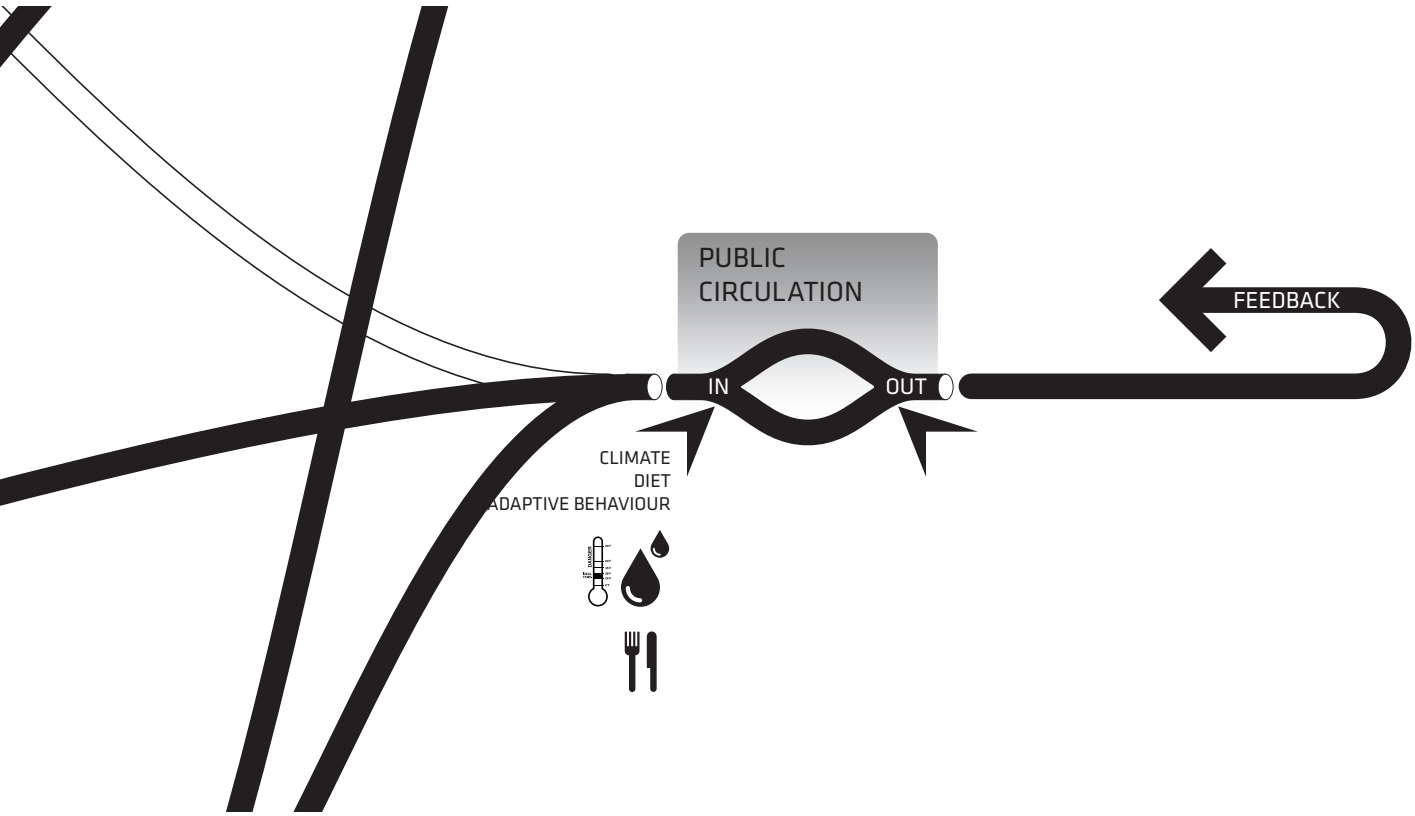
The separations between enclosures double as conduits for service flows. In this way, they are conceived as hybrid mechanisms – architectural mediation devices which simultaneously separate (animals) and connect (support).

The separation distances between incompatible cells are conditioned by a list of values from the animal database that reflect jumping capacities and vehicular passage. The space between animal territories, at a height 18 feet below the terrain, is used as a service conduit for the movement of animal keepers and zoo maintenance staff, for the flows of food and water, and the return flows of waste. The jumping distance data is conditioned by requirements regarding such flows through mapping and truncating functions.

Each exhibit has a corresponding private quarters for animals to bed down at night and to facilitate temporary isolation as it may arise. These spaces are fully enclosed, and are modest in size relative to the open exhibits. Accessed by animals through descending ramps within the exhibits, they provide nodal points where animal keepers can get access to treat and observe the animals within a manageable space. Interfaces between the worlds of the animals and zoo staff, they are directly connected to both; most quarters lay under the terrain with direct access from the service conduits, while those that sit elevated in the tree canopy have access from the roof above.

The service level is conceived as an urban network, where communities with shared qualities are drawn towards each other to form cores of intensity. The position of each animal's private quarters is driven by vectors generated by the force directed layout (FDL) simulation; the Animal class is equipped with methods to search its neighbourhood for animals who have similar dietary requirements. Should any be found, vectors are generated that point to average positions amongst those being considered. The cumulative effect is to create clustered neighbourhood nodal points within the network. These points can be further re-enforced with human programs related to the study of certain kinds of species, or as depots for the distribution of materials, food, or waste.

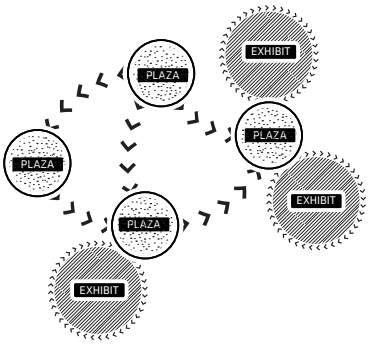
FIG 2.45
ANIMAL QUARTERS


PUBLIC
CIRCULATION
FEEDBACK
IN
OUT
CLIMATE
DIET
ADAPTIVE BEHAVIOUR

VISITOR PATHWAYS

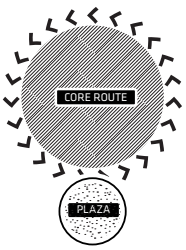
STRUCTURED DERIVES

FIG 2.46
PROCESSUAL FLOWS
PUBLIC CIRCULATION



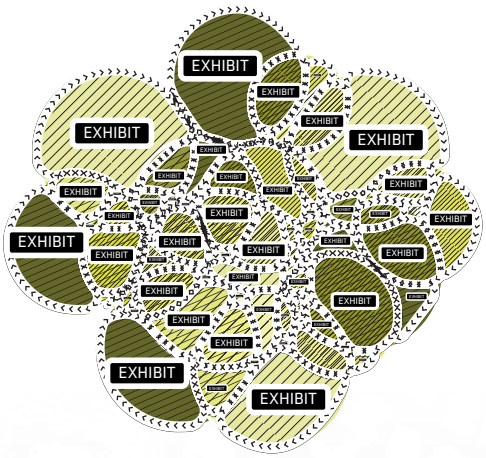
NO HIERARCHY

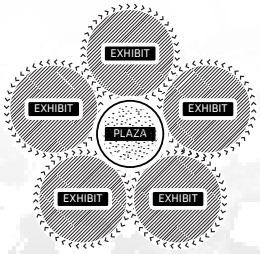
MULTIPLE DISTRIBUTION SPACES
MULTIPLE CIRCULATION PATHS



HIERARCHICAL SINGLE LOOP

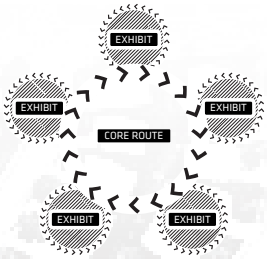
SINGLE DISTRIBUTION SPACE
SINGLE LINEAR PATH





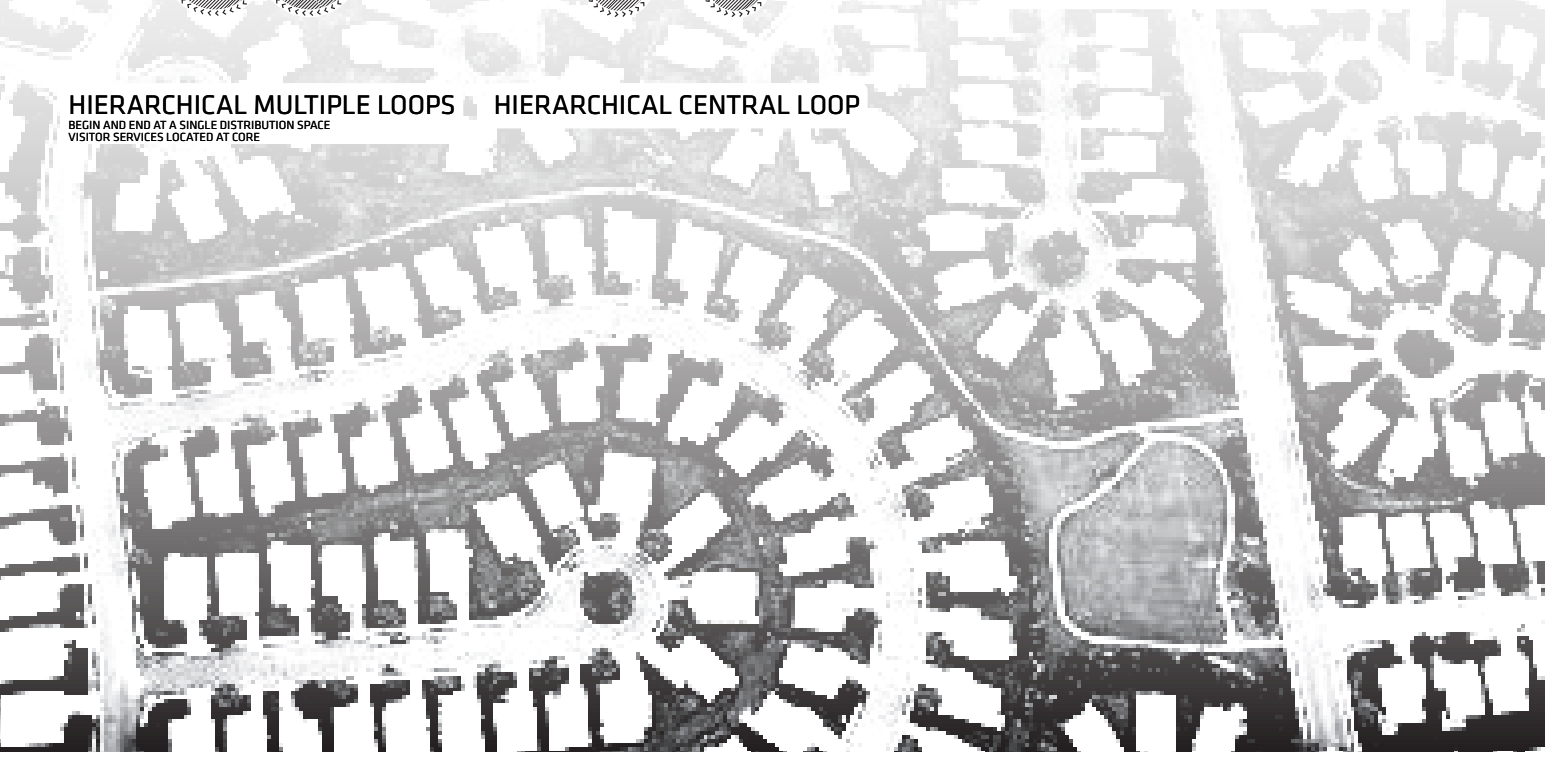
HIERARCHICAL MULTIPLE LOOPS

BEGIN AND END AT A SINGLE DISTRIBUTION SPACE
VISITOR SERVICES LOCATED AT CORE



HIERARCHICAL CENTRAL LOOP

AHIERARCHICAL, OVERLAPPING LOOPS



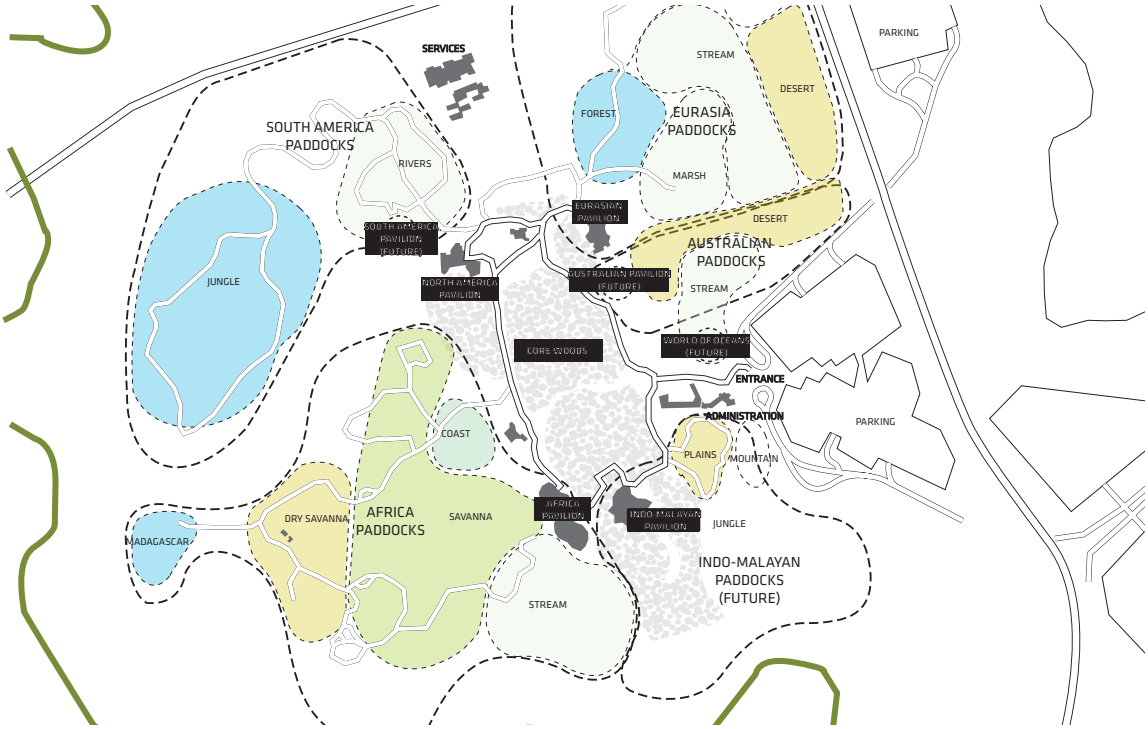
This section describes a simulation developed for laying out pathways and follows with a portion about a strategy for locating and drawing out singularities within the system, moments for pause, reflection and concentrated engagement amidst the web of perpetual motion.

We might read the evolution of the zoo's internal logic - particularly that of visitor circulation and exhibit plan - as one paralleling the suburbanization of the city. The exhibits of the first European inner-city menagerie style zoos were laid out as lots bound by the dense street like passageways. Animals were typically held in separate roofed in enclosures of concrete or steel bars. The zoos built from the mid-20th century onwards tend to be much more spatially generous in order to foreground ecology, but its consequence is that the lengths of paths connecting exhibits are longer and their points of connection are few and far between. These zoos resemble the morphology of suburban enclaves with their gate-like demarcations, arterial roads, and benign crescents and cul-de-sacs. Both systems emphasize exclusivity, limit choice and chance, and implement a system of controlled passage. The confinement accompanying the spatial evolution of the zoo restricts the zoo visitor's ability to draw their own novel and personal connections between exhibits and species. They are forced instead to passively observe their environment along overly structured corridors.

With the design for the zoo's system of visitor pathways, the intent is to return a sense of wilderness - whether that of the urban derive or the nature walk - to its experience. This step is conceived as a hybrid system somewhere between the openness of the bidirectional grid and the directed control of its counterpart, the line or corridor. Lying somewhere between these two bookends, this thesis posits, is a nuanced middle-ground that offers its visitors the interactivity of constructing their own narrative through a dense set of pathways, which are conditioned by material logic of relatedness and proximity. The collection is liberated from the control of a single-serving narratives - a reduced one whose future revision is almost a certainty - instead rendered as a sort of "choose your own adventure"[viii] experience where it is expected that visitors will have more meaningful experiences as active agents.

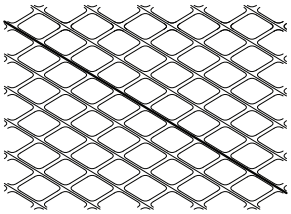
VIII. *CHOOSE YOUR OWN ADVENTURE* BOOKS, FIRST PUBLISHED BY BANTAM BOOKS FROM 1979-1998, NOW BY CHOOSECO, HTTP://CYOA.COM

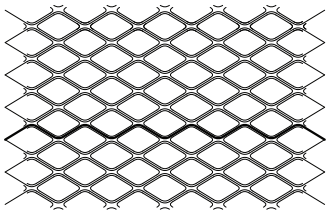
FIG 2.47
ZOO PUBLIC CIRCULATION STRATEGIES
ILLUSTRATION OF EXISTING TYPES AND THE PROJECT'S THE INTENT WITH REGARD TO VISITOR PATHWAYS OVERLAID ON AERIAL VIEW OF GENERIC RESIDENTIAL SUBDIVISION

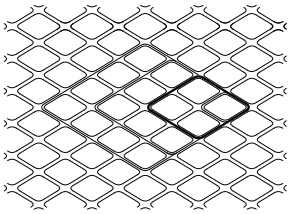


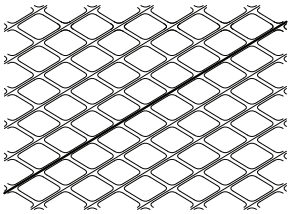
LINEAR INDEXES

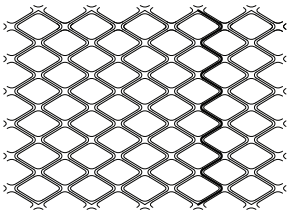
CIRCUITOUS INDEXES

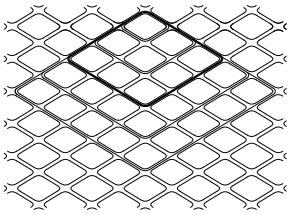












THE STRAIGHT PATH

THE LINEAR SWITCHBACK

THE CIRCUIT

This work is indebted to its precedents in the material experiments of Frei Otto, which were since followed with the digital reconstructions by Lars Spuybroek (NOX) and more recently by MRGD Architects. This portion of the thesis intends to delve deeper into the already explored territory and examine the potential in the abstractions of such a simulation to become a material system, and its consequences.

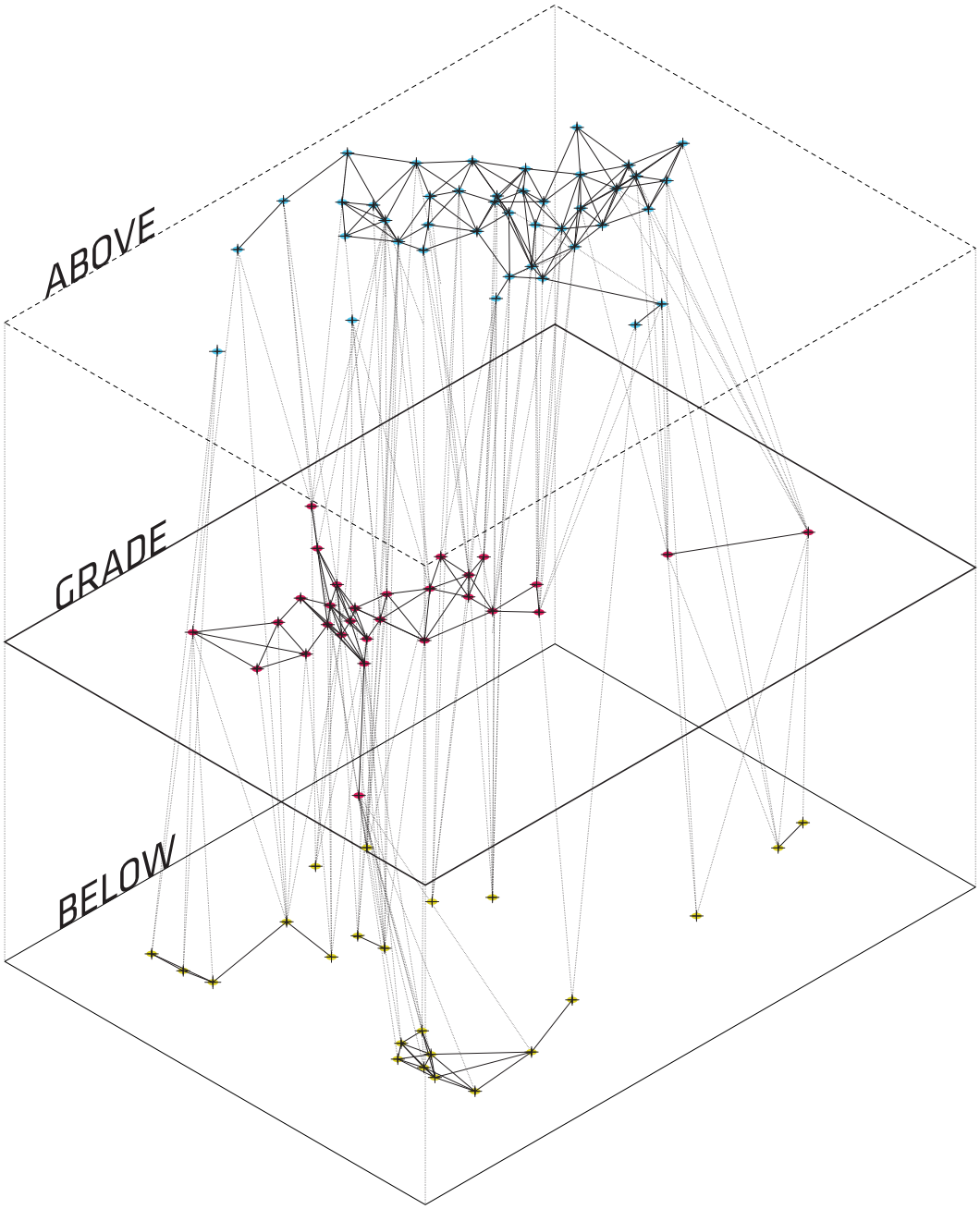
What results from the simulation is a network of human passageways smoothly bifurcating between possible alternate courses. The paths run through the exhibits connected to their centres. Each exhibit is defined by an ideal viewing elevation corresponding with its animal's adaptive behaviour. Reduced to three primary levels, each exhibit is to be viewed either from a path at grade with the habitat dipping underneath it, a path burrowing below grade, and one elevated on posts. Flooring of open steel grating, and guardrails comprised of vertical steel-plate pickets allow for the unobstructed passage of spatial phenomena - visual, aural, tactile, olfactory - into and through the paths.

BUILDING IT "RIGHT"

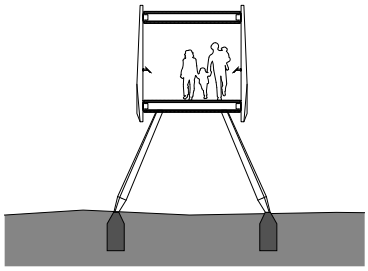
This stage also intends to develop a structurally informal system as counterpoint to the supposed right-ness of man. A staple of humanistic thought, man is privileged as elevated above other forms of life; this is evidenced by his standing upright, his thinking, and building with straight lines and right angles. Le Corbusier went an extra step by his suggestion that human life is ***opposed*** to animal life and that the irrational meandering donkey paths, around which ancient cities evolved, attested to this fundamental incompatibility, as centres of congestion and disease. Within the animal context of the zoo, these roles are reversed, and the "logic" of the donkey path takes on an altogether different meaning.

FIG 2.48 ↖
METRO TORONTO ZOO MASTERPLAN
AS A HIERARCHICAL CENTRAL LOOP - EACH ECO-REGION IS DISTINCT AND ISOLATED FROM EACH OTHER

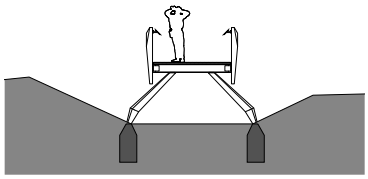
FIG 2.49 ←
GRID CIRCULATION STUDY
DIAGRAMS IILLUSTRATING THE POTENTIAL FOR ALTERNATE CIRCULATORY ROUTES GIVEN BY GRID SYSTEM



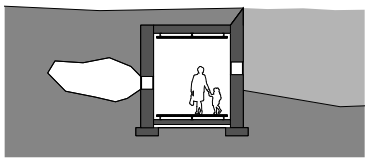
I ABOVE EXHIBIT GRADE
OSTS WITH AN OPTION FOR A FULLY ENCLOSED TRAJECTORY
IMALS WHO FLY OR CLIMB



T GRADE
I ALLOWS PASSAGE UNDERNEATH
IMALS WHO FLY OR CLIMB



HIBIT GRADE
TE TUNNEL RETAINING SOIL OR WATER, PERFORATED TO ALLOW VIEWING
IMALS WHO SWIM OR BURROW



THE BUNDLING SIMULATION

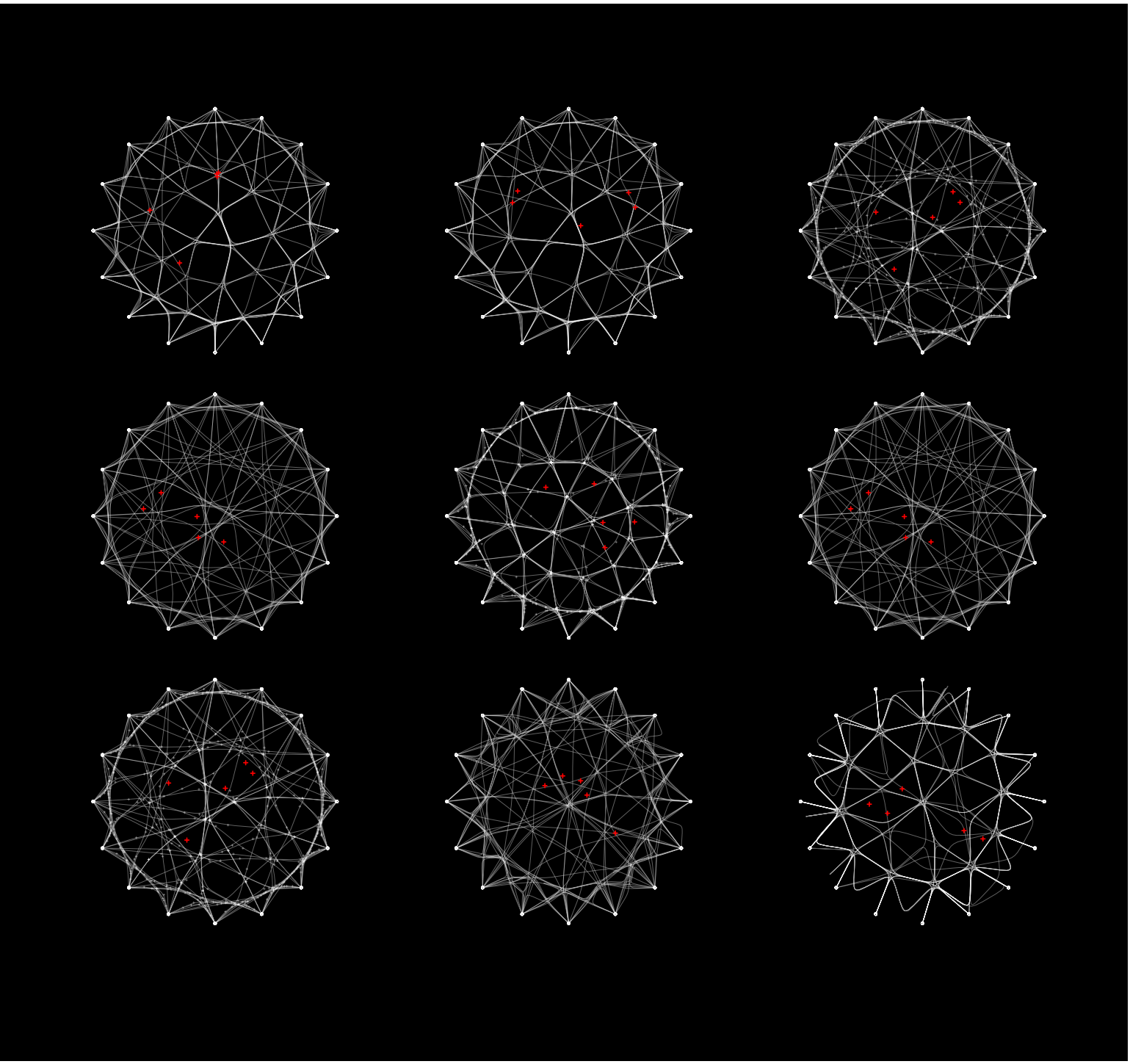
Serving to increase connectivity between disparate parts of the zoo, a tangled web of linear paths connect exhibits of related species. To optimize and limit inordinate redundancies within the system, the pathways are simulated as moistened threads which have a tendency to bundle and gather together. A consequence of this bundling is the smooth transitioning between directions and thus supports slippage between more structured navigations of the same system.

The simulation of the bundling and gathering effects of wet threads was built as a simulation in Processing using the physics library of Jeff Traer. Its initial state takes off from where the force directed layout program leaves; a text file produced by that program (the latter's) is parsed and its lines used as arguments as new fixed Particles are instantiated at each exhibit's centre. These Particles are assembled into two arrays, one of a new class called Human, the other a new class called Animal. The Human class is constructed simply by using the x, y, and z-coordinates and a string identifier read from the file while the Animal class takes these attributes as well as their strata, diet, temperature and humidity requirements.

Once these objects are in place, the initialization phase moves on to the construction of Hair objects. Nested iterative sequences cycle through each Human object calculating distances between it and every one of the Animal objects and storing this in a float field built into the Animal class. On each Human cycle, this list is sorted using a Comparator class that will compare each distance, sorting from smallest to largest. Once sorted, the closest Animals are used as arguments along with the Human to construct each Hair.

A similar process of assigning distances between each Animal, and every other one in the array accompanies the construction of Hairs between Animal objects. After sorting, each Animal in the list must pass through a series of conditional gateways in order to be constructed. A counting function - comprised of an integer field and a corresponding method for its incremental addition - is responsible for keeping track of how connected each object is, triggered by the construction of each Hair. The Animal to Animal Hairs are also distinguished by a character used to denote three different types of connections. Each connection refers to a type of relation-

FIG 2.50
AXONOMETRIC DIAGRAM OF 3 STRATA & CONNECTIONS BETWEEN EXHIBITS



ship, the first of which stands out as it and its constituent Particles are forced to maintain constant height relative to grade along their length; this to ensure that there are pathways that don't insist on ascents or descents. This first type denotes connections between Animals that belong to the same stratum and within certain proximity, the second, equality in climate as well as proximity, and the third equality in diet as well as proximity. The Hairs are distinguished in this way, and with a visual correspondence of colour differentiation, in order to ensure that exhibits are accessible to their neighbours across the multi-dimensional data set. With each test for equality and proximity, gate connections are also being tested to ensure that the Animal objects do not become overcrowded.

The Hairs themselves are in principle an array of free moving Particles attached to a fixed Particle at each end. The size of this array is governed by the distance between these ends which are given in the construction process. The initial positions of the free moving Particles are equidistant between fixed extremities and a Spring is constructed between each and its neighbour in the array. The draw loop enacted on each time step in the simulation, handles the appearance of the Hairs as smoothly-curved linear elements. Bezier curves are drawn between vectors midway between each set of neighbours and the midway between the consecutive set. The intermediate Particle is used as a position or the Bezier handles to pass through. Though this information appears solely to drive the display on screen, the coordinates of the Bezier ends and handles will get recorded to a text file to be processed into a three dimensional form in the modelling software.

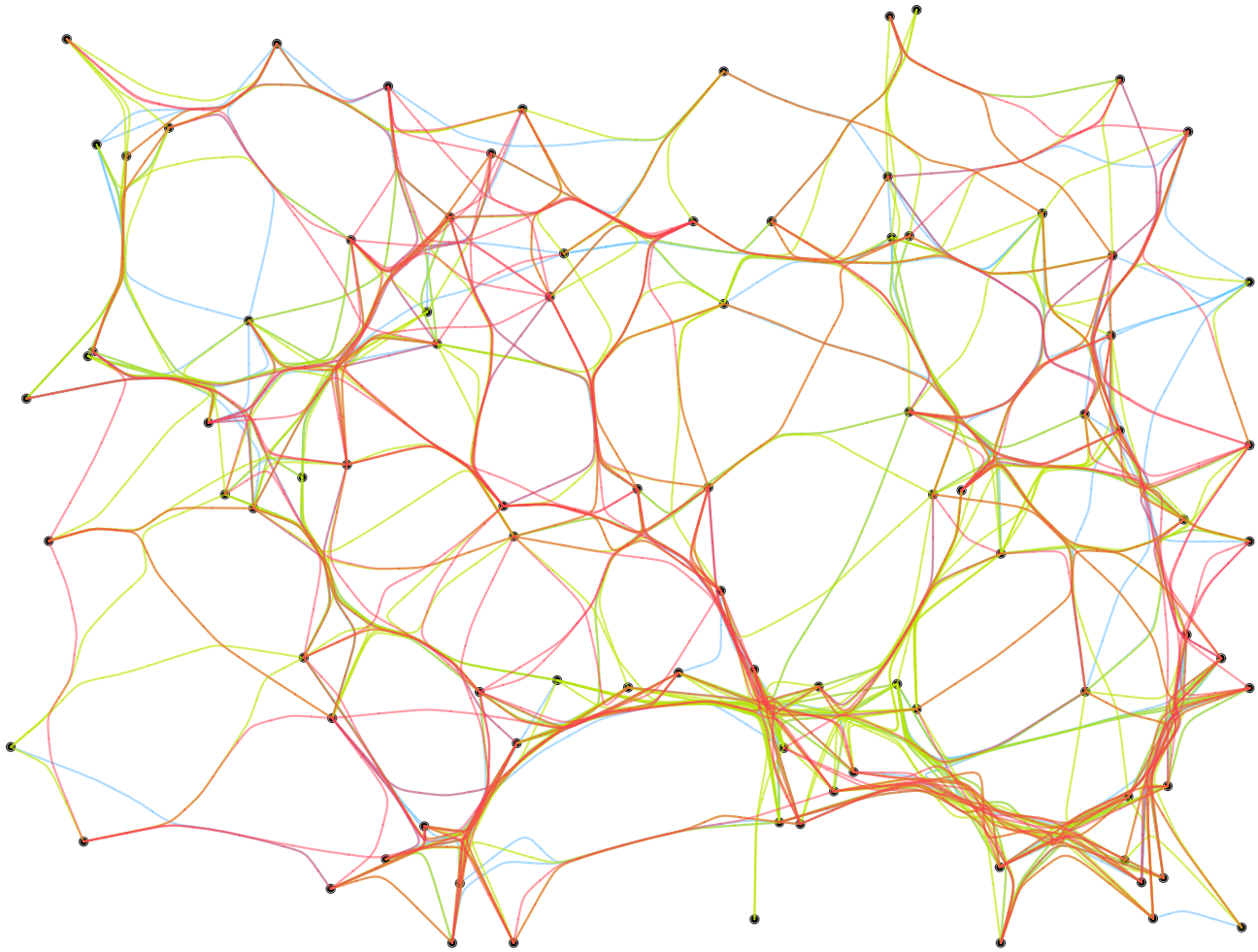
Still in the initialization phase, attraction forces are added between Particles in the system to produce the clinging action. Cycling through each Particle and every other one, an Attraction is constructed, its strength and minimum distance being conditioned by the initial distances between them. If the Particles are beyond a certain distance, they will be turned off and will have no effect.

The recurring portion of the simulation then, apart from advancing the time step of the physics system and rendering of the geometry in the display window, is in the interaction of the attractive forces which propel the Particles towards each other

FIG 2.51
DIAGRAMS IILLUSTRATING SIMULATION IN DEVELOPMENT
POLAR ARRAY OF FIXED PARTICLES CONNECTED TO EACH OTHER BY STRINGS OF FREE PARTICLES; ATTRACTIONS BETWEEN THESE PARTICLES GENERATE BUNDLING BEHAVIOURS; REPELLENT PARTICLES (RED) CAN BE INSERTED WITHIN THE SYSTEM AS OBSTACLES

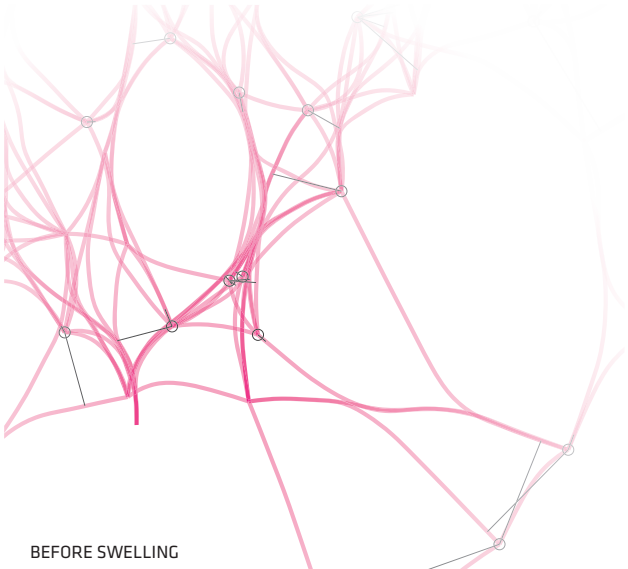
VISITOR PATHWAYS, CONNECTING EXHIBITS

- EXHIBIT CENTRE
- CONNECTION A: SAME STRATUM
- CONNECTION B: SAME CLIMATE
- CONNECTION C: SAME DIET

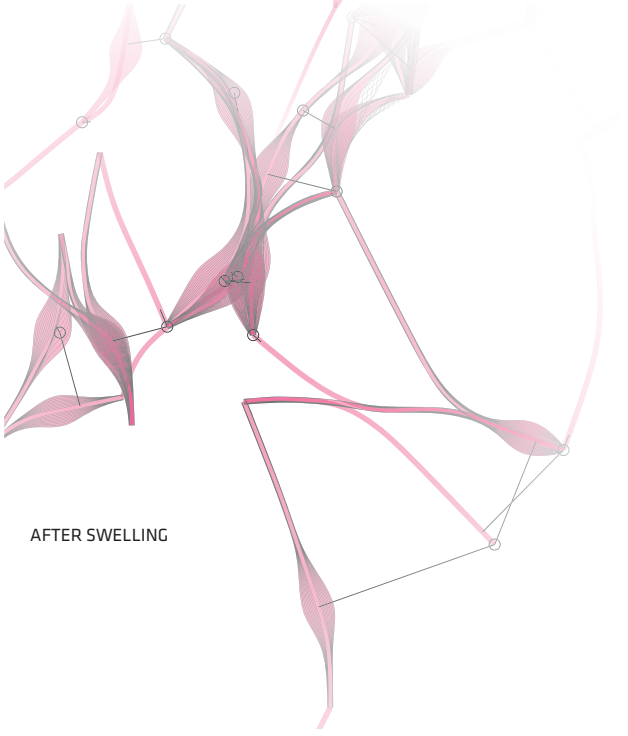


and continuously re-inscribe their associated position Vector. Upon export each array of Beziers and end lines representing each Hair are written each to a separate line in a text file. In the parametric model, these lines are reassembled and finally joined into continuous curves to be used as rails, which can be lofted with the sectional geometry of the visitor pathway.

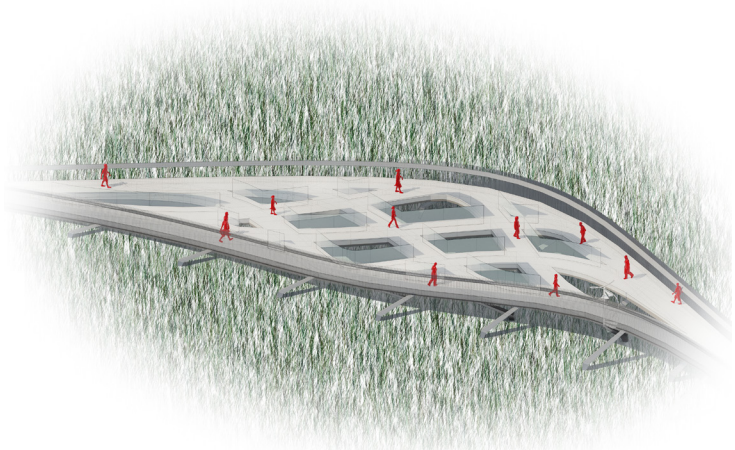
FIG 2.52
PATH OPTIMIZATION SIMULATION
EACH COLOUR REFERS TO A DIFFERENT TYPE OF CONNECTION AS THEY RELATE TO ONE OF THREE POSSIBLE CRITERIA: STRATA, CLIMATE, AND DIET,



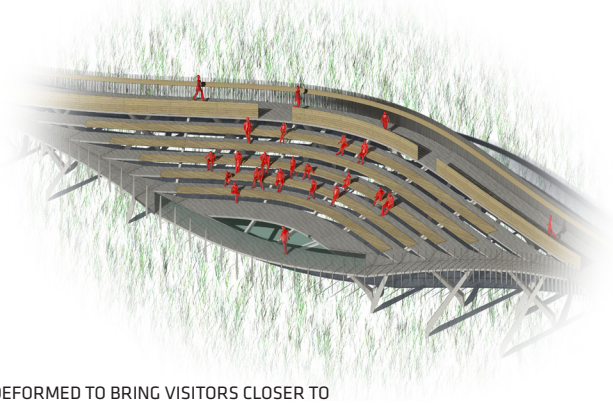
BEFORE SWELLING



AFTER SWELLING



PERFORATIONS ALLOW FOR EXCHANGE BETWEEN
ANIMALS, ZOO STAFF, AND VISITORS



SURFACE DEFORMED TO BRING VISITORS CLOSER TO
HABITAT SURFACE AND DEFINE GATHERING SPACE

GRADATION IN THE DENSITY OF METAL GRATING
ALLOW LANDSCAPE THROUGH SURFACE

SWELLS

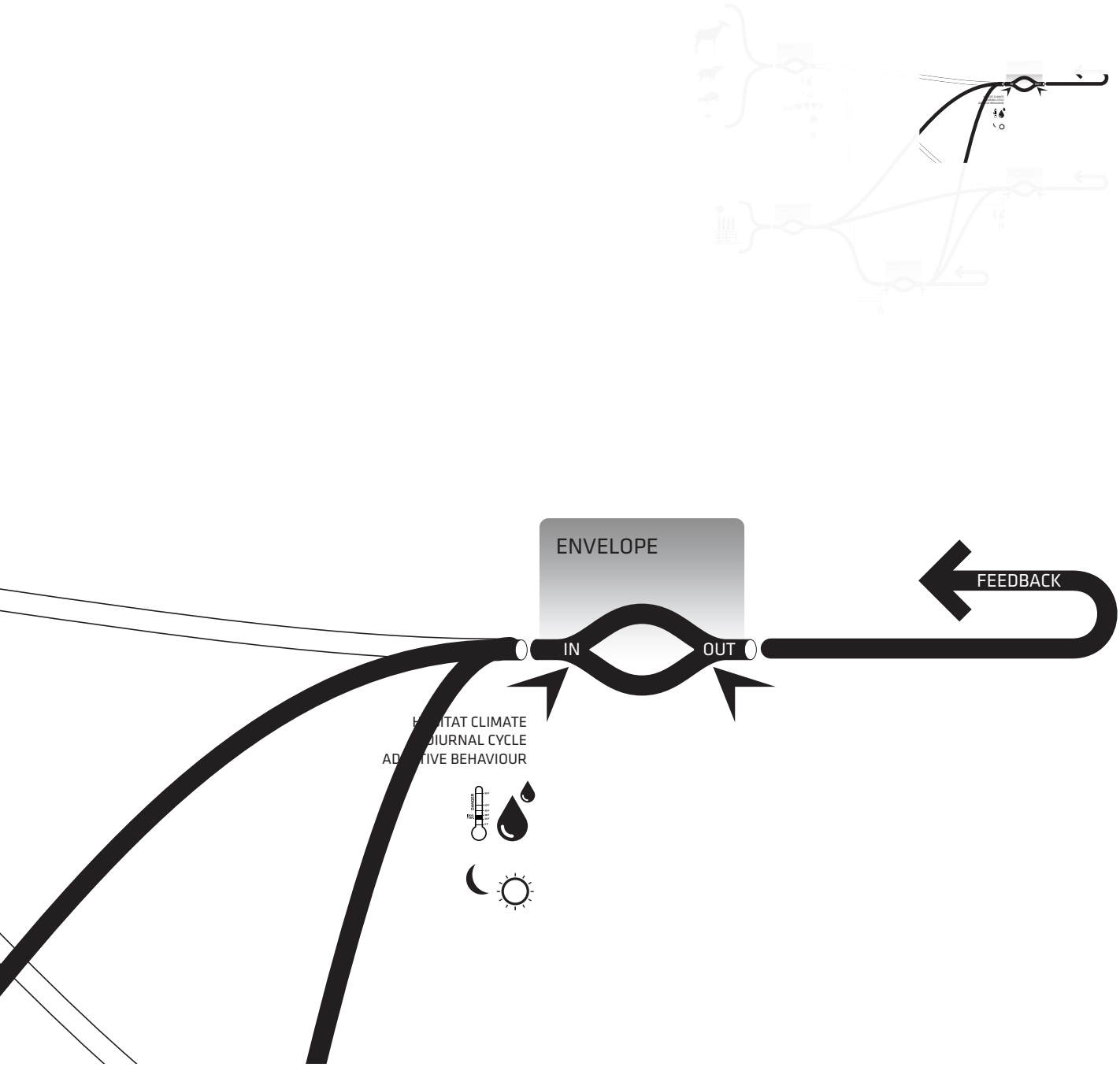
The counterparts parts to the Human program dedicated to motion and flow are restive moments for reflection, dining and recreation. These parts are imagined as swells or engorgements within the path system of linear elements. Key rest areas are given explicitly in the force directed layout simulation and they are incorporated into a voronoi partitioning process. The generative process to be dealt with here is the vantage points along the paths themselves. At these Animal viewing spots, the path widens to accommodate benches and viewing platforms as well as signage and other interpretive features.

The strategy for the deployment of these swells departs from the intuition that these points would be better suited to long lengths of pathways. Along with providing respite from lengthy walks between exhibit centres, they are better suited for viewing over longer ranges and are ill-suited to shorter lengths which are typically congested with other paths.

In the parametric model, paths below a given length are culled to produce a refined list to receive the swells. For this list, a corresponding one is generated finding the closest of the exhibit centres to it. From this exhibit the parameter along this curve locates the apex of the swell. A Gaussian curve function - a bell shaped curve easing in and out of its limits - describes the transition from normal path to swell. It is driven by three primary variables – position of top limit along the curve, the height or amount of swelling at this point, and the length along the curve over which this transition occurs. Positions of construction planes along the curve are fed to this function which generates values to be used for scaling. These scaling values operate non-uniformly on the section geometry of the path prior to sweeping. Once these sections are in place, each list of them along each path are swept to produce three dimensional geometry.

FIG 2.53 ←
SWELLING DIAGRAM
OVERALL PATH SYSTEM BEFORE & AFTER "SWELLING" ACTION; EXHIBITS TRIGGERING SWELLS ARE MARKED

FIG 2.54 →
AXONOMETRIC SWELLS
RENDERINGS ILLUSTRATING THREE TYPES OF VISITOR ACTIVITY AT SWELL CONDITIONS ALONG THE PATHS


ENVELOPE
FEEDBACK
IN
OUT
HABITAT CLIMATE
DIURNAL CYCLE
ADAPTIVE BEHAVIOUR

ENVELOPE

ENVIRONMENTAL MEDIATION

FIG 2.55
PROCESSUAL FLOWS
ENVELOPE

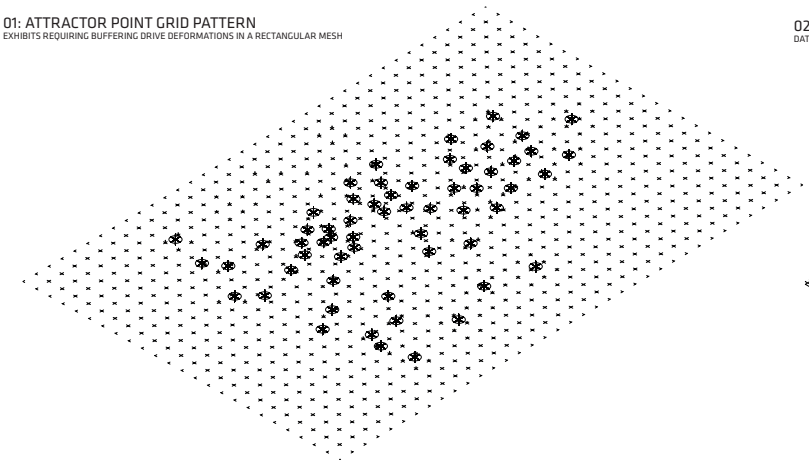
OVERVIEW

In so much as it imposes material limits on space, the envelope required to house the flora and fauna of habitats foreign to that of the site, always threatened to undo the project's aspirations to boundlessness and fluctuation. Two morphological strategies aim to counteract both the size and fixity of its body; on the one hand its depth is reconceived as a multi-layered membrane, paper thin at its edges and swelling to contain an interior environment and its attendant mechanical installations. On the other its planimetric edges are soft and irregular undoing the objectness that accompanies orientation with its sense of fronts and backs. The entirety is conceived as a moment of suspended animation, just as a cloud's body, composed of individual water molecules condenses momentarily to take on material embodiment.

Its surface is broken down by means of a process of recursive subdivision, the monotony of its expanse being counteracted by the fluctuations in scale. The panels, once divided, register the field of information in their subsequent specialization and differentiation.

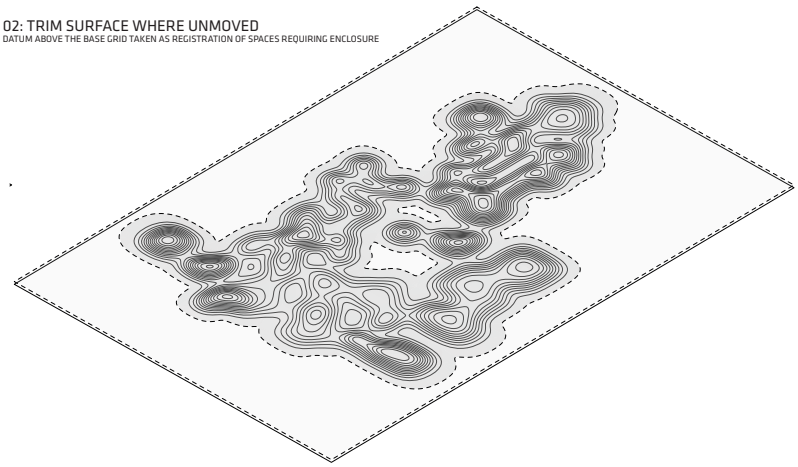
FIG 2.56
AXONOMETRIC OVERVIEW OF ENVELOPE

01: ATTRACTOR POINT GRID PATTERN
EXHIBITS REQUIRING BUFFERING DRIVE DEFORMATIONS IN A RECTANGULAR MESH



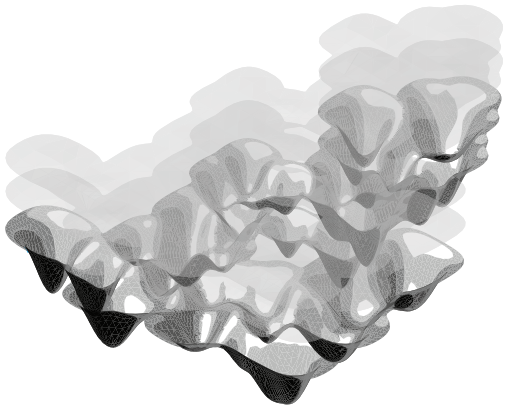
1

02: TRIM SURFACE WHERE UNMOVED
DATUM ABOVE THE BASE GRID TAKEN AS REGISTRATION OF SPACES REQUIRING ENCLOSURE



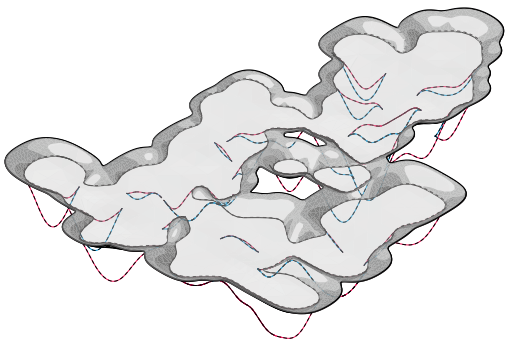
2

03: MIRROR, REPEAT AND SCALE ALONG Z
OPEN MESH TO ENCLOSE BUFFER ZONE UNDER THE ROOF, AND VERTICAL LOAD TRANSFER AND ENVELOPE



3

04: TRIM TO EXHIBIT GRADE
TOP OF BEARING WALL ALONG LINE OF INTERSECTION



4

THE GLOBAL SURFACE

The envelope embodies its material conditioning by registration of its milieu and the animals it encloses.

The geometry of the climatically separated portion of the zoo is generated by an attractor pattern assembled in a parametric model. The list of animals in the source animal database provides this design component with a list of Boolean values indicating which exhibits require enclosure as well as Doubles indicating humidity and temperature requirements. The scheme generates a soft undulating form conceived of as a 2 ply membrane swelling in areas requiring larger buffers from the local environment. Tapering in towards its outer edges, approaching its minima, the two layers dissolve into one another, leaving the ground open to the sky above.

The attractor pattern, implemented through a custom visualbasic.Net (vb.Net) script, in principle operates by assigning values to each in a regular field of points according to their proximity to sample points. The sample points in this case come from a list of the exhibit centres culled to exclude those exhibits which do not require the envelope. In this particular implementation, the strength of each attractor's influence on the field is conditioned by the humidity and temperature values. The greater sectional depth allows for a buffer of air separation as well as room for mechanical duct-work. The added depth simultaneously provides for a secondary means of servicing exhibits from above which coincides with the hot and humid climatic portions supporting higher proportions of tree dwelling species.

The mechanism is constructed to register the field which is more than a simple one to one correlation of the underlying data. As every grid point is processed, a gate condition ensures that the distance to each attractor point is under a given value. The values will accumulate intensity from all attractors within this range so that areas of the zoo with neighbouring species requiring the envelope will be driven higher than areas containing sole attractors. A Gaussian function produces the values to ensure smooth transitions both in and out of the zones of intensity. The intent is to describe a soft flowing form, a barely perceptible thickness at its edges, swelling inconspicuously towards its centre; reducing the visual weight and thus presence of the roof.

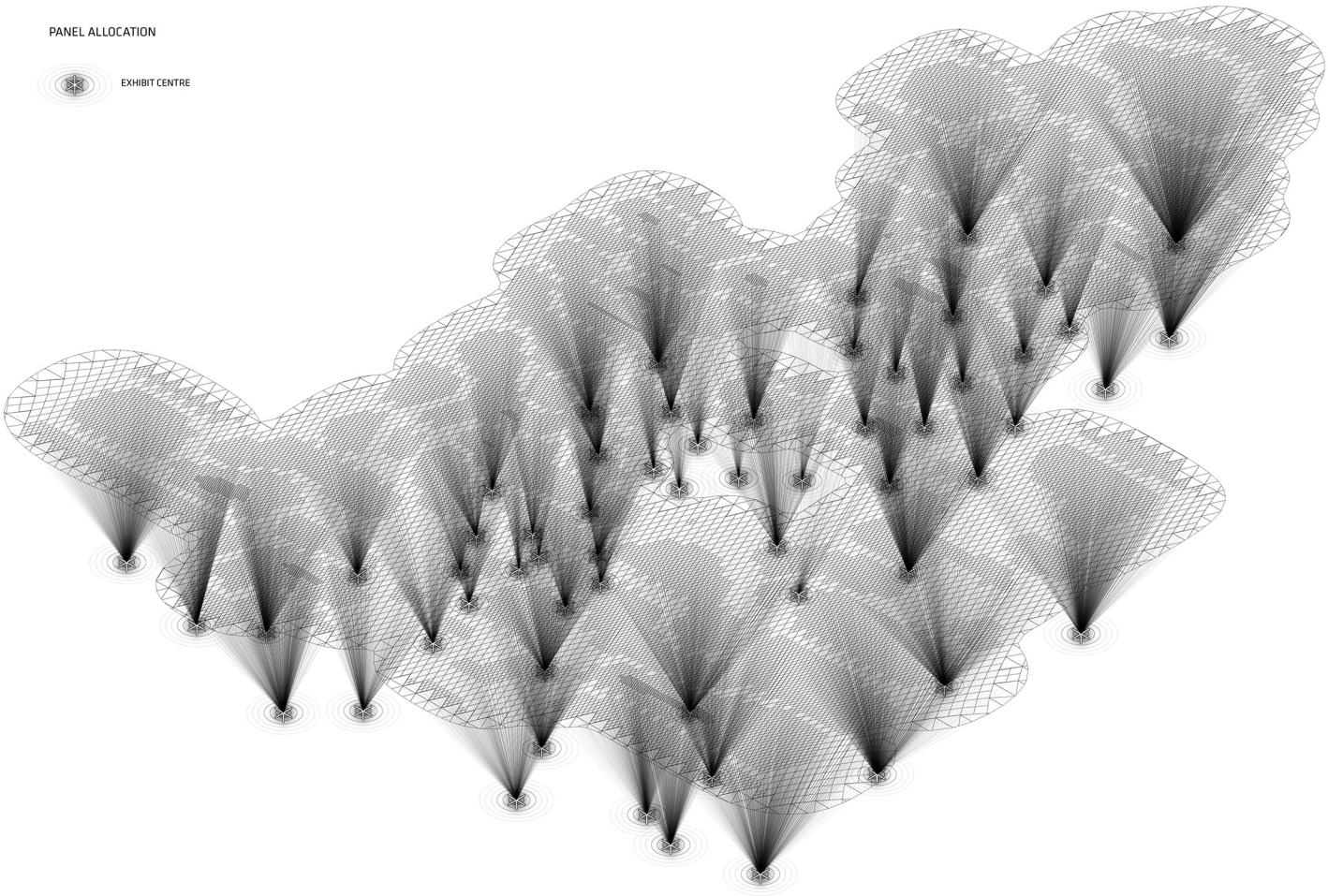
FIG 2.57
ILLUSTRATION DESCRIBING THE PROCESS BEHIND THE GENERATION OF THE SURFACES

Lines are drawn starting from the grid of points in the z-direction, their length given by the values processed thus far. By connecting the end points of these lines, a topographical surface is generated. In order to amplify the idea of an eroded edge, a figure receding into a ground, a section plane cut parallel with the horizontal plane above the bottom of the surface intersects with the surface to produce a curve. The curve bounds only those areas requiring enclosure; trimming the surface with the curve leaves those that do not open to the sky.

Subsequent steps involve using the same basic sectional depths but scaled as required. First, this surface is mirrored about the horizontal plane to complete the other half of the swell. A second mirroring scaled non-uniformly along the z-axis, intersects the ground plane and thus provide for the transfer of roof loads to the ground. Interior arches mirroring the minima, but unsheathed break up larger interior spans.

PANEL ALLOCATION

EXHIBIT CENTRE



SKIN COMPONENTS

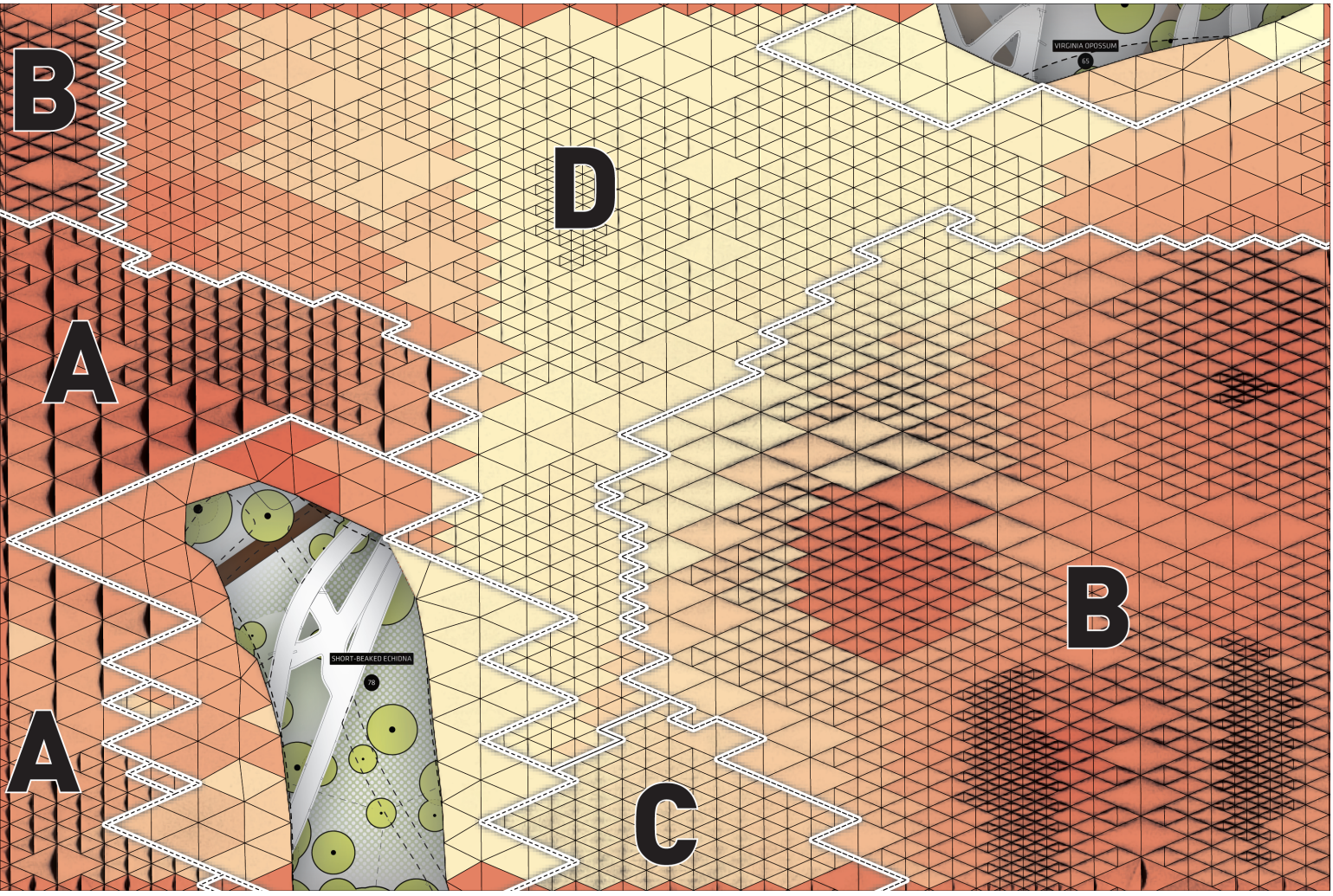
The panelization of the surface begins with a process of recursive subdivision. An initial population of surfaces generated by a regular diagrid are tested against the underlying one. The difference between the two drive successive loops through a subdivision routine, each producing smaller panels more closely approximating the base surface. The movement between scales is a registration of surface curvature, itself a registration of difference between species.

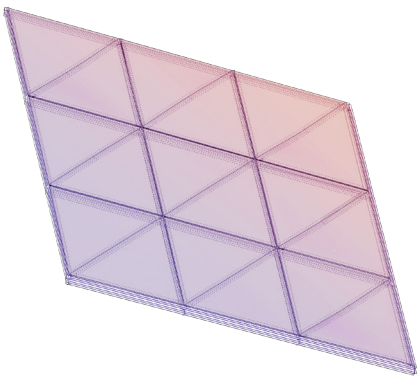
Once the scale of panels are in place, each one is identified and differentiated. Unlike much experimentation with parametric modelling involving the population of scaffolds with components, the intent of this portion of the design was to shift not only in degree but in kind as well. Material behaviour shifts from the conventional spectrum of continuous gradation towards one with subsets that can trigger altogether different behaviours. The process begins by breaking the base surface down into isoparametric subsets of it surface using UV domain intervals. From these surfaces, the midpoints of its edges are sorted and shifted to produce a diagonal grid (or diagrid) of points. Through these points new diamond shaped surfaces are created.

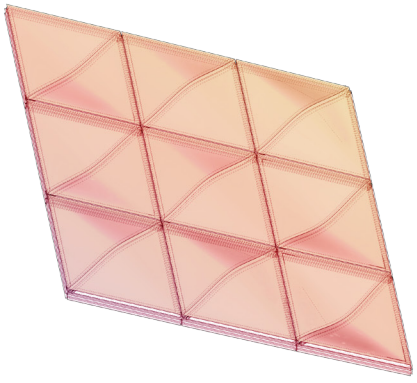
These new panels are fed along with their centroids, the exhibits centroids, and other exhibit attributes to a custom vb.Net component. This script goes through each of the panels and finds the index of the closest of the list of exhibits and using this same integer places its associated attributes into new variables. These variables are checked against a series of conditional gates to assess whether the exhibit the panel encloses belongs to a nocturnal animal, one capable of flying of climbing, or one that requires high humidity and heat levels. Each original panel is subsequently funneled through to a different output channel.

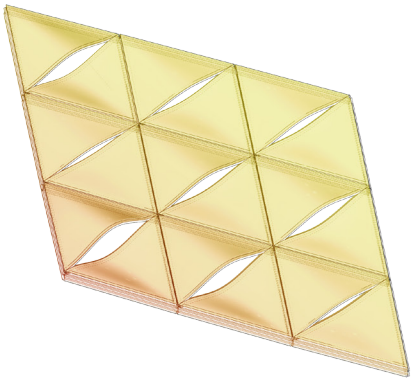
Each panel is composed of two triangular fiberglass panels. They range in opacity depending on the light levels required by the habitat they enclose. Likewise, depending on the need for controlling humidity and heat levels, the two portions swell in opposing directions. Operating like gills, in this swollen and opposite configuration, they channel the movement of air in and out through ventilation grills. In scenarios that require sealing the habitat off from the site's local climate, the two

FIG 2.58
OVERVIEW SHOWING DISTRIBUTION AND ALLOCATION OF PANELS


B
A
D
A
B
C
VIRGINIA OPOSSUM
65
SHORT-BEAKED ECHIDNA
78







halves meet at a colinear edge and become conjoined. These attributes, which combine to produce a diverse and varied population of panels, are applied in varying intensities, driven by proximity to loci within the field.

FIG 2.59
DETAIL OF FRAGMENT AND INDIVIDUAL PANELS

CHAPTER 3

EMERGENT PHENOMENA
THE PROCESSUAL ARTEFACTS

THE DRAWING SET

PROCESSUAL RESIDUE

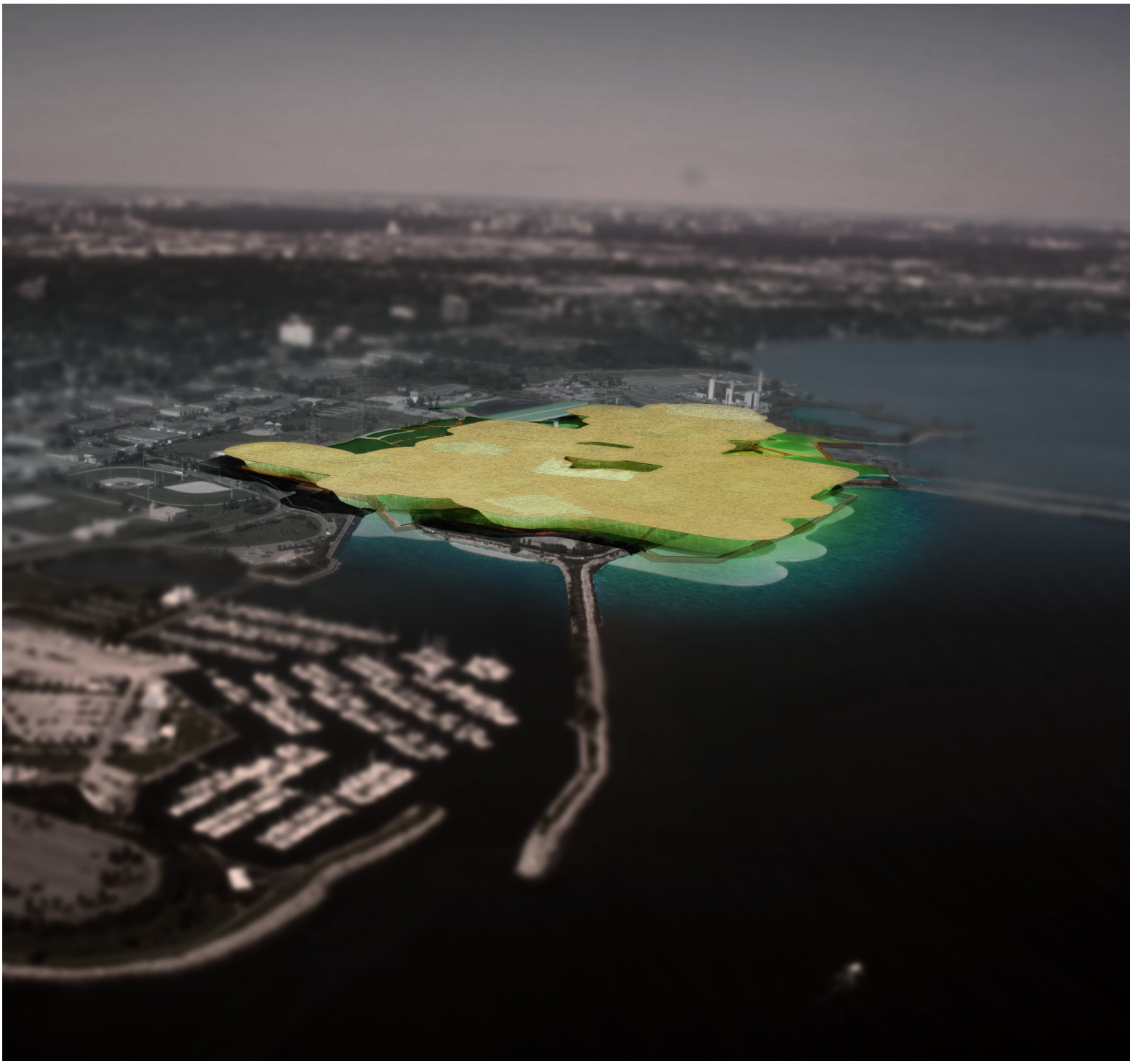
The thesis should be read principally as a chronicle of experience in multiple dimensions. It is decipherable as an emergent end that must make do with - and perhaps even thrive on - its unsettled imprecision. It is an endeavour that is ambiguous - both by design and accident - about its identity. It is neither pure methodology, nor resolute architectural project.

The concluding drawings are to be seen as the consequences of the methodology enquired into through the speculative design. They should be read as an idealization of process, whose barometer of success is measured primarily in the relations amongst parts and the spaces between things.

Any disorientation encountered in trying to decode the drawings is fully intended - just as with emergent systems they demand an active gaze where shifts in perception are a fundamental component in the construction of intelligible “bodies”. They capture the image of an environment in a state of becoming - one without privileged vantage points, lacking fronts, backs, or centres.

FIG 3.60
SITE PLAN

FIG 3.61
AERIAL PERSPECTIVE



ANIMAL PROGRAM

1. NAKED MOLE RAT
2. MBARAPI
3. WARTHOG
4. SERVAL
5. CARACAL
6. MEERKAT
7. WHITE-NOSED COATI
8. SOUTHERN 3-BANDED ARMADILLO
9. KOALA
10. SOUTHERN HAIRYNOSED WOMBAT
11. WHITE-HEADED VULTURE
12. TAMMAR WALLABY
13. RED-BILLED OXPECKER
14. PRZEWALSKI'S HORSE
15. GROUND PANGOLIN
16. MANDRILL
17. KOMODO DRAGON
18. OUSTALET'S CHAMELEON
19. EMU
20. GALAPAGOS TORTOISE
21. NORTH ISLAND BROWN KIWI
22. CANADA LYNX
23. SIBERIAN TIGER
24. MEDITERRANEAN HORSESHOE BAT
25. TASMANIAN DEVIL
26. GIANT ANTEATER
27. LION-TAILED MACAQUE
28. NORTH AMERICAN PORCUPINE
29. OKAPI
30. PYGMY HIPPOPOTAMUS
31. BINTURONG
32. CLOUDED LEOPARD
33. KINKAJOU
34. SUN BEAR
35. OCELOT
36. SUGAR GLIDER
37. BIRDS OF PARADISE
38. BRAZILLIAN TAPIR
39. SOUTHERN TWO-TOED SLOTH
40. BONOBO (PYGMY CHIMP)
41. GOLDEN LION TAMARIN
42. MANGABEY
43. SIAMANG
44. BORNEAN ORANGUTAN
45. WHITE-TUFTED-EAR MARMOSET
46. MONGOOSE LEMUR
47. BRAZILIAN AGOUTI
48. ARCTIC FOX
49. GRAY WOLF
50. POLAR BEAR
51. NORWAY LEMMING
52. LITTLE PENGUIN
53. GOLIATH FROG
54. SACRED IBIS
55. CUVIER'S DWARF CAIMAN
56. JOHNSTON'S CROCODILE
57. GREEN PEAFOWL
58. ANDEAN FLAMINGO
59. CAPYBARA
60. SEA OTTER
61. BUSH BABY
62. ZEBRA DUIKER
63. GRAY-HEADED FLYING FOX
64. FENNEC FOX
65. VIRGINIA OPOSSUM
66. SOUTHERN TAMANDUA
67. SUMATRAN RHINOCEROS
68. AARDVARK
69. MOUSE DEER
70. EASTERN BARRED BANDICOOT
71. LONG-EARED JERBOA
72. NORTHERN VISCACHA
73. ROSY-FACED LOVEBIRD
74. CALIFORNIA LEGLESS LIZARD
75. DEMOISELLE CRANE
76. BURROWING OWL
77. SPOT-BILLED PELICAN
78. SHORT-BEAKED ECHIDNA
79. CARACAL
80. MOUNTAIN GORILLA
81. MOUNTAIN ZEBRA
82. DWARF CASSOWARY
83. RED PANDA
84. SCIMITAR HORNED ORYX
85. MOUNTAIN LION
86. ANDEAN CONDOR
87. JAPANESE GIANT SALAMANDER
88. MOUNTAIN GAZELLE
89. ROCK HYRAX
90. AOUDAD

VISITOR PROGRAM

91. REFRESH CENTRE 01
92. REFRESH CENTRE 02
93. PICNIC SPOT 01
94. PICNIC SPOT 02
95. ORIENTATION & DISTRIBUTION CENTRE

FACILITIES PROGRAM

96. ADMINISTRATIVE OFFICES
97. SERVICE AND MAINTENANCE
98. ANIMAL HEALTH CARE
99. FOOD STORAGE & DISTRIBUTION
100. QUARANTINE AREA
101. WASTE MANAGEMENT
102. SHIPPING & RECEIVING

SITE PROGRAM

103. NEWPARKING
104. PROPOSED LRT STOP
105. PLAYINGS FIELDS
106. MEETING POINTS

FIG 3.62
ROOF PLAN

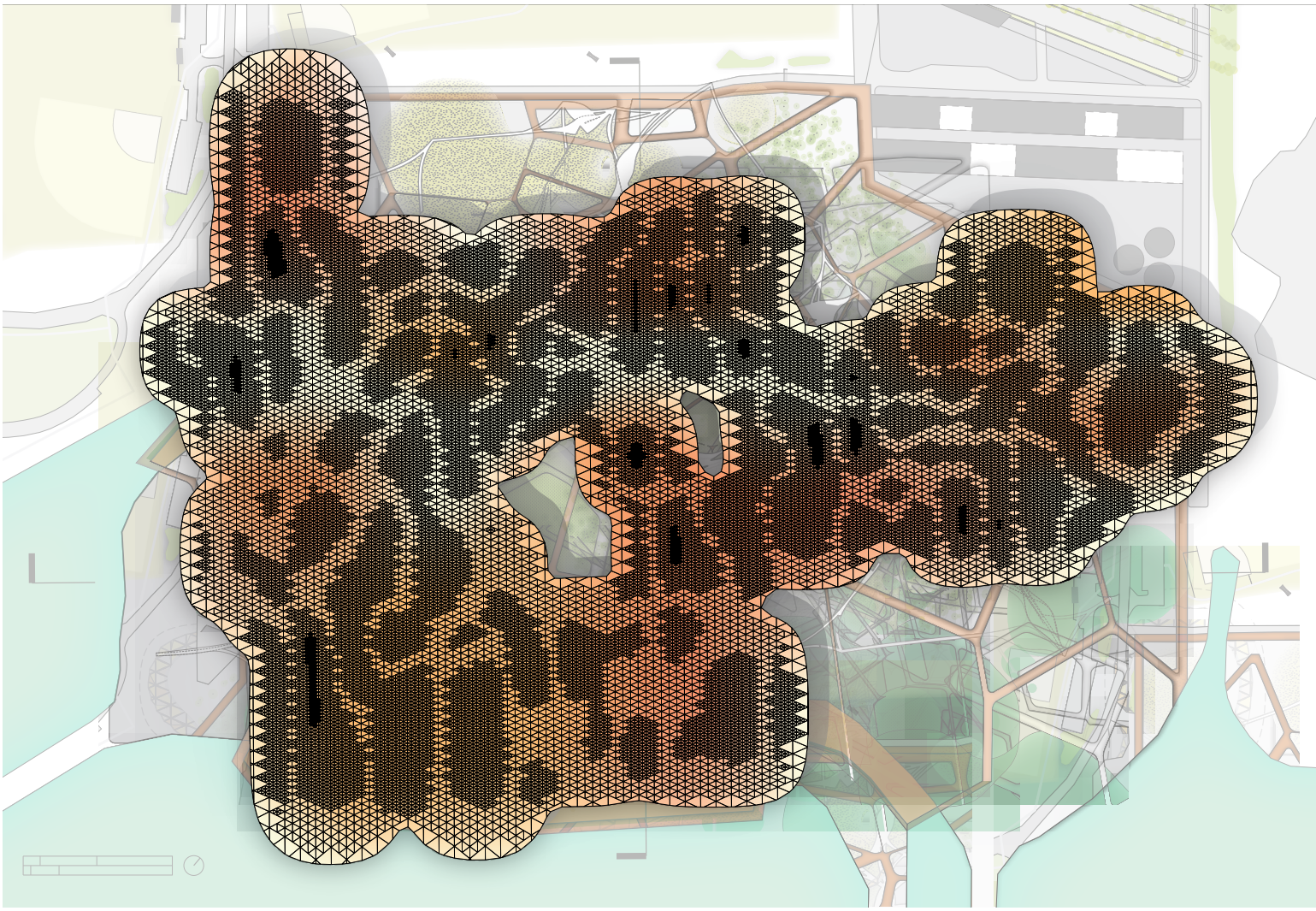
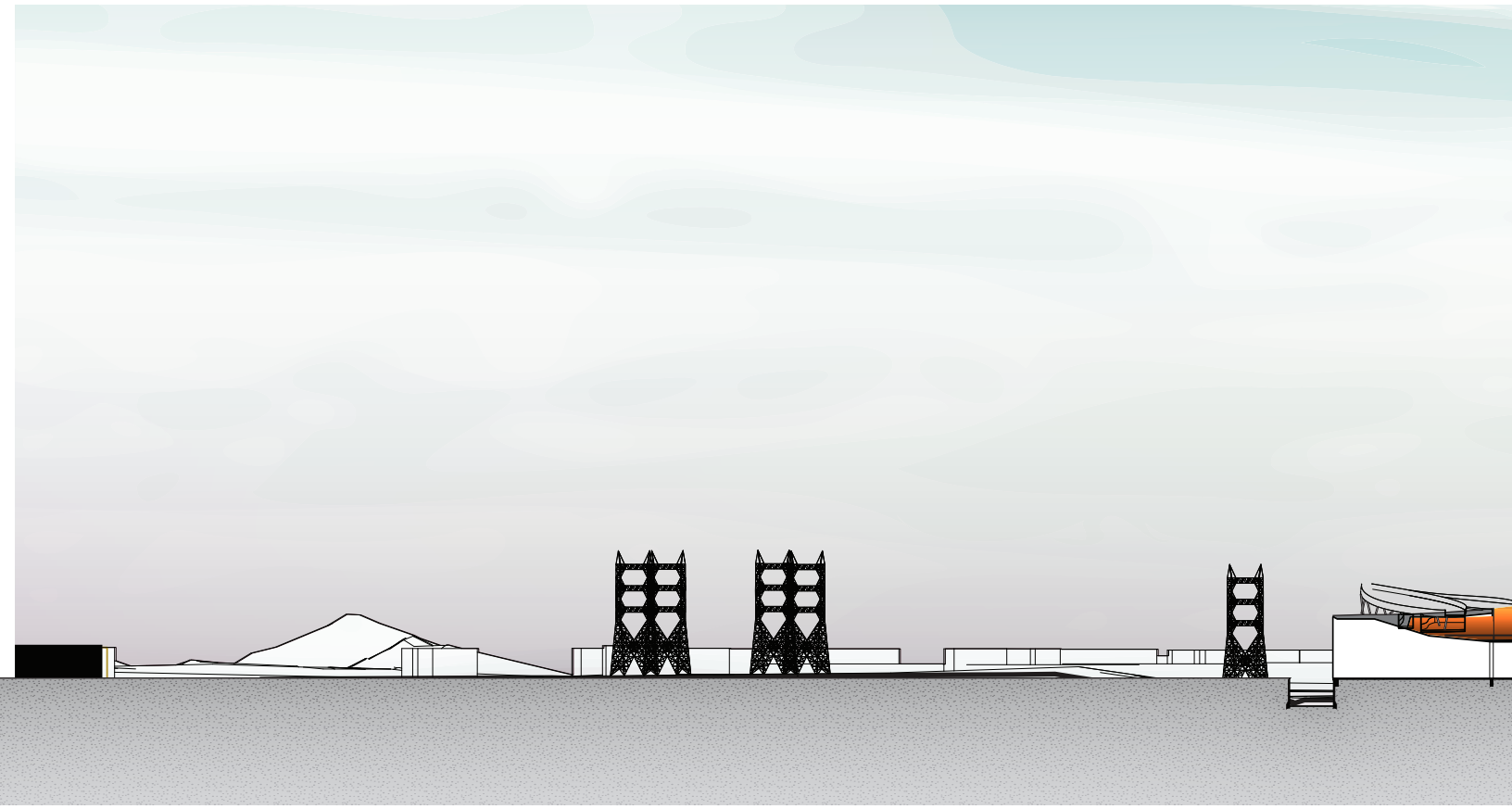
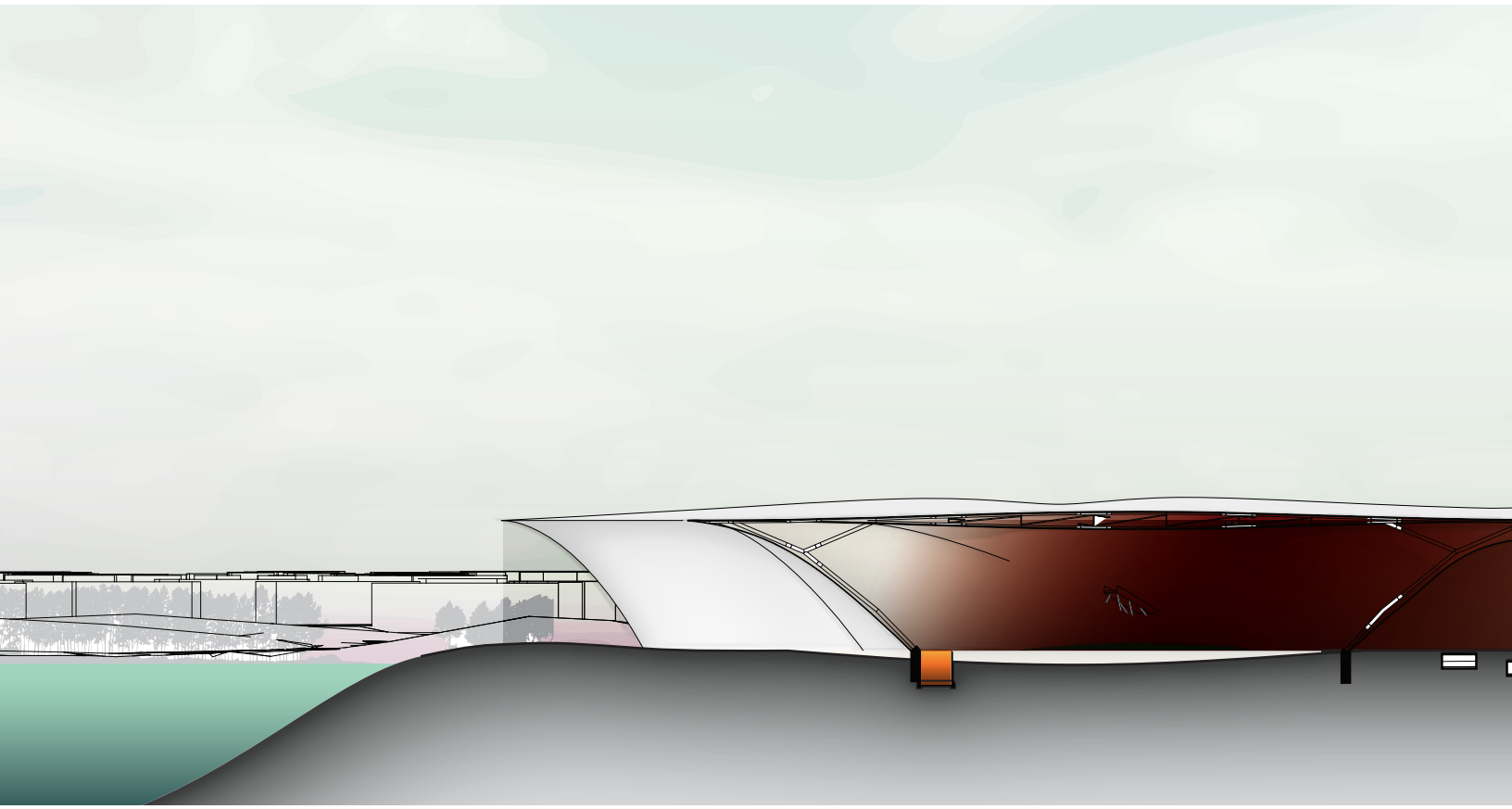
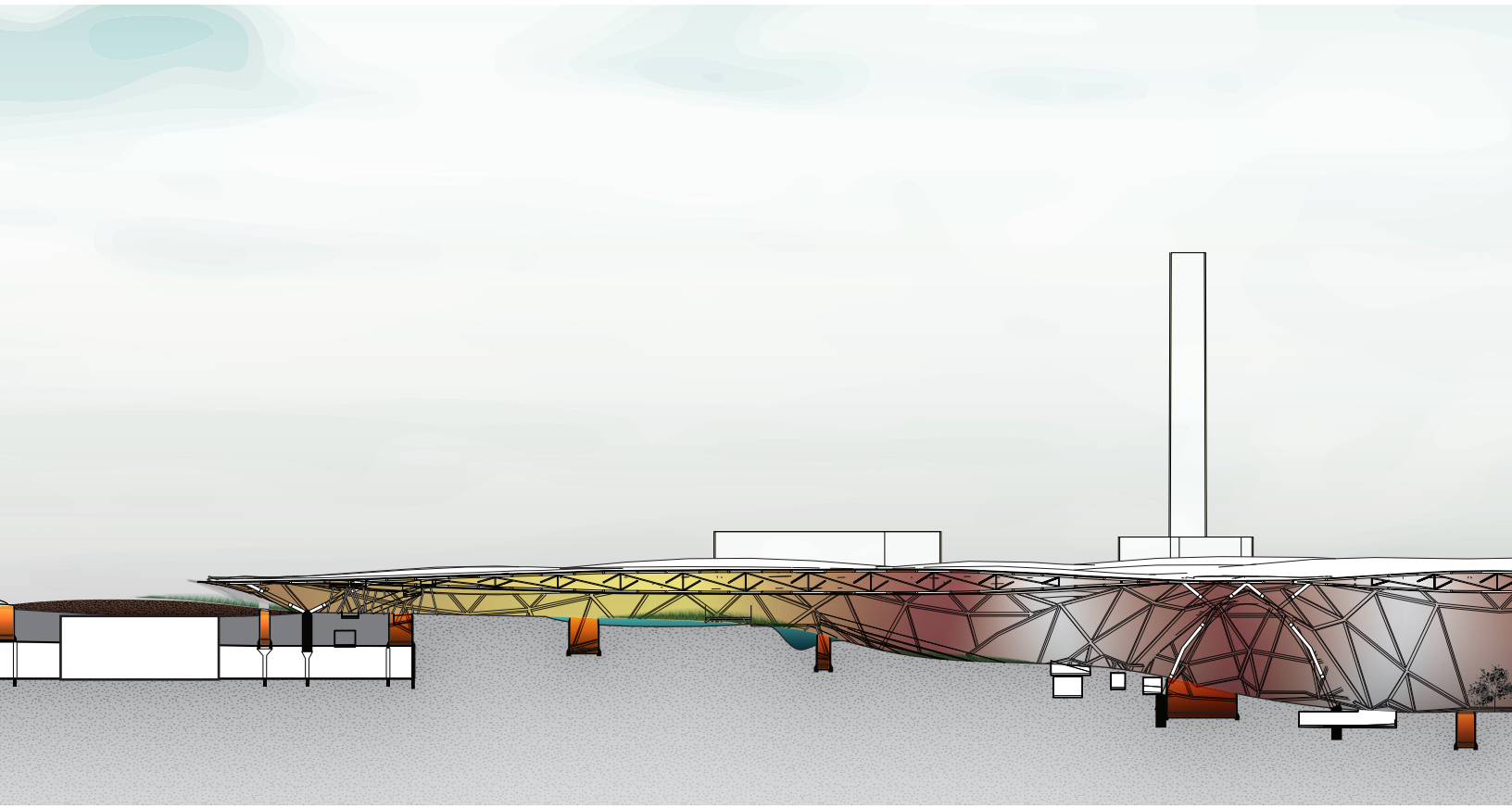


FIG 3.63
PLAN - ABOVE EXHIBIT LEVEL

FIG 3.64
PLAN LEVEL - BELOW EXHIBIT LEVEL







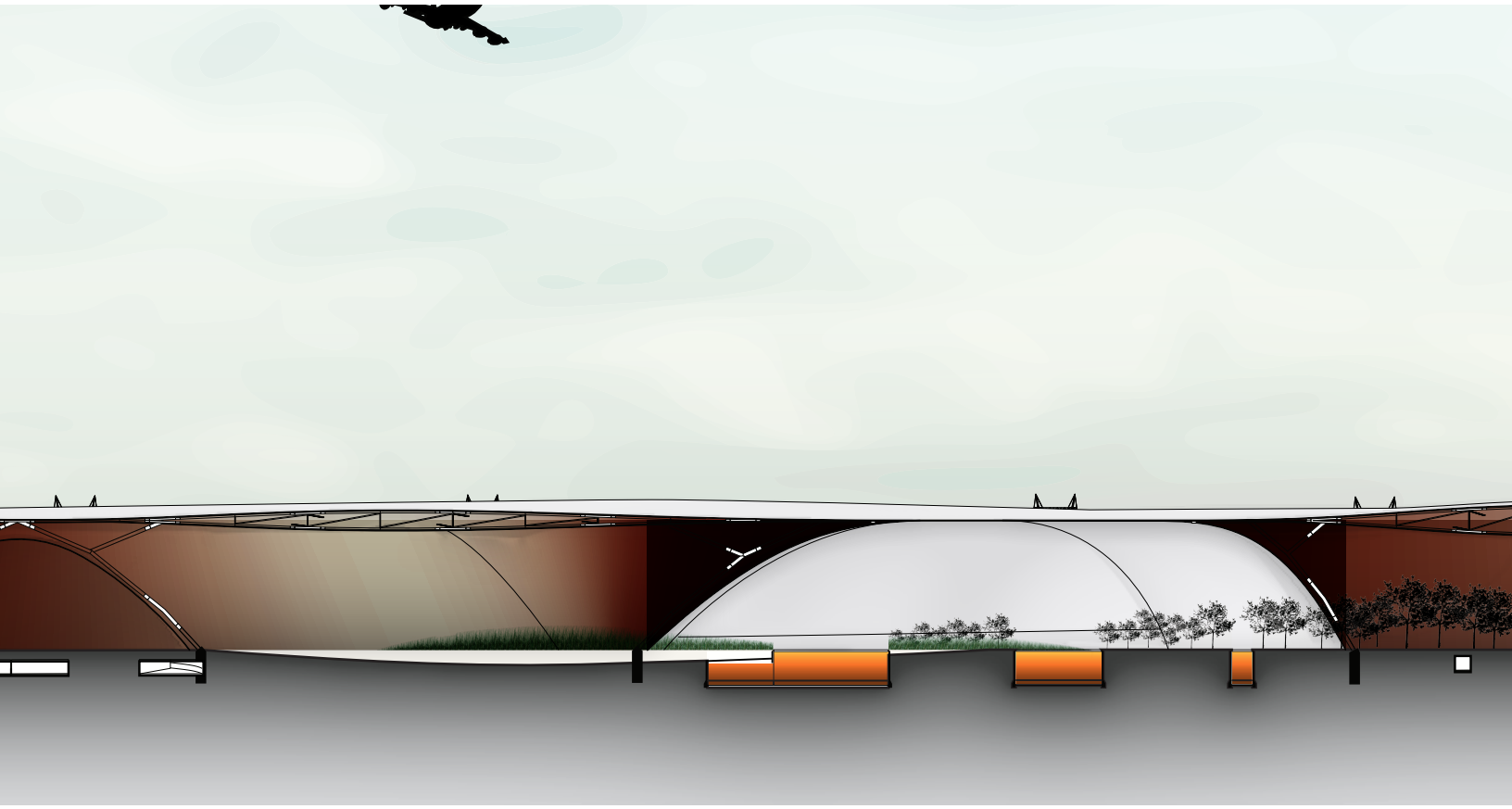
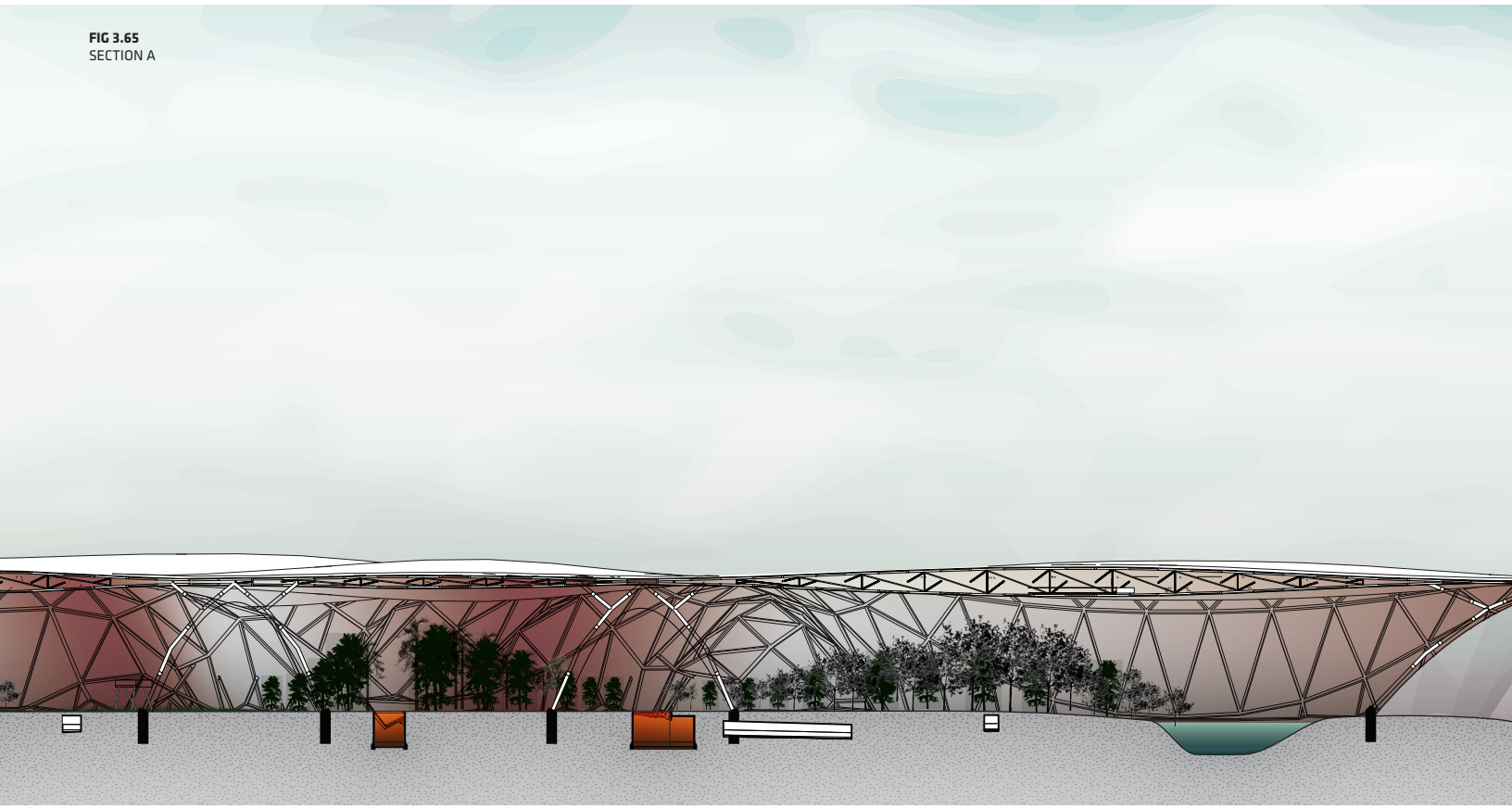


FIG 3.65
SECTION A



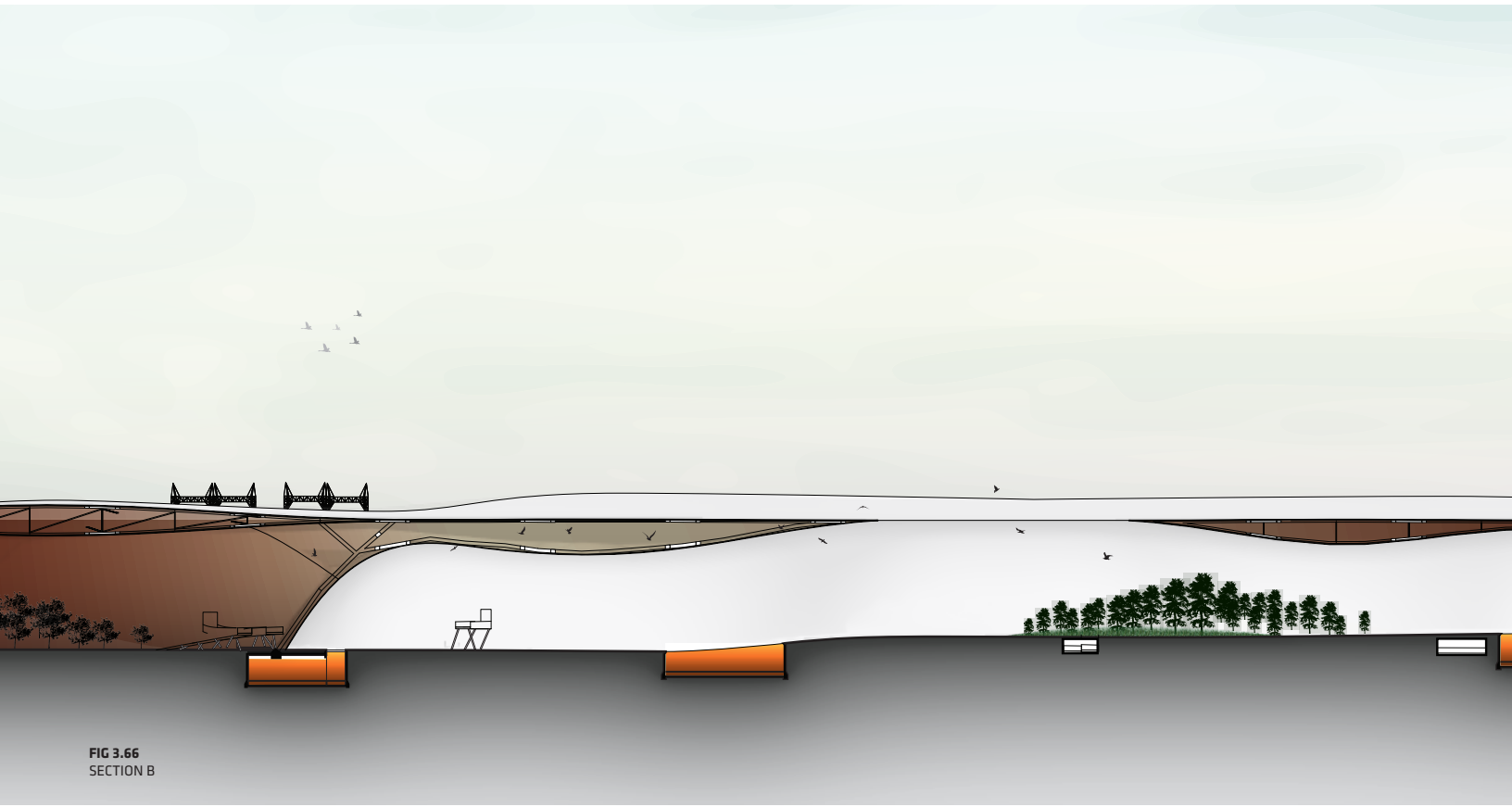


FIG 3.66
SECTION B

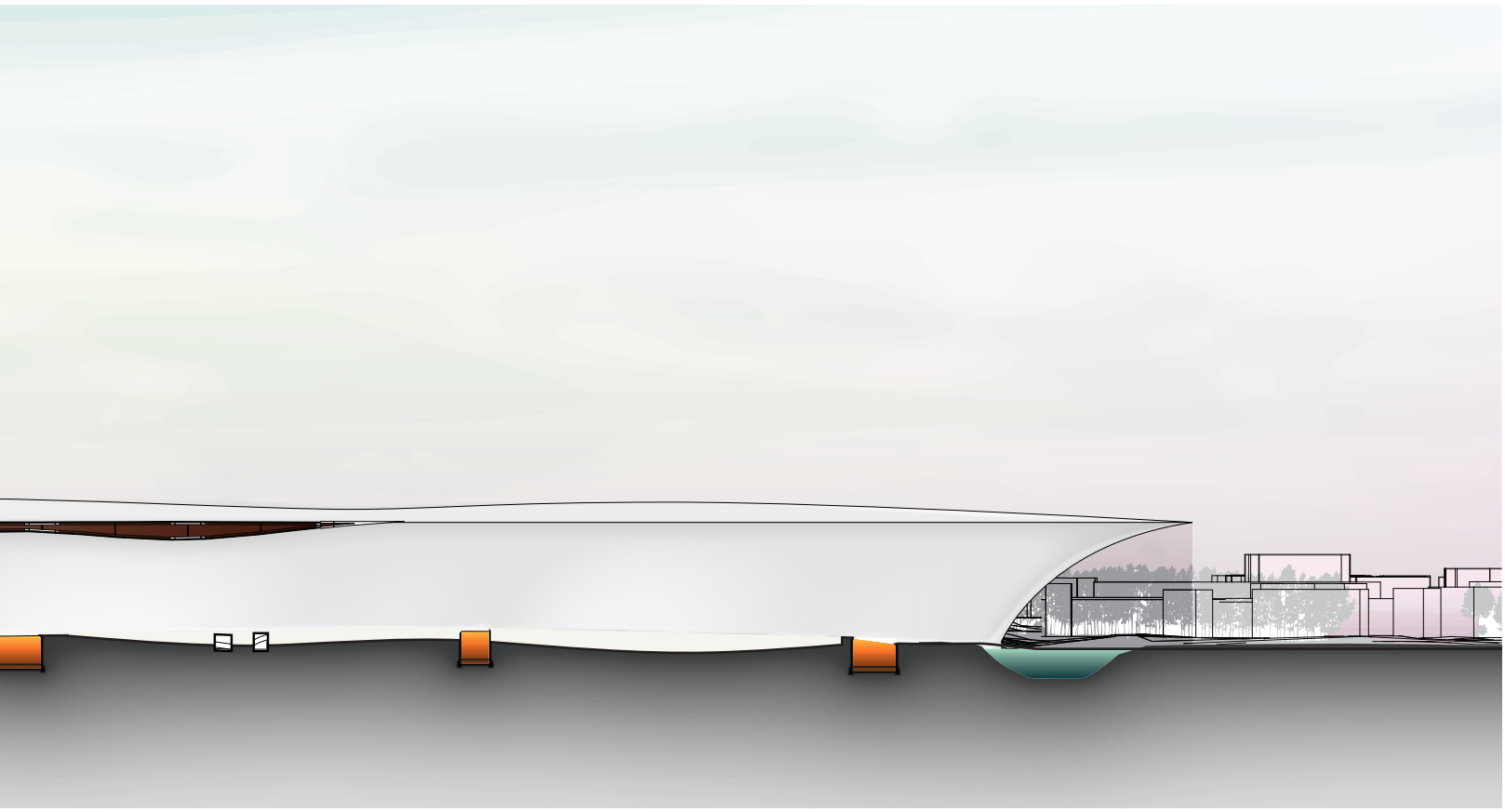


FIG 3.67
SECTIONAL PERSPECTIVE OF FRAGMENT

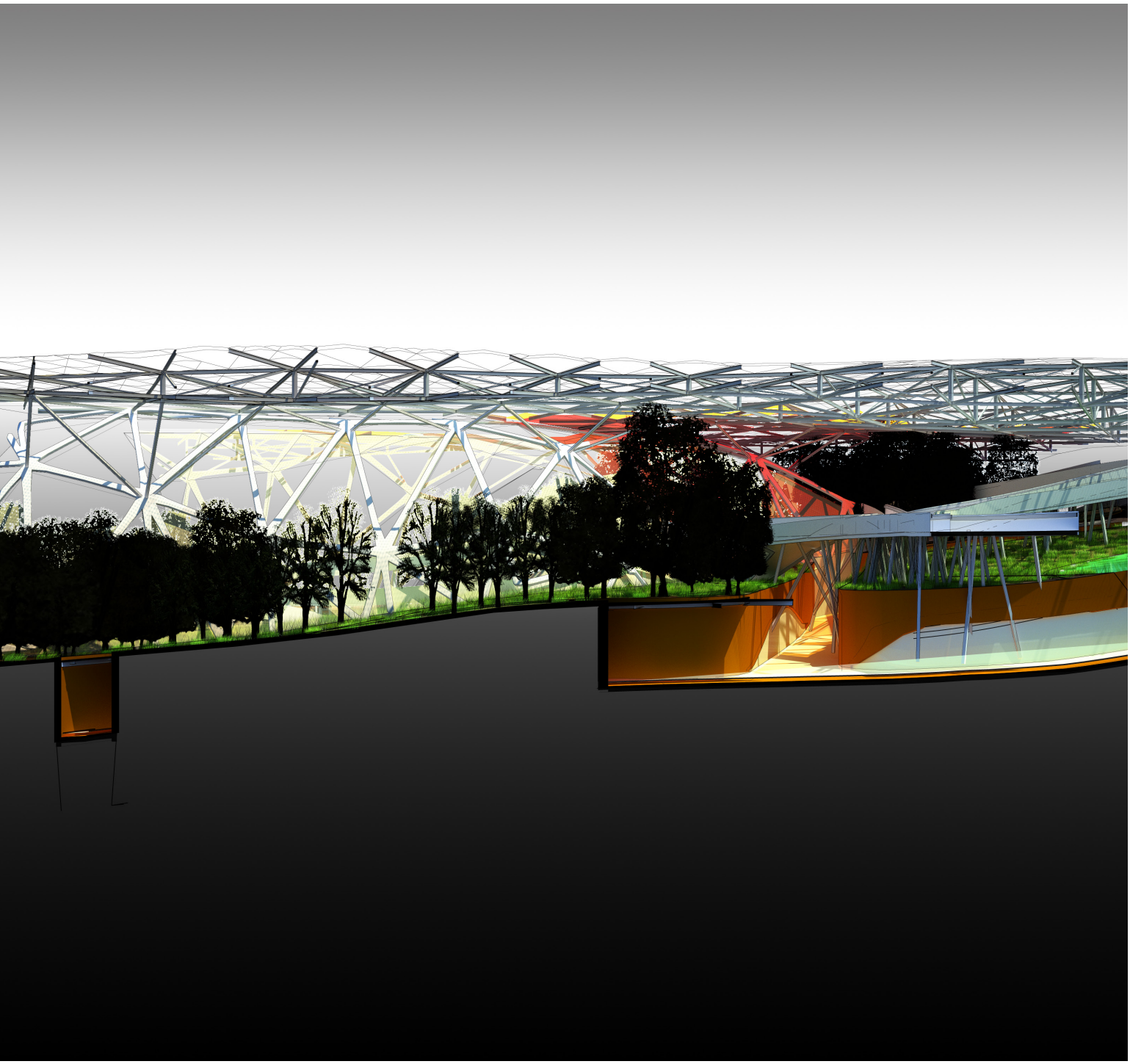
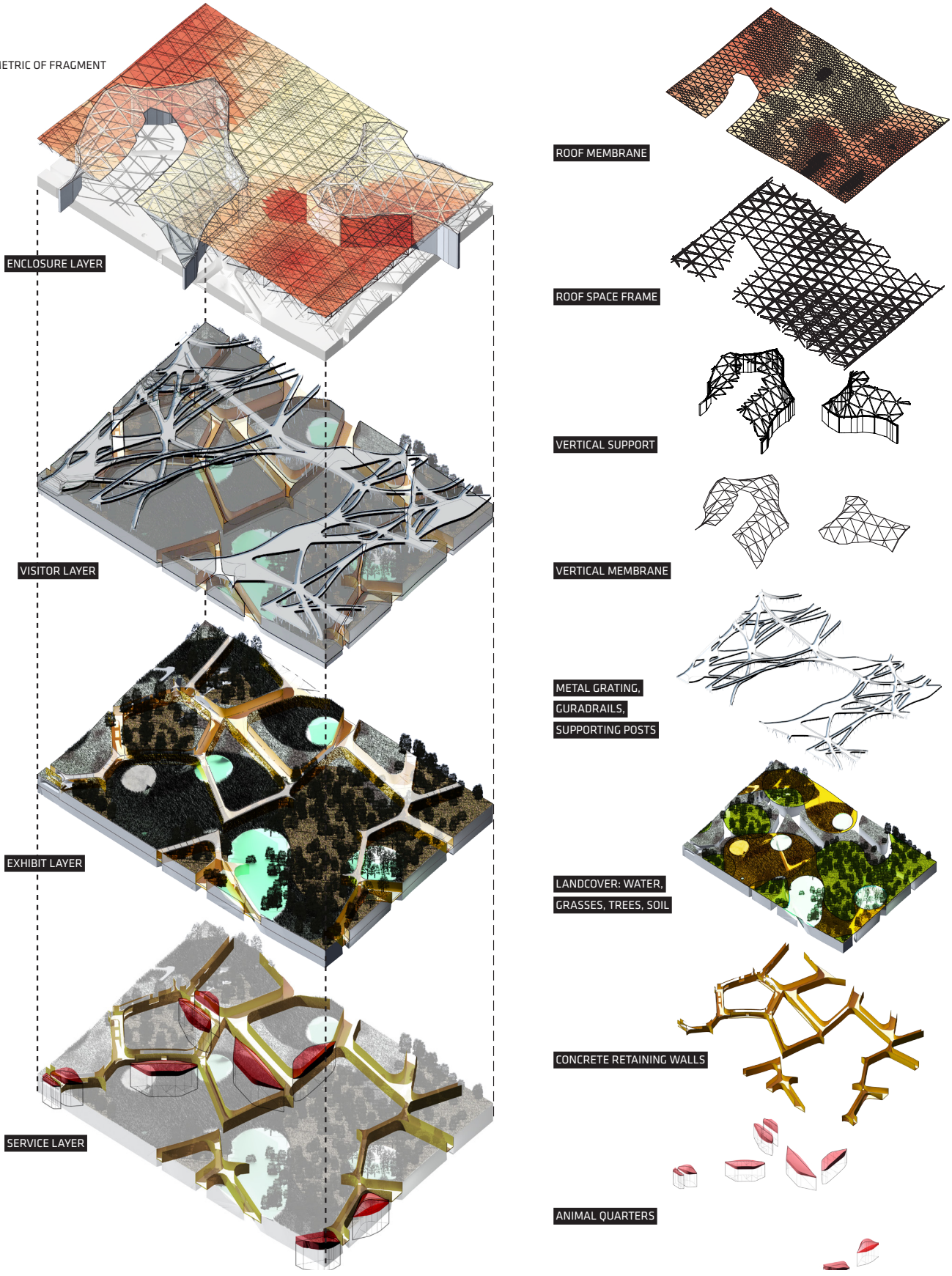


FIG 3.68
EXPLODED AXONOMETRIC OF FRAGMENT



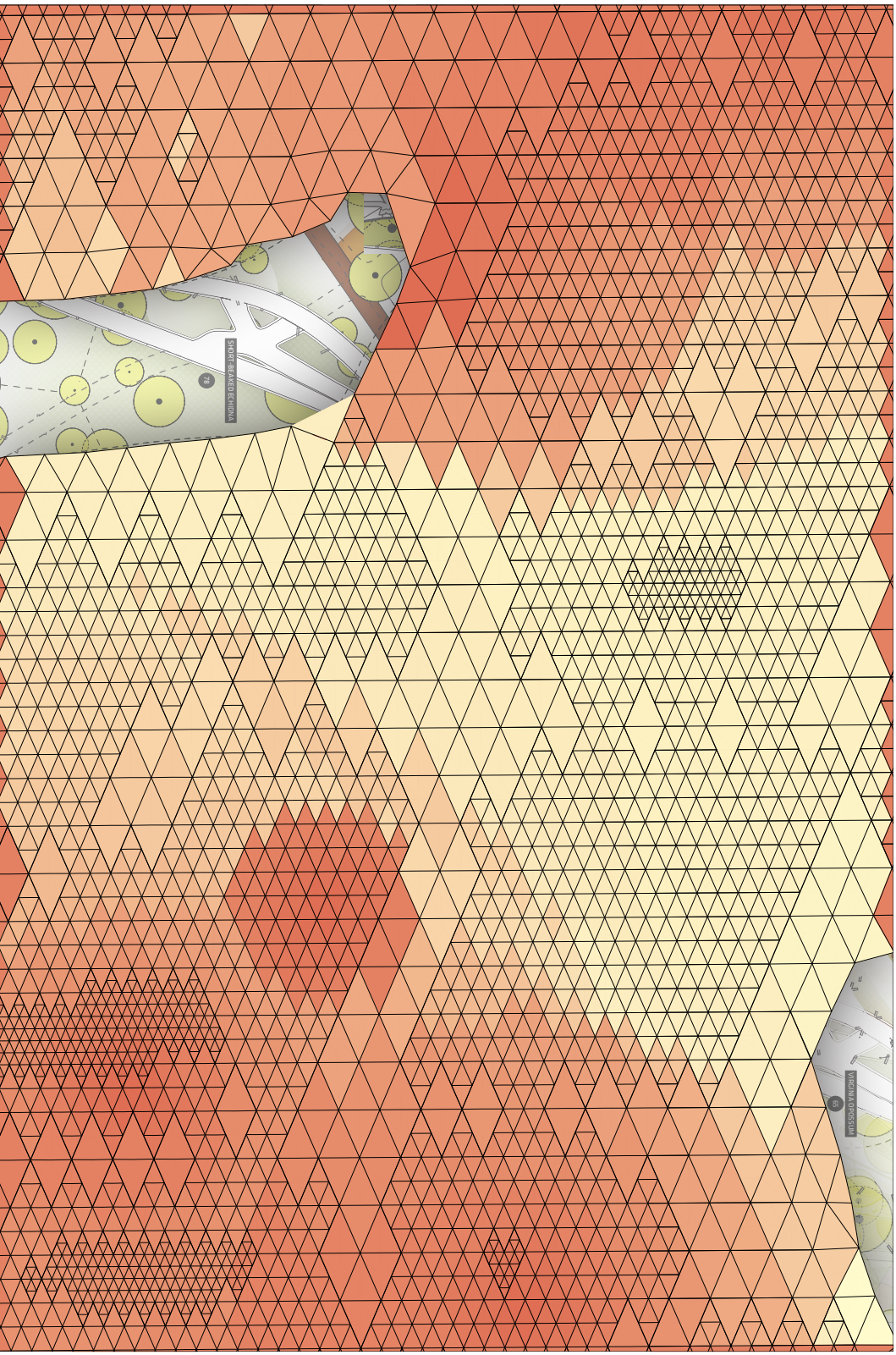
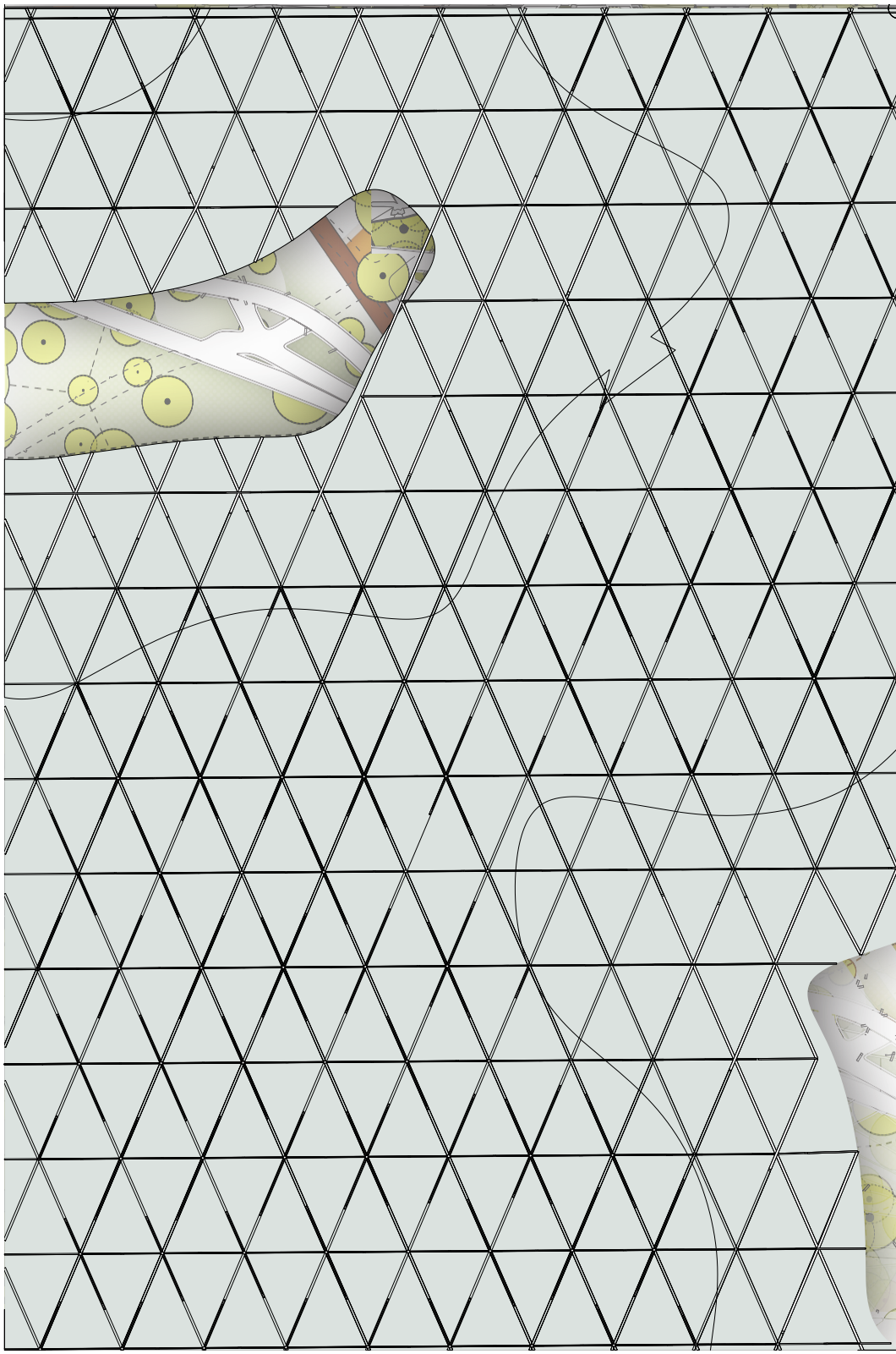


FIG 3.69
PLAN FRAGMENT - OF ROOF

FIG 3.70
PLAN FRAGMENT - THROUGH ROOF



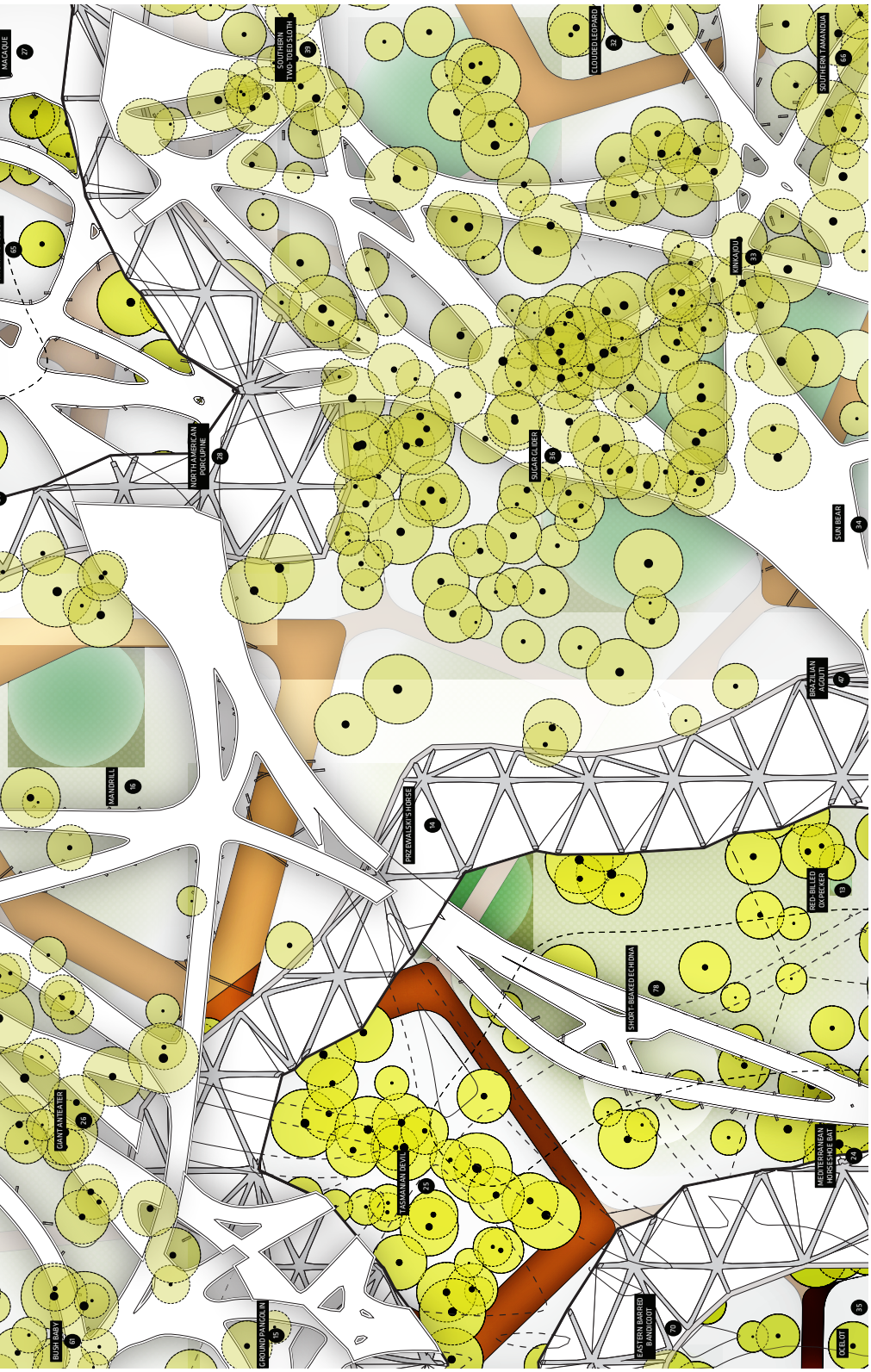


FIG 3.71
PLAN FRAGMENT - ABOVE EXHIBIT LEVEL

FIG 3.72
PLAN FRAGMENT - BELOW EXHIBIT LEVEL

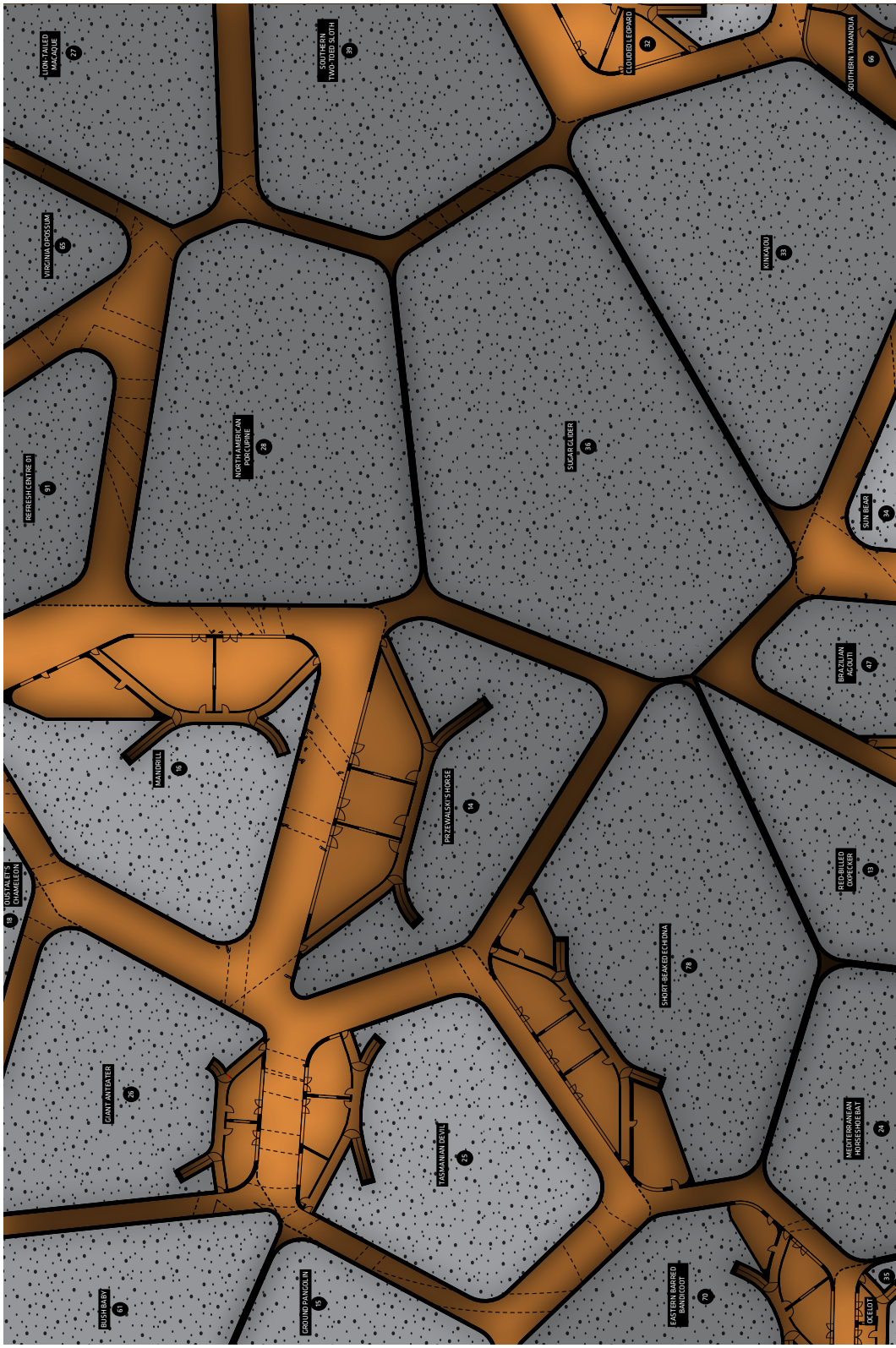


FIG 3.73
VIGNETTE - VIEW FROM WITHIN SERVICE CHANNEL

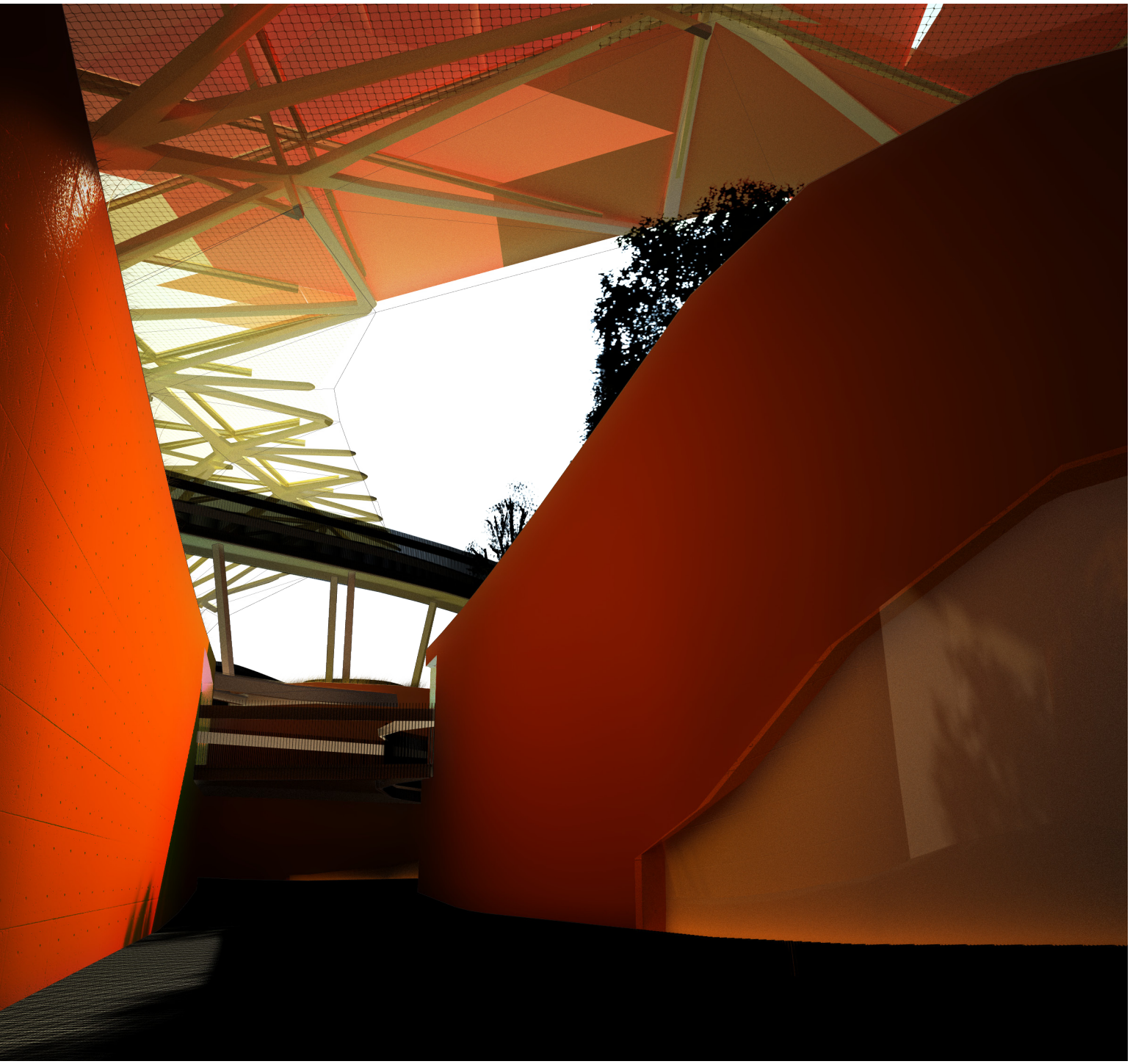


FIG 3.74
VIGNETTE - VIEW FROM GIANT ANT-EATER EXHIBIT

FIG 3.75
VIGNETTE - VIEW FROM MEDITERRANEAN HORSE-SHOE BAT EXHIBIT

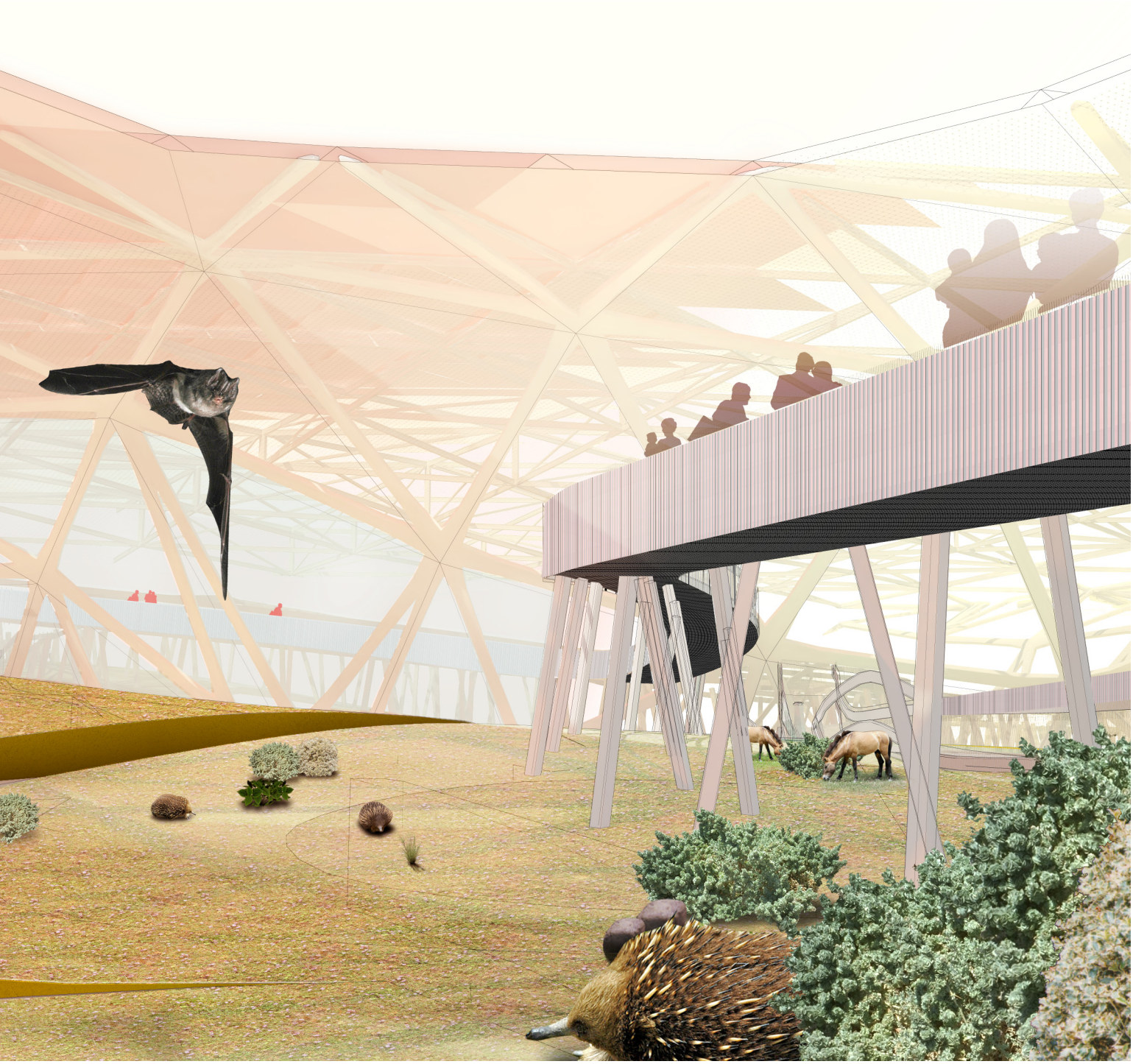
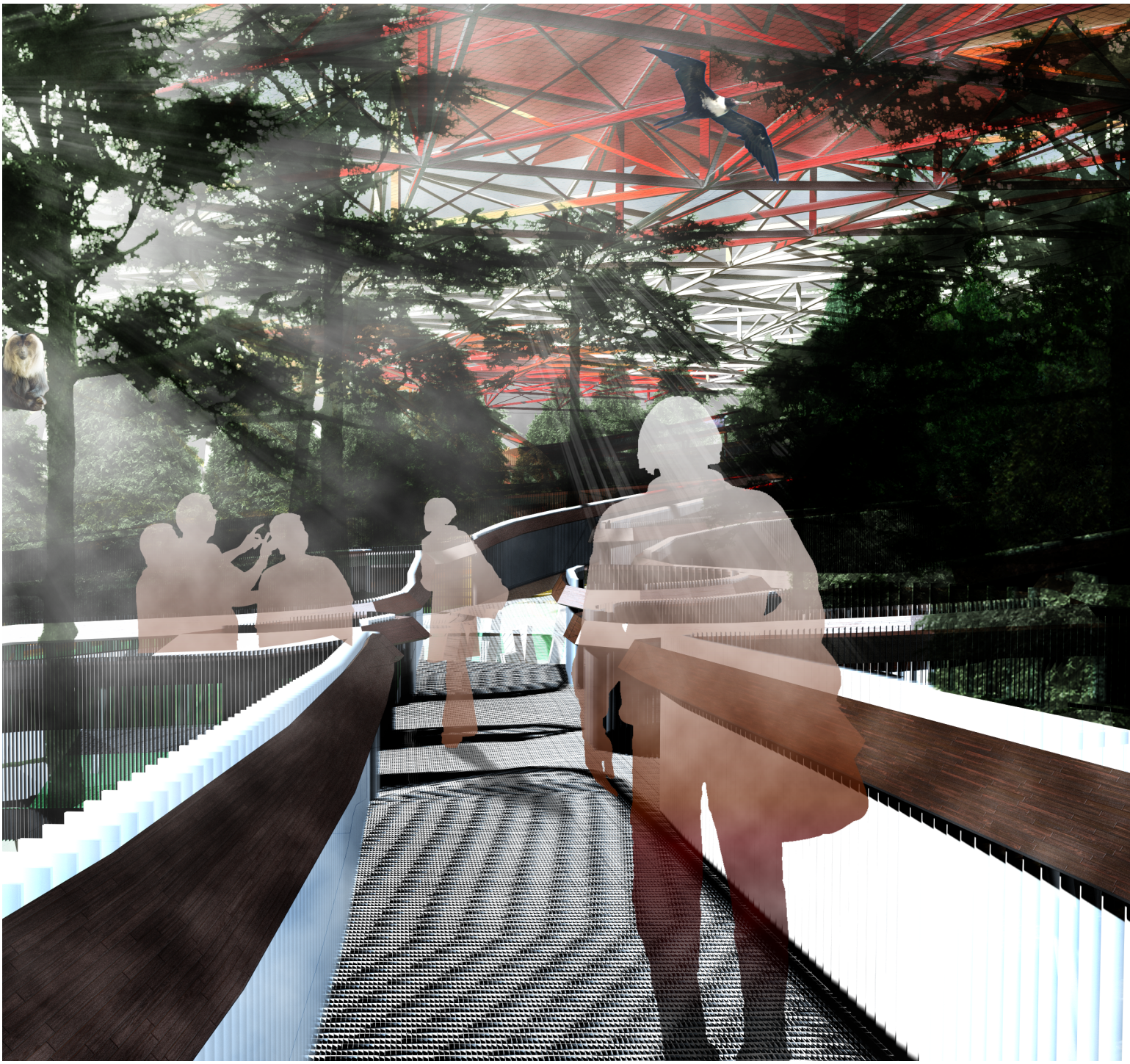
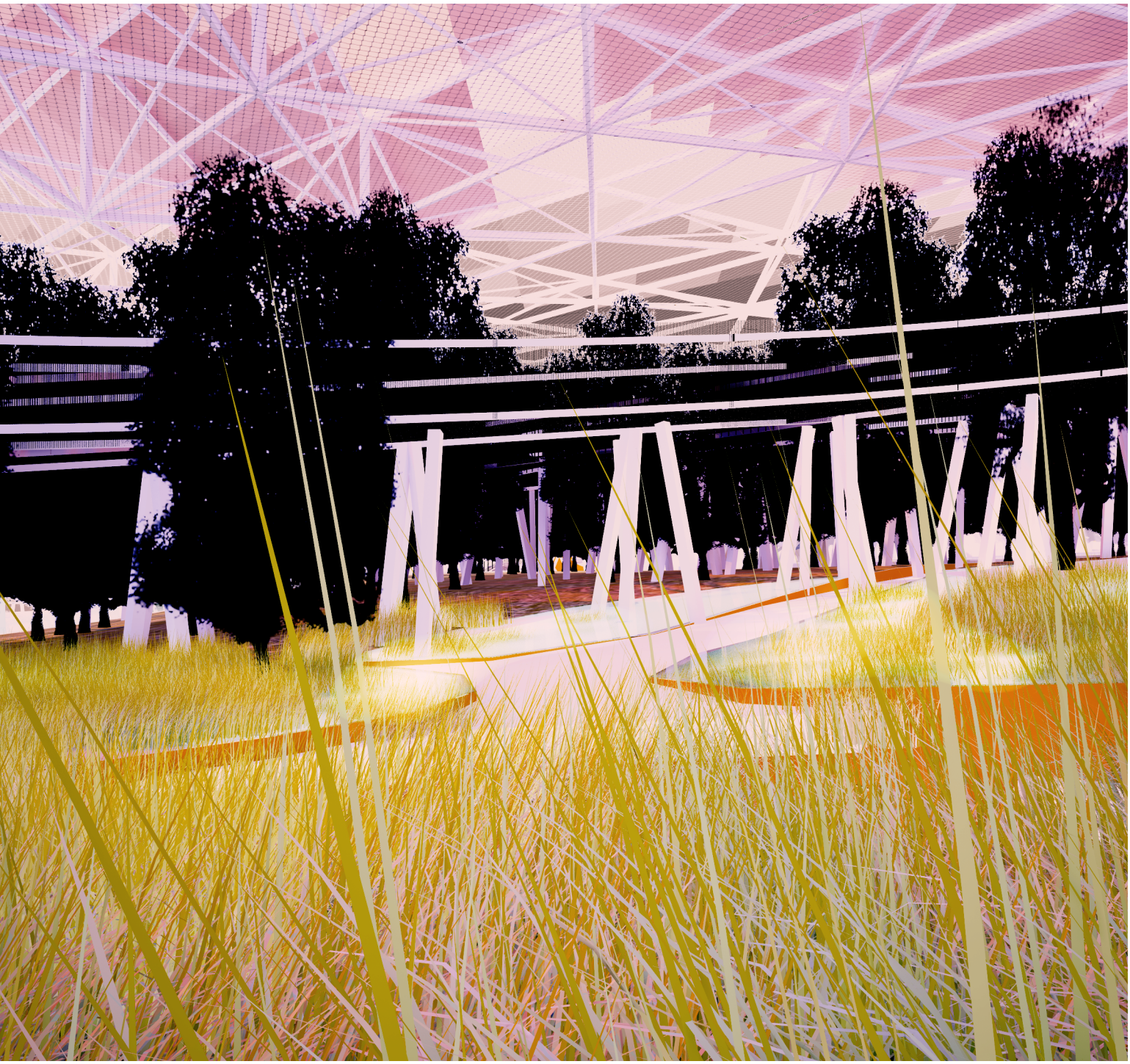


FIG 3.76
VIGNETTE - VIEW ALONG VISITOR PATH IN TREE CANOPY





CONCLUDING REMARKS

FEEDING FORWARD

The thesis begins with questions entrenched in architecture's intertwinement with life. It asks how architecture might respond to the world as a continuous product of non-linear dynamic systems that transcend all of our societal resolve to create a distinct and coherent human milieu. It seeks to know how the practice of architecture can more precisely engage in the flows that generate our material reality. Is the built environment to remain isolated in its singular orientation - tailored around the perceptions of the Human? Or might it be considered as just one contribution amongst others, modelled after and inserted into the very flows in which it moves and is moved by?

The thesis departs from an interest in the processes that give rise to matter, seeing in the conceptual framework given by emergence a possible ground common to both natural and cultural phenomena. The investigation seizes on what it perceives to be dormant potential in the zoo program, one it considers to be bound by undue quantities of artifice. The methods of its spatial construction themselves have limited the very qualities that they have purported to make accessible. The discrete, separated enclosures and the linear circulation systems of the traditional zoo program are symptoms of a single problem- a reductive and over-simplified approach to complex ecologies; one that might be alleviated by a thorough re-orientation of design practice.

A parallel undertaking, embedded in the same investigation, speculates on a new turn in the computational paradigm. Previous generations of research have remained far above the fray, either sequestering their investigations in the purely theoretical, or contentedly settling on more formal explorations. The zoo, on the other hand, is a program of diverse inhabitation, and it allows degrees of flexibility but warrants engagement with issues of program, environment, and ecology.

The thesis is partly a negotiation of what is seen to be an institutionalized opposition between techne and poesis - between the methods, mediums, and rules which structure how we build, and the aspirations we have for the evocative powers of environment. It imagines a scenario wherein they are inseparable, by way of parallel processes where the two feed off one another. Particular to the design for a zoo, the

FIG 3.77
VIGNETTE - VIEW FROM CLOUDED SNOW LEOPARD EXHIBIT

thesis ponders the possibility that meaning, by way of form, might be produced by the registration of an adaptive environment responding to the program of a diverse range of inhabitation. The zoo is a materialization that operates simultaneously as a pedagogical instrument and a life support system.

SUMMARIZING RESEARCH

As an exposition of process - and with it - an undercurrent of methodology, the thesis research demands travel across a range of disciplines and territories - from zoology and biology to computer science and information technology - along the way acquiring foreign languages and customs. In order to understand its limits, the project takes theoretical principles - of unmediated developmental processes - to their logical conclusions; in an attempt to move beyond the broad sweep of rhetoric to locate with greater precision their breaking points - points in the process where the contingencies of reality might make such pursuits either unfeasible and/or untenable - through the intimacy of lived experience.

Partway between theory and practice, computation is regarded as a contemplative craft, however disembodied it may be. It allows one to “try things on”, if only just in a fleeting way, and thus enquire into consequence. As a cooperative element, it can speed or heighten the acquisition of experience, a critical part in the development of intuition.

CONSTRUCTING THE MACHINE

The actual act of constructing generative design machines is resolutely grounded in matter, energy and acts of synthesis that transfer material flows into new organizations. This assembly necessitates an intimacy with the seeds that will set the machine into motion (inputs) as well as its acceptable ranges of behaviour and desired (optimal) performance (or outputs). It must spell out the rules by which these seeds become transformed into full-fledged materializations. It is a logistical or engineering approach, which seeks out descriptions of the conditions which give rise to diversity, limiting the amount by which this diversity is explicitly given in the instructions. The algorithmic script operates like its theatrical double, asking of its actors to bring to their roles something that is not quite spelled out, but in between the lines. If the machine’s construction engaged intellectual faculties, it makes space for play, an activity fully engrossed in entirely different issues of tuning and

composition. This activity is about testing feedback response to stimuli. Its efficacy lies entirely in the intuition and feeling of its operator. As we work with these instruments - ones we have constructed - our bodies' reflexes are set in motion. The heart quickens, the blood rushes. Things feel right, or they don't, and they do so in various shades of intensity.

What should be obvious, is that technology, in and of itself, will not produce complexity. It needs thoughtful orchestration. The suggestion of formal complexity - particularly the vast versioning processes and specificity that is generated by scripting and other elaborate computational procedures - might be better described in its closer resemblance to complication than to complexity. This is not to say that the modes of operation themselves, are faulty. Nor is it to say that they do not have the ability to cooperatively generate complexity. It is simply that their deployment without an active and reflective understanding of underlying processes will not necessarily produce the complex.

What technology demands, but simply can't provide itself (not yet at least), are productive, meaningful and relevant questions. Without them the utility of any tools that promise the augmentation - quantitative or qualitative - of our design searches may be doubtful. What the computer excels at, what it is built for, is solving well defined problems. With clearly defined problems, especially those with measurable resolution, the computer is a very capable and useful addition to the architect's arsenal. Part of the merits of a computationally driven line of enquiry is in its inherent capacity to recursively return to the question, each time refining it as more is learned, and consequently generating answers of greater authority and precision. At the very least, while technology may not itself be capable of asking important questions, it is certainly more than capable of provoking new ones.

Imagining the cyborgian subsuming of body and machine is accompanied by a number of problems. Particularly worrisome to the logic of distributed intelligence is that of the oversight of a project - of responsibility. By separating thinking and action - manifested in the compounding of atomic decisions into singular resolute wholes - we risk blissful ignorance, We somehow convince ourselves, that we are

not responsible for what we don't know, or what we can't see. The more opacity and depth our machines acquire in attempting to contend with the vicissitude of life, the more we risk delivery into, not out of, a troubled reality. Working with machines must foreground responsibility, and not its retreat.

Computationally generated architecture can, at times, be mired in slavery to the mistakes it employs. Its simulation of natural processes relate particularly to mis-appropriations of scale, whether of time or space, but rarely are these conceived in terms of programmatic events and inhabitation. Genetic algorithms, likewise, presume that processes of natural selection - which typically can only be perceived from the perspective of time-lines of millions of years - can be simulated by synthetic models over the course of minutes or hours. The shapes of perceptible bodies are always a product of aggregates of smaller building blocks, and thus, there is an inextricable interdependence between the two scales. The same inter-component behaviour that might generate particular phenomena at a certain scale in nature, when manipulated to be perceptible at a different one, will generate different phenomena. In translation the performative is lost; the process that generated the pattern or shape is no longer necessary or relevant.

As long as the aforementioned mistakes are partitioned within a project, they are limited to bearing - for better or worse - on just that part. This thesis enquired into the consequence of a process operating autonomously, from start to finish, across all scales, and not surprisingly, it became extremely problematic at times. Many of its breaking points are weakened specifically by the imprecision of the model being used to represent the scenario. Others stem from the impracticality of searching for a coherent system to deal with the full breadth of reality's vicissitude; typically this latter scenario is really the same as the former, but in the context of an architectural practice (and not a scientific one) it may warrant distinction. The utility and applicability of the systems approach in architecture - either through parametric models or algorithmic scripts - should be weighed against the time it might take to develop it, as a model that will hold true for a wider range of conditions. Even then, after all is said and done, unless these processes yield something truly remarkable, or that might not be possible by other means, one has to wonder about the merits of process-heavy pursuits in practice.

Returning to the particular experience of the project's investigations, problems arise with the evolution of its inputs, the system by which the data was being classified. At the most practical level, machines are geared to processing data formatted to very particular specifications and this precision makes the "machines" prone to breaking down. The largest obstacle continued to be the time required to tend to these issues, and the lack of immediacy that one might get from their counterparts in manual drawing. These issues relating to lag times come to bear on our ability to assess consequence. We might attribute many of these problems not to the methods themselves, but to the impracticality of deploying them in parallel across all scales. As stated previously, when confined to clearly stated problems - with well defined start and end points - they would not be an issue.

PROBLEMS: ENTERING

Notable lapses in the smooth processual flow occurred at both the beginning and end of the zoo design- on entry and exit into the abstractions of the virtual. Near the start, antithetical leaps or assumptions had to be taken in order to give the project some leverage. Several programmatic elements were given explicit and fixed positions on the site, notably those that interfaced with the site, such as entry and service programs. Human programmatic elements were not conducive to the logic of the animal properties, and these were dealt with independently, in far more determinate ways. The immediacy of intuition in these cases, trumped the idealized process of self-determination. Since it was deemed too cumbersome to allow these elements to be "discovered" by process, so-called "autonomy" had to be discarded temporarily.

PROBLEMS: EXITING

There is trouble, as well, at the end of the processes, on exiting the system, and returning from the abstractions of the virtual environment back into an architectural one. It is at this point that the untenability of attempting to develop autonomous mechanical systems across all scales becomes evident again. At some point, the play that these processes allow require fixing in order to be read architecturally. Moving between scales, from site plan, to architectural plan and on to the detail, the development of mechanical systems for this orchestration becomes extremely cumbersome.

Getting swept up in an approach that allows one to continuously test options, one which might help to define problems as well as generate its possible solutions, proves to be extremely problematic. Towards the end of the project, details such as the ones relating to swells within the visitor pathways and their possible inhabitation made more sense as manually designed articulations of the machine-generated diagram. This may be partly a function of available time and resources, but it also attests to the limitation of being bound to purity in process. Though it may be self-evident, processes that preserve real-time interdependency and take nothing for granted, make for difficult paths.

IF WE WERE TO GO FURTHER

If the project were to continue, it might spend considerable time investigating the performance - and thus, consequence - of its building systems. These might include various assessments ranging from the size of its environmental impact, its ecological footprint, to its capacity to passively regulate its climate to the performance of structural elements measured against their material consumption, and even cost.

STRUGGLE FOR CONTROL

The degree to which the management of living forces as a human endeavour can and should approximate them in their process are central questions to the thesis, though ones to which it cannot provide any resolute answers. They ask us to contend with what distinguishes man from animal, and architecture from life. Within those narratives within architectural discourse that intimate faithfulness to "nature" there is a concealed struggle for control, a concern with domination between master and subject. The perils of being "seized" or "captivated" by the increasing persuasiveness of our media, looms overs us like a charmer over its snake. The danger of becoming enslaved to any so-called reality is one that demands ongoing attention. An orientation to reality, rather, that considers the simulacra to be a continuous regenerative and cooperative force, might better address our perceptions as a fundamental part of its construction. Lest we allow ourselves to drift, reality threatens to masquerade as if it is unadulterated.

> *The will to mastery becomes all the more urgent the more technology threatens to slip from human control.*[41]

41. MARTIN HEIDEGGER, *THE QUESTION CONCERNING TECHNOLOGY, AND OTHER ESSAYS* (TORONTO: FITZHENRY & WHITESIDE, 1977)

NEW DEMANDS ON PRACTICE

Addressing more pragmatically the problems that accompany new modes of practice, architecture will have to develop new strategies, and even entire new positions within the architectural office to manage the inconceivable quantities of data produced by generative machines. If these endeavours are intended to engender transparency, and in so doing move towards greater precision and authority - linking form and performance in building and moving outside the limited realm of the metaphor - the architect will have to become more comfortable with processing quantitative information. Though rarely discussed, the need to develop strategies and methods for dealing with this engineering data is a very real one.

Questions still attend how one might form closure on a loop which aspires to operate like the open-ended searches of living systems. How do we know when to stop our synthetic evolutionary systems, declaring them to be “final”? How will we know when we have “arrived”? What is being discussed here is more than just optimization, a pursuit of single and fixed ideals. It might be more accurate to explain the search itself in terms of event; a moving target which is conditioned by, just as it conditions, the project’s situation. The response, therefore, necessitates not fixed forms, but flexible approaches, those capable of adaptive response. For every move or decision we make, our environment responds; it makes us just as we make it.

THE FUTURE

We should continue to ask how complexity theories can be made to operate in practice beyond the metaphorical - specifically the material realm - and what impact this has on our architecture. Likewise, we must continue to ponder the distinctions one might make between emergence, always operating on the world regardless of its willed involvement, and its conceptual inclusion, played out in a controlled synthetic laboratory-like setting. These practices, more than simply shaping our built environment, are changing who we are.

APPENDICES

hairExtensions01fv_3d | Processing 1.0.3

File Edit Sketch Tools Help

hairExtensions01fv_3d | Animal | Hair | Human | Table

```
  fixed[j] = animals[j].p;
}

  for (int j=0; j<rowCountHumans; j++){
  float x = hairPlayInitHumans.getFloat(j,0);
  float y = hairPlayInitHumans.getFloat(j,1);
  float z = hairPlayInitHumans.getFloat(j,2);
  String label = hairPlayInit.getString(j,3);
  humans[j] = new Human(x,y,z,label);

  fixed[j+rowCount] = humans[j].p;
}

for (int i = 0; i < animals.length; i++) {

  PVector pPosA = new PVector(fixed[i].position.x, fixed[i].position.y, fixed[i].position.z);

  for (int j = i+1; j < animals.length; j++) {
    PVector pPosB = new PVector(fixed[j].position.x, fixed[j].position.y, fixed[j].position.z);

    float distance = PVector.dist(pPosA, pPosB);

    if(animals[i].connected<3){

      if( distance<200 && animals[i].stratum.equals(animals[j].stratum) && animals[j].connected<3){
        x= 'b';
        Hair tempStrand = new Hair(fixed[i], fixed[j], x);
        hairs = (Hair[])append(hairs, tempStrand);
        animals[i].countConnections();
        animals[j].countConnections();
      }
      else if(animals[j].connected<3 && distance<200 && animals[i].temp.equals(animals[j].temp) && animals[i].humidity.equals(animals[j].humidity)){
        x= 'c';
        Hair tempStrand = new Hair(fixed[i], fixed[j], x);
        hairs = (Hair[])append(hairs, tempStrand);
        animals[i].countConnections();
        animals[j].countConnections();
      }
      else if(animals[j].connected<3 && distance<200 && animals[i].diet.equals(animals[j].diet)){
        x = 'a';
        Hair tempStrand = new Hair(fixed[i], fixed[j], x);
        hairs = (Hair[])append(hairs, tempStrand);
        animals[i].countConnections();
        animals[j].countConnections();
```

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Processing is an open source programming language. Developed be approachable to non-traditional users including artists, designers, researches and hobbyists, the project was initiated by Ben Fry and Casey Reas in 2001 whilst studying at the MIT Media Lab. Their goal was to allow "ideas to be 'sketched' in code". It began with an interest in teaching the fundamentals of scripting and computer control logics, but has since blossomed into a thriving professional tool that has been used for major music videos, publications, and large scale installation works. It is sustained by an active community-driven forum and regular contributions of new libraries from various developers.

Processing is written in a dialect of Java that makes regularly used functions more convenient to access. Along with its syntax, the project includes several key libraries, as well as the Processing Development Environment, an IDE (Integrated Development Environment) with a simple set of features. It differs from Java in its simplification of common procedures into more compact forms. Noted as being more forgiving than C/C+, Processing's proximity eases the transition to such advanced languages.

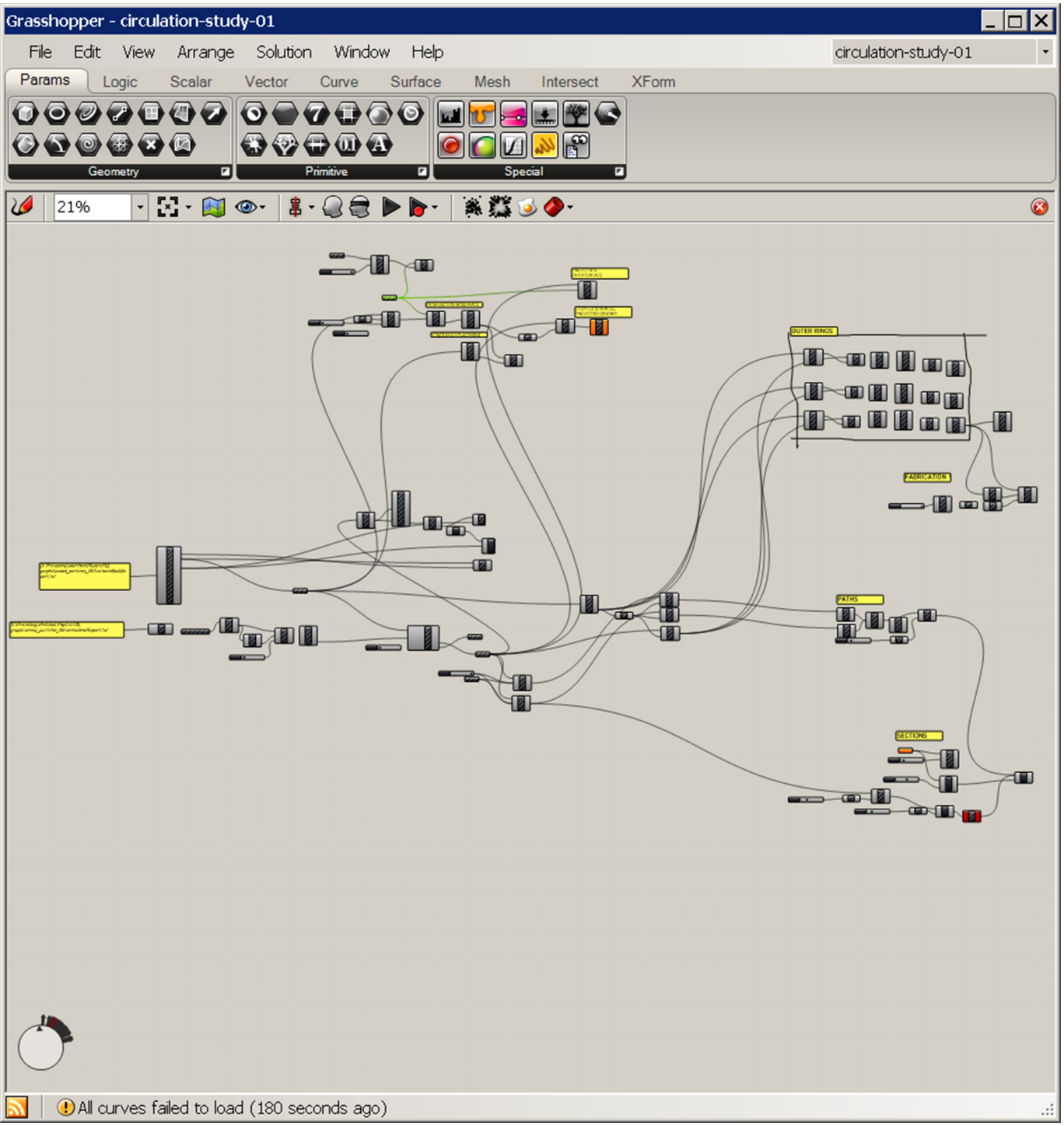
> *The Processing project encourages a style of work that builds code quickly, understanding that either the code will be used as a quick sketch, or ideas are being tested before developing a final project. This could be misconstrued as software engineering heresy. Perhaps we're not far from "hacking," but this is more appropriate for the roles in which Processing is used.*[42]

42. HTTP://PROCESSING.ORG/LEARNING/GETTINGSTARTED/

Libraries continue to be contributed by users to create simple and direct means to implement regularly used code. Processing's IDE is very accessible; it strips away that which might be required by heavier application development and adds built-in capacity to export to the web. Their programs can be viewed online as applets or as stand-alone applications for use on computers with a standard Java installation.

Processing lends itself to being incorporated into design strategies by non-specialists. Its built-in libraries ease working with 3-D geometry and the exchange of data in other media. Alongside other emerging computational technologies, Processing is being used in design studios and schools all over the world.

FIG 4.1
SCREENGRAB OF THE PROCESSING IDE IN USE


Grasshopper - circulation-study-01
File Edit View Arrange Solution Window Help
circulation-study-01
Params Logic Scalar Vector Curve Surface Mesh Intersect XForm
Geometry
Primitive
Special
21%
OUTER RINGS
FABRICATION
PATHS
SECTIONS
All curves failed to load (180 seconds ago)

Parametric software, like the explicitness of programming, is geared towards understanding and interrogating the processes behind the development of form. Though it tends not to be made explicit to its users, parametric features perform just as algorithmic codes do- by manipulating time and processing by serial procedures. What distinguishes parametric software from the typical algorithm is primarily in its interface with users - instead of running an algorithm once with a clear temporal beginning and end it is run continuously. One builds a parametric rig in incremental pieces picking up data somewhere in the process and delivering it elsewhere after first undergoing some kind of manipulation. Visual feedback on screen indicates to users the consequences of each operation as it is deployed.

Grasshopper - a plugin for Rhinoceros 3D used extensively in the thesis work - is implemented primarily through a graphic user interface - parallel to a 3 dimensional space represented on screen - described as a series of operations which can be plugged together to create processual flows. In addition to regular geometric features and functions, users have access to "blank" components that read scripted code, in either vB.net or C.

The parametric rig is independent from the data which it processes. Its construction is driven by two distinct procedures or motivations. While it is constructed typically to search for new design options for a specific set of conditions, implicit, as well, is an intention to understand, in each design problem, a more generic condition which might borrow from the investigation, either through the user's experience, or literally, by re-purposing the parts of its mechanisms. This might be conceived along the lines of an "abstract machine" which can drive different kinds of forms in the world. Its processual development, distinct from the form it produces, re-orients emphasis in the design process from concerns typological or morphological to the mechanisms that give rise to them; towards producing novel and divergent combinations.

Parametric software might be seen partly as a response to the rise of custom fabrication and its attendant endless variation. Designers, not confined to standardized materials, have shifted their attention to the rules or parameters that govern these forms

FIG 4.2
SCREENGRAB OF GRASSHOPPER IN USE

	COMMON NAME	AVG. WEIGHT (LB)	AVG. LENGTH (IN)	AREA	SCIENTIFIC NAME	CONTINENT	HABITAT	ORDER	CLASS	SKIN	ACTIVE	SPECIALIZATION
1	Oryx	440	62.5	4000	Oryx dammah	Asia	Desert	Artiodactyla	Mammalia	fur	diurnal	ground
2	Naked Mole Rat	0.09	3.5	400	Heterocephalus glaber	Africa	Desert	Rodentia	Mammalia	skin	diurnal	underground
3	Zebra	887.5	110	3600	Equus grevyi	Africa	Grassland	Perissodactyla	Mammalia	fur	diurnal	ground
4	Antelope	385	90	6000	Hippotragus niger niger	Africa	Grassland	Artiodactyla	Mammalia	fur	diurnal	ground
5	Warthog	220	47	2500	Phacochoerus aethiopicus	Africa	Grassland	Artiodactyla	Mammalia	fur	diurnal	ground
6	Caracal	30	32.5	1200	Caracal caracal	Africa	Grassland	Carnivora	Mammalia	fur	nocturnal	ground
7	Serval	29.5	34	1200	Leptailurus serval	Africa	Grassland	Carnivora	Mammalia	fur	crepuscular	ground
8	Spotted Hyena	85	42	2500	Crocuta crocuta	Africa	Grassland	Carnivora	Mammalia	fur	diurnal	ground
9	Meerkat	2	12	1000	Suricata suricatta suricatta	Africa	Grassland	Carnivora	Mammalia	fur	diurnal	ground
10	White-nosed Coati	8.8	21	800	Nasua narica	North America	Grassland	Carnivora	Mammalia	fur	diurnal	trees
11	Southern Three-banded Armadillo	3.25	12	500	Tolypeutes matacus	South America	Grassland	Cingulata	Mammalia	carapace	nocturnal	underground
12	Koala	20	30	600	Phascolarctos cinereus	Australia	Grassland	Diprotodontia	Mammalia	fur	diurnal	ground
13	Southern Hairynosed Wombat	56	33.6	750	Lasiorhinus latifrons	Australia	Grassland	Diprotodontia	Mammalia	fur	crepuscular	underground
14	White-headed Vulture	9.5	34	600	Trigonoceps occipitalis	Africa	Grassland	Falconiformes	Aves	feathers	diurnal	air
15	Tammar Wallaby	17.5	18	1500	Macropus eugenii	Australia	Grassland	Marsupialis	Mammalia	fur	nocturnal	ground
16	Red-billed Oxpecker	0.11	8	400	Buphagus erythrorhynchus	Africa	Grassland	Passeriformes	Aves	feathers	diurnal	air
17	Przewalski's Horse	770	83	2400	Equus caballus przewalskii	Asia	Grassland	Perissodactyla	Mammalia	fur	diurnal	ground
18	Ground Pangolin	27.5	21.7	800	Manis temminckii	Africa	Grassland	Pholidota	Mammalia	scales	nocturnal	underground
19	Mandrill	82.5	32	2500	Mandrillus sphinx	Africa	Grassland	Primates	Mammalia	fur	diurnal	trees
20	Komodo Dragon	175	90	500	Varanus komodensis	Asia	Grassland	Sauria	Reptilia	rough skin	diurnal	ground
21	Oustalet's Chameleon	5	23	250	Furcifer oustaleti	Africa	Grassland	Squamata	Reptilia	scales	diurnal	trees
22	Ostrich	243	88	1600	Struthio camelus australis	Africa	Grassland	Struthioniformes	Aves	feathers	diurnal	ground
23	Emu	93.5	67.5	1200	Dromaiusnovaehollandiae	Australia	Grassland	Struthioniformes	Aves	feathers	diurnal	ground
24	Galapagos Tortoise	660	48	600	Geochelone nigra	South America	Grassland	Testudines	Reptilia	carapace	diurnal	ground
25	North Island Brown Kiwi	6.93	19.49	300	Apteryx australis	Australia	Temperate Forest	Apterygiformes	Aves	feathers	nocturnal	ground
26	Canada Lynx	39	27	2400	Lynx canadensis	Europe	Temperate Forest	Carnivora	Mammalia	fur	nocturnal	ground
27	Mountain Lion	150	80	4000	Puma concolor	North America	Temperate Forest	Carnivora	Mammalia	fur	nocturnal	ground
28	Giant Panda	275	60	5000	Ailuropoda melanoleuca	Asia	Temperate Forest	Carnivora	Mammalia	fur	crepuscular	trees
29	Siberian Tiger	440	90	1200	Panthera tigris altaica	Asia	Temperate Forest	Carnivora	Mammalia	fur	crepuscular	ground
30	Mediterranean Horseshoe Bat	0.03	3	500	Rhinolophus euryale	Europe	Temperate Forest	Chiroptera	Mammalia	fur	nocturnal	air
31	Tasmanian Devil	15.5	41.5	500	Sarcophilus harrisii	Australia	Temperate Forest	Dasyuromorphia	Mammalia	fur	nocturnal	ground
32	Andean Condor	25	44	600	Vultur gryphus	South America	Temperate Forest	Falconiformes	Aves	feathers	diurnal	air
33	Giant Anteater	63	30	750	Myrmecophaga tridactyla	South America	Temperate Forest	Pilosa	Mammalia	fur	diurnal	ground
34	Lion-tailed Macaque	24	22	600	Macaca silenus	Asia	Temperate Forest	Primates	Mammalia	long hair	diurnal	trees
35	North American Porcupine	39.75	25.5	600	Erethizon dorsatum	North America	Temperate Forest	Rodentia	Mammalia	quills	nocturnal	trees
36	Okapi	550	98	3000	Okapia johnstoni	Africa	Tropical Rainforest	Artiodactyla	Mammalia	fur	diurnal	ground
37	Pygmy Hippopotamus	475	62	1000	Hexaprotodon liberiensis	Africa	Tropical Rainforest	Artiodactyla	Mammalia	skin	nocturnal	water
38	Binturong	45	30	1200	Arctictis binturong	Asia	Tropical Rainforest	Carnivora	Mammalia	fur	crepuscular	trees
39	Clouded Leopard	42.5	36	2500	Neofelis nebulosa	Asia	Tropical Rainforest	Carnivora	Mammalia	fur	nocturnal	trees
40	Kinkajou	5.5	19	500	Potos flavus	South America	Tropical Rainforest	Carnivora	Mammalia	fur	nocturnal	trees
41	Sun Bear	102.5	48	2500	Helarctos malayanus	Asia	Tropical Rainforest	Carnivora	Mammalia	fur	nocturnal	trees
42	Ocelot	20	30	1200	Leopardus pardalis	South America	Tropical Rainforest	Carnivora	Mammalia	fur	nocturnal	ground
43	Sugar Glider	0.24	6	500	Petaurus breviceps	Australia	Tropical Rainforest	Marsupialis	Mammalia	fur	nocturnal	trees
44	Birds of Paradise	0.53	24.5	1200	Paradisaeidae	Australia	Tropical Rainforest	Passeriformes	Aves	feathers	diurnal	air
45	Brazillian Tapir	440	72	2000	Tapirus terrestris	South America	Tropical Rainforest	Perissodactyla	Mammalia	fur	diurnal	water
46	Southern Two-Toed Sloth	13	25	800	Choloepus didactylus	South America	Tropical Rainforest	Pilosa	Mammalia	fur	nocturnal	trees
47	Bonobo (Pygmy Chimp)	95	32	2400	Pan paniscus	Africa	Tropical Rainforest	Primates	Mammalia	fur	diurnal	trees
48	Chimpanzee	95	36	2400	Pan troglodytes	Africa	Tropical Rainforest	Primates	Mammalia	fur	diurnal	trees
49	Golden Lion Tamarin	0.9	10.5	1200	Leontopithecus rosalia	Africa	Tropical Rainforest	Primates	Mammalia	long hair	diurnal	trees
50	Mangabey	16.1	22.1	1200	Lophocebus albigena	Africa	Tropical Rainforest	Primates	Mammalia	fur	diurnal	trees
51	Siamang	23	32	2500	Symphalangus syndactylus	Asia	Tropical Rainforest	Primates	Mammalia	fur	diurnal	trees
52	Sumatran Orangutan	132.5	54	3000	Pongo pygmaeus abelii	Asia	Tropical Rainforest	Primates	Mammalia	long hair	diurnal	trees
53	Western Lowland Gorilla	370	60	4000	Gorilla gorilla	Africa	Tropical Rainforest	Primates	Mammalia	fur	diurnal	ground
54	White-tufted-ear Marmoset	0.75	9	600	Callithrix jacchus	South America	Tropical Rainforest	Primates	Mammalia	fur	diurnal	trees
55	Ring Tailed Lemur	6.25	17.8	2400	Lemur catta	Africa	Tropical Rainforest	Primates	Mammalia	fur	diurnal	trees
56	Brazilian Agouti	6	20	500	Dasyprocta leporina	South America	Tropical Rainforest	Rodentia	Mammalia	fur	crepuscular	ground
57	Arctic Fox	11.75	22.4	1000	Vulpes lagopus	North America	Tundra	Carnivora	Mammalia	fur	nocturnal	ground
58	Gray Wolf	80	67	2400	Canis lupus	North America	Tundra	Carnivora	Mammalia	fur	nocturnal	ground
59	Polar Bear	1065	100	7000	Ursus maritimus	North America	Tundra	Carnivora	Mammalia	fur	diurnal	water
60	Norway Lemming	0.2	4.9	1000	Lemmus lemmus	Europe	Tundra	Rodentia	Mammalia	fur	nocturnal	underground
61	Little Penguin	2	16	1200	Eudyptula minor	Australia	Tundra	Sphenisciformes	Aves	feathers	diurnal	water
62	Goliath Frog	6.6	10.25	400	Conraua goliath	Africa	Wetlands	Anura	Amphibia	skin	nocturnal	water
63	Japanese Giant Salamander	55	60	600	Andrias japonicus	Asia	Wetlands	Caudata	Amphibia	skin	nocturnal	water
64	Sacred Ibis	3	30	500	Threskiornis aethiopicus	Africa	Wetlands	Ciconiiformes	Aves	feathers	diurnal	water
65	American Alligator	330	147.5	800	Alligator mississippiensis	North America	Wetlands	Crocodilia	Reptilia	scales	diurnal	water
66	Johnston's Crocodile	30	102	1000	Crocodylus johnstoni	Australia	Wetlands	Crocodilia	Reptilia	scales	diurnal	water
67	Green Peafowl	7.2	81	600	Pavo muticus	Asia	Wetlands	Galliformes	Aves	feathers	diurnal	ground
68	Andean Flamingo	6.16	47.5	600	Phoenicoparrus andinus	South America	Wetlands	Phoenicopteriformes	Aves	feathers	diurnal	water
69	Capybara	100	48	800	Capybara	South America	Wetlands	Rodentia	Mammalia	fur	crepuscular	water
70	sea otter	64.9	49	2000	Enhydra lutris	Asia, N. America	coastal	Carnivora	Mammalia	fur	diurnal	water
71	bush baby	0.5	8	500	Galago senegalensis	Africa	woodlland	Primates	Mammalia	fur	nocturnal	trees
72	zebra duiker	38.5		3200	Cephalophus zebra	Africa	forest	Artiodactyla	Mammalia	fur	diurnal	ground
73	gray-headed flying fox	1.5	10	2400	Pteropus poliocephalus	Australia	wetlands	Chiroptera	Mammalia	fur	nocturnal	air
74	mountain gazelle	51.15		4000	Gazella gazella	Africa	scrub forest, mountain	Artiodactyla	Mammalia	fur	diurnal	ground
75	fennec fox	3.3		2400	Vulpes zerda	Africa	desert	Carni vora	Mammalia	fur	nocturnal	underground
76	virginia opossum	11	18	1200	Didelphis virginiana	North America	woodland	Didelphimorphia	Mammalia	fur	nocturnal	trees
77	southern tamandua	9.9	28	1600	Tamandua tetradactyla	South America	Rainforest	Pilosa	Mammalia	fur	nocturnal	trees
78	giraffe	3421	204	8000	Giraffa camelopardalis	Africa	Grassland	Artiodactyla	Mammalia	fur	diurnal	ground
79	Sumatran rhinoceros	3080	110	4000	Dicerorhinus sumatrensis	Asia	Rainforest	Perissodactyla	Mammalia	skin	diurnal	water
80	aardvark	154		2600	Orycteropus afer	Africa	grassland	Tubulidentata	Mammalia	skin, hair	nocturnal	underground
81	rock hyrax	8	21	1200	Procavia capensis	Africa	grassland	Hyracoidea	Mammalia	fur	diurnal	underground
82	mouse deer	14	30	500	Tragulus napu	Asia	Rainforest	Artiodactyla	Mammalia	fur	nocturnal	ground
83	eastern barred bandicoot	1.4	10	1200	Perameles gunnii	Australia	grassland	Peramelemorphia	Mammalia	fur	nocturnal	ground
84	long-eared jerboa	0.06	3.15	700	Euchoreutes naso	Asia	desert	Rodentia	Mammalia	fur	nocturnal	underground
85	northern viscacha	2.75	15	600	Lagidium peruanum	South America	mountains	Rodentia	Mammalia	fur	crepuscular	ground
86	rosy-faced lovebird	0.12	5.91	1000	Agapornis roseicollis	Africa	desert	Psittaciformes	Aves	feathers	diurnal	air
87	California legless lizard	0.007	6.68	300	Anniella pulchra	North America	desert	Squamata	Reptilia	scales	nocturnal	underground
88	demoiselle crane	5.181	35.43	1200	Anthropoides virgo	Asia	grassland	Gruiformes	Aves	feathers	diurnal	air
89	burrowing owl	0.3125	10	1200	Athene cunicularia	South America	desert	Strigiformes	Aves	feathers	diurnal	underground
90	spot-billed pelican	10.78	126	1200	Pelecanus philippensis	Asia	wetlands	Pelecaniformes	Aves	feathers	diurnal	air
91	short-beaked echidna	10	15	1200	Tachyglossus aculeatus	Australia		Monotremata	Mammalia	fur	diurnal	underground

THE DATABASE

ARBOREAL	NATATORIAL	SOLITARY	SEDENTARY	DIET	TEMPERATURE	HUMIDITY	COVER	TREES	GRASS	BUSHES	SOIL	ICE	WATER	HEIGHT OF TRENCH (FT)
no	no	no	no	herbivore	hot	dry	soil	0	0	0	100	0	0	10
no	no	no	yes	herbivore	hot	dry	soil	0	0	0	100	0	0	6
no	no	no	no	herbivore	hot	mixed	grass	5	75	10	0	0	10	10
no	no	no	no	herbivore	hot	mixed	grass	5	75	10	0	0	10	10
no	no	no	no	herbivore	hot	mixed	grass	5	75	10	0	0	10	10
no	no	yes	no	carnivore	hot	mixed	grass	5	75	10	0	0	10	15
no	no	yes	no	carnivore	hot	mixed	grass	5	75	10	0	0	10	15
no	no	yes	no	carnivore	hot	mixed	grass	5	75	10	0	0	10	15
no	no	no	no	carnivore	hot	mixed	grass	5	75	10	0	0	10	6
yes	no	no	yes	omnivore	temperate	mixed	grass	5	75	10	0	0	10	6
no	no	yes	no	insectivore	hot	mixed	grass	5	75	10	0	0	10	6
no	no	yes	yes	herbivore	hot	mixed	grass	5	75	10	0	0	10	10
no	no	no	no	herbivore	hot	mixed	grass	5	75	10	0	0	10	10
no	no	yes	no	saprovore	temperate	mixed	grass	5	75	10	0	0	10	50
no	no	yes	yes	herbivore	hot	mixed	grass	5	75	10	0	0	10	10
no	no	yes	no	sanguinivores	temperate	mixed	grass	5	75	10	0	0	10	50
no	no	no	no	herbivore	temperate	mixed	grass	5	75	10	0	0	10	10
yes	yes	yes	yes	insectivore	temperate	mixed	grass	5	75	10	0	0	10	10
yes	no	no	yes	omnivore	hot	mixed	grass	5	75	10	0	0	10	15
yes	no	yes	yes	carnivore	hot	mixed	grass	5	75	10	0	0	10	6
yes	no	yes	yes	insectivore	hot	mixed	grass	5	75	10	0	0	10	6
no	no	no	no	omnivore	hot	mixed	grass	5	75	10	0	0	10	6
no	yes	yes	no	omnivore	hot	mixed	grass	5	75	10	0	0	10	6
no	yes	no	no	herbivore	hot	mixed	grass	5	75	10	0	0	10	6
no	no	yes	yes	carnivore	hot	mixed	trees	75	15	0	0	0	10	6
no	no	yes	yes	carnivore	temperate	mixed	trees	75	15	0	0	0	10	15
no	no	yes	yes	carnivore	temperate	mixed	trees	75	15	0	0	0	10	15
yes	no	yes	no	herbivore	temperate	mixed	trees	75	15	0	0	0	10	15
no	yes	yes	yes	carnivore	temperate	mixed	trees	75	15	0	0	0	10	15
no	no	no	no	insectivore	temperate	mixed	trees	75	15	0	0	0	10	15
no	no	yes	yes	carnivore	temperate	mixed	trees	75	15	0	0	0	10	6
no	no	yes	no	saprovore	temperate	mixed	trees	75	15	0	0	0	10	15
no	yes	yes	no	insectivore	temperate	mixed	trees	75	15	0	0	0	10	10
yes	no	no	yes	omnivore	temperate	mixed	trees	75	15	0	0	0	10	15
yes	no	yes	yes	herbivore	temperate	mixed	trees	75	15	0	0	0	10	15
no	no	yes	no	herbivore	hot	wet	trees	75	15	0	0	0	10	10
no	yes	no	no	herbivore	hot	wet	trees	75	15	0	0	0	10	10
yes	no	yes	yes	omnivore	hot	wet	trees	75	15	0	0	0	10	6
yes	no	yes	no	carnivore	hot	wet	trees	75	15	0	0	0	10	15
yes	no	no	yes	nectarivore	hot	wet	trees	75	15	0	0	0	10	15
yes	no	yes	yes	omnivore	hot	wet	trees	75	15	0	0	0	10	15
no	no	yes	yes	carnivore	hot	wet	trees	75	15	0	0	0	10	15
yes	no	no	no	omnivore	hot	wet	trees	75	15	0	0	0	10	15
yes	no	yes	yes	omnivore	hot	wet	trees	75	15	0	0	0	10	50
no	yes	yes	no	herbivore	hot	wet	trees	75	15	0	0	0	10	10
yes	no	yes	no	herbivore	hot	wet	trees	75	15	0	0	0	10	10
yes	no	no	yes	herbivore	hot	wet	trees	75	15	0	0	0	10	15
yes	no	no	yes	omnivore	hot	wet	trees	75	15	0	0	0	10	15
yes	no	yes	no	omnivore	hot	wet	trees	75	15	0	0	0	10	15
yes	no	no	yes	omnivore	hot	wet	trees	75	15	0	0	0	10	15
yes	no	yes	yes	herbivore	hot	wet	trees	75	15	0	0	0	10	15
yes	no	yes	no	omnivore	hot	wet	trees	75	15	0	0	0	10	15
no	no	no	yes	omnivore	hot	wet	trees	75	15	0	0	0	10	15
yes	no	no	no	herbivore	hot	wet	trees	75	15	0	0	0	10	15
yes	no	no	yes	herbivore	hot	wet	trees	75	15	0	0	0	10	15
no	no	yes	yes	herbivore	hot	wet	trees	75	15	0	0	0	10	6
no	no	no	no	carnivore	cold	dry	ice	0	10	15	0	75	0	10
no	no	no	no	carnivore	cold	dry	ice	0	10	15	0	75	0	15
no	yes	yes	no	carnivore	cold	dry	ice	0	0	0	0	50	50	15
no	no	no	no	herbivore	cold	dry	ice	0	10	15	0	75	0	6
no	yes	yes	no	piscivores	cold	dry	ice	0	0	0	0	50	50	6
no	yes	yes	yes	omnivore	hot	mixed	water	0	15	15	0	0	70	6
no	yes	yes	yes	carnivore	hot	mixed	water	0	15	15	0	0	70	6
no	yes	yes	no	insectivore	hot	mixed	water	0	15	15	0	0	70	6
no	yes	no	no	carnivore	hot	mixed	water	0	15	15	0	0	70	6
no	yes	yes	yes	carnivore	hot	mixed	water	0	15	15	0	0	70	6
no	no	yes	no	omnivore	hot	mixed	water	0	15	15	0	0	70	6
no	yes	no	no	herbivore	hot	mixed	water	0	15	15	0	0	70	10
no	yes	no	yes	herbivore	hot	mixed	water	0	15	15	0	0	70	6
no	yes	yes	no	piscivore	temperate	wet	water	0	0	0	10	0	90	
yes				omnivore	hot	mixed	trees	50	25	25	0	0	0	
no	no	yes	no	herbivore	hot	mixed	trees	75	15	10	0	0	0	
yes	no	no	no	herbivoe	temperate	mixed	trees	80	20	0	0	0	0	
no	no	yes	no	herbivore	hot	dry	soil	0	25	25	50	0	0	
no	no	no	no	omnivore	hot	dry	soil	0	15	15	70	0	0	
yes	no	yes		omnivore	temperate	mixed	trees	65	20	10	5	0	0	
yes	no			insectivore	hot	wet	trees	75	0	15	0	0	10	
no	no	no	no	herbivore	hot	dry	grass	15	65	10	10	0	0	
no	yes	yes	no	herbivore	hot	wet	trees	50	0	15	10	0	25	
no	no		no	insectivore	hot	mixed	grass	10	50	25	15	0	0	
no	no	no	no	herbivore	hot	dry	soil, rock	0	15	15	70	0	0	
no	no	yes	yes, no	herbivore	hot	humid	trees	65	15	0	5	0	15	
no	no	yes	no	insectivore	temperate	mixed	grass	10	75	0	10	0	0	
				insectivore	cold	dry	soil	0	0	0	100	0	0	
no	no	no	no	herbivore	temperate	dry	soil	0	10	10	75	0	5	
yes	no	no	no	herbivore	hot	dry	soil	10	0	10	80	0	0	
no	no	yes	yes, no	insectivore	hot	dry	soil	0	0	25	75	0	0	
no	no	"yes, no"	no	omnivore	temperate	dry	soil	0	15	15	50	0	20	
no	no	no	no	carnivore	temperate	dry	soil	5	15	10	70	0	0	
no	yes	no	no	carnivore	hot	humid	water	10	10	10	10	0	60	
no	no	yes	no	insectivore	temperate	mixed	soil	15	25	25	35	0	0	

THE FORCE DIRECTED LAYOUT SIMULATION

REFER TO "ENVIRONMENTAL CALIBRATION"
IN
CHAPTER 2: CONSTRUCTING THE ZOO MACHINE

```
//This Processing simulation was developed to augment a process of laying out program. It consists of a
      physics simulation of particles connected by links. Its primary function is one of sorting animals
      into a series of lists according to different criteria and allocating each with different rules and
      behaviours.
import upsdnPhysics.*;
import controlP5.*;
import superCAD.*;
import damkjer.ocd.*;
import toxi.math.noise.*;
import processing.opengl.*;
import processing.pdf.*;

PImage aerialPhoto;
PFont font;
Camera camera1;

//initialization of variables
boolean dispEdges, dispServiceGrid, record = false;
boolean export = false;
boolean dispTriangulation = false;
boolean getConnected = false;
boolean stillTicking = true;
int tickCount = 0,
maxTicks = 1000;

float drawingScale = 1.0/5.0 ;
float transX = 0;
float transY = 0;

ControlP5 controlP5;
int sliderValue = 32;

int gateDist = sliderValue;
boolean debugging = false;

float attDist =1;
float attStrength = 3200;
float aqd, aqs;
float lLength, lStrength, lDamping =10 ;
float clStrength, clDamping = 10, clLength;
float lcStrength, lcDamping = 10, lcLength;
float ahlStrength, ahlDamping = 10, ahlLength;
float allSep = 3, dietSep = 3, strataSep = 3;
float gateFactor = 1;
float[][] AHregionCoordinates;

Zoo z = new Zoo();
Vector3D animalsCentroid;

int count = 0;

void setup() {
 size(1026,830);

 controlP5 = new ControlP5(this);
 controlP5.setAutoInitialization(true);

 Slider s1 = controlP5.addSlider("gateDist",0,100,128,25,25,10,100);

 //Anchor Links controls
 Slider s2 = controlP5.addSlider("lLength",
 0, 500, 1, 75,25,10,100);
 Slider s3 = controlP5.addSlider("lStrength",
 0, 10, 1, 125,25,10,100);
 Slider s4 = controlP5.addSlider("clLength",
 0, 500, 1, 175, 25, 10, 100);
 Slider s5 = controlP5.addSlider("clStrength",
 0, 10, 1, 225, 25, 10, 100);

 Slider s6 = controlP5.addSlider("lcLength",
 0, 500, 1, 275, 25, 10, 100);
 Slider s7 = controlP5.addSlider("lcStrength",
 0, 10, 1, 325, 25, 10, 100);
 Slider s8 = controlP5.addSlider("allSep",
 0, 10, 10, 375, 25, 10, 100);
 Slider s9 = controlP5.addSlider("dietSep",
 0, 10, 10, 425, 25, 10, 100);
 Slider s10 = controlP5.addSlider("strataSep",
 0, 10, 10, 475, 25, 10, 100);
 Slider s11 = controlP5.addSlider("gateFactor",
 0, 5, 5, 525, 25, 10, 100);
 Slider s12 = controlP5.addSlider("ahlLength",
 0, 500, 1, 575, 25, 10, 100);
 Slider s13 = controlP5.addSlider("ahlStrength",
 0, 10, 1, 625, 25, 10, 100);

 frameRate(24);
 aerialPhoto = loadImage("lgp-mcp-04-1pxEQ1ft-cropped-1-5b.png");
 setupSpecials();

 font = createFont("Silkscreen-9", 9);
 textFont(font, 9);

 ps = new ParticleSystem( 0, 0.25 );

 initAnchors();
 initAnimals();
 initHumans();
 smooth();
}

void draw() {
  if (record) {
    // Note that #### will be replaced with the frame number. Fancy!
    beginRecord(PDF, "frame-####.pdf");
    saveFrame("animal-FDL-####.png");
  }
  if(count==200 & !getConnected){
    getConnected= true;
  }

   if(getConnected){
    println("Get connected!");
    addMoreLinks();
    getConnected=!getConnected;
   }


  adjustLinks();
  image(aerialPhoto,0,0);
  fill(0,75);
  rect(10,10,width-20, 130);
  float[][] points = new float[z.animals.size()][2];
  for (int i = 0; i < z.animals.size(); i++) {
  Animal a = (Animal)z.animals.get(i);
   points[i][0] = a.p.position.x;
```

```
  points[i][1] = a.p.position.y;
}
Animal y = (Animal)z.animals.get(1);

Delaunay mesh = new Delaunay(points);
Hull myHull = new Hull( points );

MPolygon myRegion = myHull.getRegion();
AHregionCoordinates = myRegion.getCoords();

tickCount++;
if(tickCount > maxTicks){
  stillTicking = false;
}

animalsCentroid = centroid(z.animals);

centroid.p.position().set(animalsCentroid.x, animalsCentroid.y, 0.0);

if (mousePressed && mouseY>140){
  fixedP.position().set(mouseX, mouseY, 0);
  fixedP.velocity.clear();
}

ps.tick( 0.1 );
z.draw();

if (dispServiceGrid){
  drawVisitorGrid();
}
if(dispEdges){
  drawEdges();
}

if(dispTriangulation){
  // draw the trianguation.
  float[][] edges = mesh.getEdges();
  for(int i=0; i<edges.length; i++){
    float startX = edges[i][0];
    float startY = edges[i][1];
    float endX = edges[i][2];
    float endY = edges[i][3];
    float d = distance(startX, startY, endX, endY);
    strokeWeight(1.4);
    if(d <= gateDist){
     stroke(255,0,222)
    }
    else{
     strokeWeight(0.4);
     stroke(50);
    }
    line( startX, startY, endX, endY );
  }
}

//screengrab
if (keyPressed && key == 'o'){
  saveFrame("animal-FDL-####.png");
}
//export geometry to text filep
if (export) {
  clusterAnalysis(mesh);

  exportToTxt(mesh);
  export=!export;
}
if (record) {
  endRecord();
  record = false;
}

for (int i=0; i<z.animals.size(); i++) {
  Animal a = (Animal)z.animals.get(i);
  handleBoundaryCollisions( a.p );
}
count++;
}

void drawEdges(){
 fill(255,0);
 strokeWeight(1);
 stroke(0, 50);

 beginShape( );
 for (int i = 0; i < anchoredLinks.size(); i++) {
 Link l = (Link)anchoredLinks.get(i);
  Particle a = l.s.getOneEnd();
  Particle b = l.s.getTheOtherEnd();
  line(a.position.x, a.position.y, b.position.x, b.position.y);
 }
 endShape();
 stroke(255, 0,0,50);
 beginShape( );
 for (int i = 0; i < centroidLinks.size(); i++) {
  Link l = (Link)centroidLinks.get(i);
  Particle a =  l.s.getOneEnd();
  Particle b = l.s.getTheOtherEnd();
  line(a.position.x, a.position.y, b.position.x, b.position.y);
 }
 endShape();
}

// really basic collision strategy:
// sides of the window are walls
// if it hits a wall pull it outside the wall and flip the direction of the velocity
// the collisions aren't perfect so we take them down a notch too
void handleBoundaryCollisions( Particle p ){
 if ( p.position.x < 350 || p.position.x > width-200 ){
   p.velocity.set( -0.9*p.velocity.x, p.velocity.y, 0 );
   p.position().set( constrain( p.position.x, 350, width-200 ), constrain( p.position.y, 350,
       height-175 ), 0 );
 }

 if ( p.position.y < 350 || p.position.y > height-175 ){
   p.velocity.set( p.velocity.x, -0.9*p.velocity.y, 0 );
   p.position().set( constrain( p.position.x, 300, width-150 ), constrain( p.position.y, 350,
       height-175 ), 0 );
 }

 if ( p.position.x >= 660 && p.position.y <= 500){
   p.velocity.set( -0.9*p.velocity.x, -0.9*p.velocity.y, 0 );
 }
}
```

```
//Section devoted to the zoo class. Zoo is a parent to all Spaces, animal and human as well as all Links.
Particle carnivore, p;
ParticleSystem ps;
Particle fixedP;
Spring s;
Anchor[] specials;
Anchor center, hot, cold, wet, dry, temperate, mixed, nocturnal, centroid, humanCounter,
      humanCounter2, supportAnchor, north, south, east, west, landAnchor, waterAnchor,
      treesAnchor, mountainAnchor;
```

```
8
9  Space selectedSpace = null;
10 Space dragSpace = null;
11 Space hoverSpace = null;
12
13 class Zoo {
14  ArrayList anchors;
15  ArrayList animals;
16  ArrayList friends, foes;
17  ArrayList humans;
18  ArrayList visitors;
19  ArrayList dietLinks, stratumLinks;
20  ArrayList wetLinks;
21  ArrayList eating, sitting;
22  ArrayList north, south,  east, west;
23  ArrayList support;
24  ArrayList aquarters, aquartersLinks;
25
26  //attraction groups
27  ArrayList aqAtt, aeAtt, allAtt, dietAtt, lcAtt;
28
29  //spring separation test
30  ArrayList supportLinks;
31  ArrayList visitorLinks;
32  ArrayList lcLinks;
33
34  ArrayList animalHumanLinks;
35
36  ArrayList spaces;
37  HashMap spacesById, animalsById;
38  ArrayList edges;
39  HashMap edgesFrom;
40  HashMap edgesTo;
41
42   Zoo() {
43     wetLinks = new ArrayList();
44
45     anchors = new ArrayList();
46     spaces = new ArrayList();
47     animals = new ArrayList();
48     friends = new ArrayList();
49     foes = new ArrayList();
50     humans = new ArrayList();
51
52     dietLinks = new ArrayList();
53     stratumLinks = new ArrayList();
54     lcLinks = new ArrayList();
55
56     eating = new ArrayList();
57     sitting = new ArrayList();
58     north = new ArrayList();
59     south = new ArrayList();
60     west = new ArrayList();
61     east = new ArrayList();
62
63     visitors = new ArrayList();
64     visitorLinks = new ArrayList();
65
66     support = new ArrayList();
67     supportLinks = new ArrayList();
68
69     aquarters = new ArrayList();
70     aquartersLinks = new ArrayList();
71
72     animalHumanLinks = new ArrayList();
73
74     aqAtt = new ArrayList();
75     aeAtt = new ArrayList();
76     allAtt = new ArrayList();
77     dietAtt = new ArrayList();
78     lcAtt = new ArrayList();
79
80     animalsById = new HashMap();
81     spacesById = new HashMap();
82
83    edges = new ArrayList();
84    edgesFrom = new HashMap();
85    edgesTo = new HashMap();
86  }
87
88   void setSelectedSpace(Space n) {
89    selectedSpace = n;
90  }
91
92   Space getSelectedSpace() {
93    return selectedSpace;
94  }
95
96   void setHoverSpace(Space n) {
97    hoverSpace = n;
98  }
99
100   Space getHoverSpace() {
101    return hoverSpace;
102  }
103
104   void setDragSpace(Space n) {
105    dragSpace = n;
106  }
107
108   Space getDragSpace() {
109    return dragSpace;
110  }
111
112   void addSpace(Space n, ArrayList listname) {
113    spaces.add(n);
114    listname.add(n);
115    spacesById.put(n.getId(), n);
116    n.setGraph(this);
117  }
118
119   Space getSpace(String id) {
120    return (Space)spacesById.get(id);
121  }
122
123   void draw() {
124
125 ////just the human program
126     for (int i=0; i<humans.size(); i++) {
127      Space a = (Space)humans.get(i);
128      a.draw();
129     }
130
131
132     for (int i=0; i<animals.size(); i++) {
133      Space a = (Space)animals.get(i);
134      a.draw();
135    }
136 //     for (int i=0; i<support.size(); i++) {
137 //      Space a = (Space)support.get(i);
138 //      a.draw();
139 //    }
140 //     for (int i=0; i<visitors.size(); i++) {
141 //      Space a = (Space)visitors.get(i);
142 //      a.draw();
143 //    }
```

```
//
//      for (int i=0; i<aquarters.size(); i++) {
//      Space a = (Space)aquarters.get(i);
//      a.draw();
//    }
      for (int i = 0; i < z.anchors.size(); i++) {
      Anchor a = (Anchor)z.anchors.get(i);
      a.draw();
    }
  }
}
```

```
//The anchor class is a type of object with a fixed particle for registering and fixing qualities.
class Anchor {
 ParticleSystem ps;
 Particle p;
 String type;
 float[] myScreenPos = { 0,0,2};

  Anchor(ParticleSystem ps, float xPos, float yPos){
    this.ps = ps;
    this.p = ps.makeParticle(.1,width/2, height/2, 0);
    this.p.makeFixed();
  }

  Anchor(ParticleSystem ps, float xPos, float yPos, String type){
    this.type = type;
    this.ps = ps;
    this.p = ps.makeParticle(.1,xPos, yPos, 0);
    this.p.makeFixed();
  }

  void draw(){
    if(this.p.isFree()){
      fill(255,0,0);
    }
    else if(this.p.isFixed()){
      fill(255);
    }

    strokeWeight(5);
    stroke(0);
    line(this.p.position.x-5, this.p.position.y, this.p.position.x+5, this.p.position.y);
    line(this.p.position.x, this.p.position.y-5, this.p.position.x, this.p.position.y+5);

    fill(0);
    float[] myScreenPos = {
     0,0,2          };

    textFont(font, 9);
    text(this.type, this.p.position.x+10, this.p.position.y+10);

    if (this.p == fixedP){
      stroke(228,255,31,128);
      strokeWeight(5);

      for ( int i = 0; i < ps.numberOfSprings(); ++i ){
        Spring e = ps.getSpring( i );
        if(e.isOn()){
          if ( this.p == e.getOneEnd() || this.p == e.getTheOtherEnd()){
            Particle a = e.getOneEnd();
            Particle b = e.getTheOtherEnd();
            stroke(0);
            strokeWeight(1);
            line(a.position.x, a.position.y, b.position.x, b.position.y);
```

```
            }
          }
        }
      }
    }
}

void initAnchors(){
  hot = new Anchor(ps, 150, 600, "hot");
   cold = new Anchor(ps, 1000, 600, "cold");
  wet = new Anchor(ps, 1000, 800, "wet");
  dry = new Anchor(ps, 150, 225, "dry");
  landAnchor = new Anchor(ps, 525, 225, "land");
  waterAnchor = new Anchor(ps, 150, 800, "water");
  treesAnchor = new Anchor(ps, 1000, 225, "trees");
  mountainAnchor = new Anchor(ps, 625, 375, "mountain");

  z.anchors.add(landAnchor);
   z.anchors.add(waterAnchor);
  z.anchors.add(treesAnchor);
  z.anchors.add(mountainAnchor);

  north = new Anchor(ps, width/2, 3*height/7, "north");
  south = new Anchor(ps, width/2, 6*height/7, "south");

  west = new Anchor(ps, 2*width/7, height/2, "west");
  east = new Anchor(ps, 5*width/7, height/2, "east");

  supportAnchor = new Anchor(ps,  6*width/7, 5*height/7, "supportAnchor");

  nocturnal = new Anchor(ps, 400, 500, "nocturnal");

  z.anchors.add(nocturnal);
  z.anchors.add(hot);
  z.anchors.add(cold);
  z.anchors.add(wet);
  z.anchors.add(dry);

  z.anchors.add(north);
  z.anchors.add(south);
  z.anchors.add(west);
  z.anchors.add(east);
  z.anchors.add(supportAnchor);

  Vector3D animalsCentroid = centroid(z.animals);

  centroid  =  new Anchor(ps, animalsCentroid.x, animalsCentroid.y, "centroid");
  centroid.p.makeFixed();
  z.anchors.add(centroid);

  float landYPos = lerp (dry.p.position.y, wet.p.position.y, .3);
  float waterYPos = lerp (dry.p.position.y, wet.p.position.y, .9);
}
```

```
//The Space class parents animal and human objects. Every space has a particle within the particle
      system, identification, type, size and initial positions.
class Space {
    Zoo z;
    Vector3D position;
    Particle p;
    ParticleSystem ps;
    Spring s;

    float[] myScreenPos = { 0,0,2 };
    String label = "";
```

```
    String type = "";
    String id = "";

    float diameter, radius, weight, area, elevation, depth;

    color colCoding;
    boolean visited;

    int[] neighbors; // associations with the neighboring animals in the mesh.
    int particleNum; // associate this animal with the particle system

    void draw(){
      if (diet.equals("carnivore")){
        stroke(229,10,70);
        strokeWeight(2);
      }
      else{
        stroke(0);
        strokeWeight(1);
      }

      fill(colCoding);
      ellipse(this.p.position.x,this.p.position.y, diameter , diameter);

      stroke(0);
      strokeWeight(2);
      point(this.p.position.x,this.p.position.y);

      if (this.p == fixedP){
        stroke(228,255,31,128);
        strokeWeight(5);
        println(label);
        fill(0);
        textFont(font, 9);
        text(label, this.p.position.x+this.diameter/2+5,this.p.position.y+this.diameter/2+5);
        ellipse(this.p.position.x,this.p.position.y, diameter , diameter);
        stroke(255);
        strokeWeight(2);
        point(this.p.position.x,this.p.position.y);
      }

      if (record) {
        fill(0);
        textFont(font, 9);
        text(label, this.p.position.x+this.diameter/2+5,this.p.position.y+this.diameter/2+5);
      }
     }

    String getId() {
      return id;
    }
    void setId(String s) {
      id = s;
    }
    void setGraph(Zoo h) {
      z = h;
    }
  }
```

```
//this class was started as a means to start typifying relationships - as each "Link" is created, a field
      called type could be filled as per a series of conditional gates, could placed in separate lists or
      whatever
class Link {
 Space space, a, b;
 Anchor c;
 Spring s;

 Link(Space a, Anchor b ){
   s = ps.makeSpring(a.p, b.p, 1, 1, 1 );
 }

  Link(Space a, Space b){
   s = ps.makeSpring(a.p, b.p, 1, 1, 1 );
   this.a = a;
   this.b = b;
 }

   Link(Space a, Anchor b,  float strength, float damping, float restLength ){
   s = ps.makeSpring(a.p, b.p, strength, damping, restLength );
   println(strength);
   this.a = a;
   this.c = b;
 }

  Link(Space a, Space b,  float strength, float damping, float restLength){
   s = ps.makeSpring(a.p, b.p, strength, damping, restLength );
   this.a = a;
   this.b = b;
 }

 Link( Animal a,  Anchor b, float strength, float damping, float restLength ){
    s = ps.makeSpring(a.p, b.p, strength, damping, restLength );
   this.a = a;
   this.c = b;
 }

 Link (float x1, float y1, float x2, float y2){
 }
}
```

```
//The Animal class has fields for many divergent criteria pertaining to each species, some which are
      used to make distinctions as to how to treat each exhibit. As a child of the Space class, each
      has  its own particle, area, as well as other spatial information but this is augmented here with
      fields to make finer distinctions between species.
String[] specialTypes = { "water", "underground",  "ground", "trees", "air"};

ArrayList anchors, wetAnimals, dryAnimals, mixedAnimals, hotAnimals, coldAnimals,
      temperateAnimals,
waterAnimals, earthAnimals, landAnimals, treeAnimals, skyAnimals, friends, foes,
undergroundAnimals, abovegroundAnimals ;
ArrayList anchoredLinks = new ArrayList();
ArrayList centroidLinks = new ArrayList();
ArrayList landcoverLinks = new ArrayList();
ArrayList landcovers = new ArrayList();

boolean dispWaterAnimals = false, dispEarthAnimals = false, dispLandAnimals =
      false, dispTreeAnimals = false, dispSkyAnimals = false, dispugAnimals = true,
      dispagAnimals = true;
float weight, area;
String diet, climate, common, special, temperature, humidity, active;
int opacity = 90;
color waterColor = color(0,200,255,opacity), skyColor = color(150,255,255,opacity),
      earthColor = color(50,50,0,opacity), landColor = color(255,255,0,opacity), treesColor =
      color(150,255,0,opacity);

HashMap specialIndices;

void setupSpecials() {
 specialIndices = new HashMap();
 for (int i = 0; i <  specialTypes.length; i++) {
```

```
  specialIndices.put(specialTypes[i], new Integer(i));
 }
}

class Animal extends Space {
 float trees, grass, soil, ice, water, bushes;
 String specialType, temp, humidity, diet, active, stratum, stratumID;
 boolean foe, nocturnalBool = false;
 Vector3D position;
 PVector aqPos, lcPos, treePos, waterPos, icePos;
 float aqRadius, lcRadius, treeRadius, waterRadius, iceRadius = 0;
 float randomAngle =0;
 int[] neighbors;
 float sepHeight, sepWidth;

 String sepType, roof, mountain;

 ArrayList neighbours;

 Animal(int index, ParticleSystem ps, String label, float weight, float area, String specialType,
     String temperature, String humidity, String diet, String active, float trees, float grass,
     float bushes, float soil, float ice, float water, String sepType, float sepHeight, float
     sepWidth, String roof, String mountain  ) {
  particleNum = index;

  this.temp = temperature;
  this.humidity = humidity;
  this.label = label;
  this.weight = weight;
  this.area = area;
  this.specialType = specialType;
  this.diet = diet;
  this.active = active;
  this.radius = sqrt(area/PI)*drawingScale;
  this.diameter = radius*2;
  this.trees = trees;
  this.grass = grass;
  this.bushes = bushes;
  this.soil = soil;
  this.ice = ice;
  this.water = water;
  this.ps = ps;

  this.roof = roof;
  this.sepType = sepType;
  this.sepHeight = sepHeight;
  this.sepWidth = sepWidth;
  this.mountain = mountain;
  this.p = ps.makeParticle(10, random((width/2)-150,(width/2)+150), random((height/2)-50,
     (height/2)+300), 0);

  position= new Vector3D(this.p.position.x,this.p.position.y,this.p.position.z());
  aqPos = new PVector(0,this.radius + this.aqRadius, 0 );

  setStratum();
  setDiet();
  anchorAnimal();
  provideAQuarters();
  setLandCover();
 }

 void setStratum(){
  if (this.specialType.equals("trees")){
   this.elevation = 25.0;
   this.stratum = "aboveground";
   this.stratumID = "C";
   colCoding = treesColor;
   treeAnimals.add(this);
   abovegroundAnimals.add(this);
   Link tempLink = new Link(this, treesAnchor,10,1,1);
   landcoverLinks.add(tempLink);
  }
  if (this.specialType.equals("ground")){
   this.elevation = 0.0;
   this.stratum = "ground";
   this.stratumID = "B";
   colCoding = landColor;
   landAnimals.add(this);
   Link tempLink = new Link(this, landAnchor,10,1,1);
   landcoverLinks.add(tempLink);
  }
  if (this.specialType.equals("underground")){
   this.elevation = -10.0;
   this.stratum = "belowground";
   this.stratumID = "A";
   colCoding = earthColor;
   earthAnimals.add(this);
   undergroundAnimals.add(this);
   Link tempLink = new Link(this, landAnchor,10,1,1);
   landcoverLinks.add(tempLink);
  }
  if (this.specialType.equals("water")){
   this.elevation = -10.0;
   this.stratum = "belowground";
   this.stratumID = "A";
   colCoding = waterColor;
   waterAnimals.add(this);
   undergroundAnimals.add(this);
   Link tempLink = new Link(this, waterAnchor,10,1,1);
   landcoverLinks.add(tempLink);
  }
  if (this.specialType.equals("air")){
   this.elevation = 25.0;
   this.stratum = "aboveground";
   this.stratumID = "C";
   colCoding = skyColor;
   skyAnimals.add(this);
   abovegroundAnimals.add(this);
  }
  if(this.mountain.equals("TRUE")){
   this.elevation = 25.0;
   this.stratum = "aboveground";
   this.stratumID = "C";
   colCoding = earthColor;
   Link tempLink = new Link(this, mountainAnchor,100,1,1);
   abovegroundAnimals.add(this);
  }
 }
 void setDiet(){
  if(this.diet.equals("carnivore") || this.diet.equals("saprovore")){
   foe = true;
   foes.add(this);
  }
  else if(this.diet.equals("omnivore")){
   if(this.weight < 25){
    foe = false;
    friends.add(this);
   }
   else{
    foe = true;
    foes.add(this);
   }
  }
  else{
   foe = false;
   friends.add(this);
```

```
  }
 }
void anchorAnimal(){
Link centroidLink = new Link(this, centroid);
centroidLinks.add(centroidLink);

 if (this.temp.equals("hot")){
  Link tempLink = new Link(this, hot,10,1,1);
  hotAnimals.add(this);
  anchoredLinks.add(tempLink);
 }
 else if (this.temp.equals("cold")){
  Link tempLink = new Link(this, cold,10,1,1);
  coldAnimals.add(this);
   anchoredLinks.add(tempLink);
 }
 else if (this.temp.equals("temperate")){
  Link tempLink = new Link(this, hot,10,1,1);
  Link tempLink2 = new Link(this, cold,10,1,1);
  temperateAnimals.add(this);
  anchoredLinks.add(tempLink);
  anchoredLinks.add(tempLink2);
 }
 if (this.humidity.equals("wet")){
  Link tempLink = new Link(this, wet,10,1,1);
  wetAnimals.add(this);
  anchoredLinks.add(tempLink);
 }
 if (this.humidity.equals("dry")){
  Link tempLink = new Link(this, dry,10,1,1);
  dryAnimals.add(this);
  anchoredLinks.add(tempLink);
 }
 if (this.humidity.equals("mixed")){
  Link tempLink = new Link(this, wet,10,1,1);
  Link tempLink2 = new Link(this, dry,10,1,1);
  mixedAnimals.add(this);
  anchoredLinks.add(tempLink);
  anchoredLinks.add(tempLink2);
 }

 if (active.equals("nocturnal")){
  this.nocturnalBool = true;
  ps.makeSpring(this.p, nocturnal.p,10, 1, 1 );
 }
}

 void provideAQuarters(){
 float tempArea;
  if (area/5 > 500){
   tempArea = 500;
  }
  else{
   tempArea = area/5;
  }
  aqRadius = sqrt(tempArea/PI)*drawingScale;
}

 void setLandCover(){
  treeRadius = sqrt((this.trees/100)*area/PI)*drawingScale;
  waterRadius = sqrt((this.water/100)*area/PI)*drawingScale;
  iceRadius = sqrt((this.ice/100)*area/PI)*drawingScale;
  treePos = new PVector(0, this.radius-treeRadius, 0);
  waterPos = new PVector(0, this.radius-waterRadius, 0);
  icePos = new PVector(0, this.radius-iceRadius, 0);
}

 void draw(){
  if (this.foe){
   stroke(150,0,00);
   strokeWeight(2);
  }
  else if(!this.foe){
   stroke(0);
   strokeWeight(1);
  }

  fill(colCoding);
  ellipse(this.p.position.x,this.p.position.y, diameter , diameter);
  stroke(0);
  strokeWeight(2);
  point(this.p.position.x,this.p.position.y);

  if (this.p == fixedP){
   stroke(228,255,31,128);
   strokeWeight(5);
   fill(0);
   textFont(font, 9);
   text(label, this.p.position.x+this.diameter/2+5,this.p.position.y+this.diameter/2+5);
   ellipse(this.p.position.x,this.p.position.y, diameter , diameter);
   stroke(255);
   strokeWeight(2);
   point(this.p.position.x,this.p.position.y);

   for ( int i = 0; i < ps.numberOfSprings(); ++i ){
    Spring e = ps.getSpring( i );
    if(e.isOn()){
     if ( this.p == e.getOneEnd() || this.p == e.getTheOtherEnd()){
      Particle a = e.getOneEnd();
      Particle b = e.getTheOtherEnd();
      stroke(0, 90);
      strokeWeight(0.5);
      line(a.position.x, a.position.y, b.position.x, b.position.y);
     }
    }
   }
  }

  if (record) {
   fill(0);
   textFont(font, 9);
   text(label, this.p.position.x+this.diameter/2+5,this.p.position.y+this.diameter/2+5);
  }
   updateNeighbours();

 noStroke();
 fill(0,200,0);
  ellipse(treePos.x+p.position.x, treePos.y+p.position.y, treeRadius*2, treeRadius*2);
  fill(200,200,0);
  ellipse(aqPos.x+p.position.x, aqPos.y+p.position.y, aqRadius*2, aqRadius*2);
}

 void updateNeighbours(){
   int count = 0;
   for (int i = 0; i < z.animals.size(); i++) {
     Animal a = (Animal)z.animals.get(i);
     if(a != this){
       if(this.diet.equals(a.diet)){
         float distance = distance(this.p.position.x, this.p.position.y, a.p.position.x,
       a.p.position.y);
           if(distance<60){
             aqPos.add(a.p.position.x-this.p.position.x, a.p.position.y-this.p.position.y, 0);
           }
       }
         aqPos.normalize();
         aqPos.mult(this.radius+aqRadius);
```

```
        if(a.trees>0 && this.trees>0){
          float distance = distance(this.p.position.x, this.p.position.y, a.p.position.x,
      a.p.position.y);
          if(distance<60){
            treePos.add(a.p.position.x-this.p.position.x, a.p.position.y-this.p.position.y, 0);
          }
          treePos.normalize();
          treePos.mult(this.radius-treeRadius);
        }
        if(a.water>0 && this.water>0){
          float distance = distance(this.p.position.x, this.p.position.y, a.p.position.x,
      a.p.position.y);
            if(distance<60){
              waterPos.add(a.p.position.x-this.p.position.x, a.p.position.y-this.p.position.y,
      0);
            }
          waterPos.normalize();
          waterPos.mult(this.radius-waterRadius);
        }
        if(a.ice>0 && this.ice>0){
      float distance = distance(this.p.position.x, this.p.position.y, a.p.position.x,
      a.p.position.y);
      if(distance<60){
        icePos.add(a.p.position.x-this.p.position.x, a.p.position.y-this.p.position.y, 0);
      }
      icePos.normalize();
      icePos.mult(this.radius-iceRadius);
      }
    }
  }
}

String getLabel() {
  return this.label;
}

boolean containsPoint(float x, float y) {
  float dx = p.position.x-x;
  float dy = p.position.y-y;
  return (abs(dx) < diameter/2 && abs(dy)<diameter/2);
}

Animal (Vector3D v) {
  position = v;
}

void setPosition(Vector3D v) {
  position = v;
}

float getZ() {
 return position.getZ();
}

String getId() {
  return id;
 }
void setId(String s) {
  id = s;
}
void setGraph(Zoo h) {
  z = h;
}

void addToCurrentPosition(float x, float y, float z){
  p.position().set(x,y,z);
}

```

```
String toString(){
  return "Node ID: "+id+", label: "+label+", position: "+position;
 }
}

void initAnimals(){
 Table animalValuesTable = new Table("animalValues-10.txt");
 int rowCountAVT = animalValuesTable.getRowCount();
 Animal[] animals = new Animal[rowCountAVT-1];

 wetAnimals= new ArrayList();
 dryAnimals = new ArrayList();
 mixedAnimals = new ArrayList();
 hotAnimals = new ArrayList();
 coldAnimals= new ArrayList();
 temperateAnimals = new ArrayList();
 waterAnimals = new ArrayList();
 landAnimals = new ArrayList();
 treeAnimals = new ArrayList();
 skyAnimals = new ArrayList();
 earthAnimals = new ArrayList();
 undergroundAnimals = new ArrayList();
 abovegroundAnimals = new ArrayList();
 friends = new ArrayList();
 foes = new ArrayList();

 for (int j=1; j<rowCountAVT; j++){
 area = animalValuesTable.getFloat(j,3);
  diet = animalValuesTable.getString(j,16);
  common = animalValuesTable.getString(j,0);
  weight = animalValuesTable.getFloat(j,1);
  special = animalValuesTable.getString(j,11);
  temperature = animalValuesTable.getString(j,17);
  humidity = animalValuesTable.getString(j,18);
  active = animalValuesTable.getString(j,10);

  float trees = animalValuesTable.getFloat(j,20);
  float grass = animalValuesTable.getFloat(j,21);
  float bushes = animalValuesTable.getFloat(j,22);
  float soil = animalValuesTable.getFloat(j,23);
  float ice = animalValuesTable.getFloat(j,24);
  float water = animalValuesTable.getFloat(j,25);

  String sepType = animalValuesTable.getString(j,26);
  String roof = animalValuesTable.getString(j,29);
  float sepWidth = animalValuesTable.getFloat(j,28);
  float sepHeight = animalValuesTable.getFloat(j,27);

  String mountain = animalValuesTable.getString(j,30);
  animals[j-1] = new Animal(j-1, ps, common, weight, area, special, temperature, humidity,
        diet, active, trees, grass, bushes, soil, ice, water, sepType, sepWidth, sepHeight, roof,
        mountain);
  animals[j-1].setId(common);
  z.addSpace(animals[j-1], z.animals);
 }
}
```

```
//the following iterative sequences manage and orchestrate the seprations and links between spaces on
      every time sliced loop.
ArrayList separations = new ArrayList();

 /*use this to addmore connetions, particularly to neighbours*/
void addMoreLinks(){
 for (int i = 0; i < z.animals.size(); i++) {
  Animal a = (Animal)z.animals.get(i);
```

```
8
9       for (int j = 0; j < z.visitors.size(); j++) {
10    Human b = (Human)z.visitors.get(j);
11
12    Link tempLinkA = new Link(a, b, 1, 1.0, 1);
13       tempLinkA.s.turnOff();
14       z.animalHumanLinks.add(tempLinkA);
15     }
16
17  for (int j = i+1; j < z.animals.size(); j++) {
18     Animal b = (Animal)z.animals.get(j);
19
20     Link sepLink = new Link(a,b);
21     sepLink.s.turnOff();
22     separations.add(sepLink);
23
24     //Animals with the same dietary needs should be associated with one another
25     if(a.diet.equals(b.diet)){
26       float d = distance(a.p.position.x,a.p.position.y,b.p.position.x,b.p.position.y);
27       Link tempLink = new Link(a, b, 50.0, 1.0, d);
28       tempLink.s.turnOff();
29       z.dietLinks.add(tempLink);
30     }
31     //Animals with the same habitat needs should be associated with one another
32     if(a.stratum.equals(b.stratum)){
33       float d = distance(a.p.position.x,a.p.position.y,b.p.position.x,b.p.position.y);
34       Link tempLink = new Link(a, b, 50.0, 1.0, d);
35       tempLink.s.turnOff();
36       z.stratumLinks.add(tempLink);
37     }
38    }
39   }
40  }
41
42  void adjustLinks(){
43    for (int i = 0; i < z.animalHumanLinks.size(); i++) {
44    Link l = (Link)z.animalHumanLinks.get(i);
45    float minDist = l.a.radius+l.b.radius;
46
47    if(l.s.currentLength()>gateFactor*minDist && l.s.isOn()){
48      l.s.turnOff();
49    }
50     if(l.s.currentLength()<gateFactor*minDist && l.s.isOff()){
51      l.s.turnOn();
52      l.s.setRestLength(ahlLength);
53      l.s.setDamping(10);
54      l.s.setStrength(ahlStrength);
55    }
56   }
57
58    for (int i = 0; i < centroidLinks.size(); i++) {
59    Link l = (Link)centroidLinks.get(i);
60    l.s.setRestLength(clLength);
61    l.s.setDamping(10);
62    l.s.setStrength(clStrength);
63   }
64
65    for (int i = 0; i < separations.size(); i++) {
66      Link l = (Link)separations.get(i);
67      float minDist = l.a.radius+l.b.radius;
68      l.s.setRestLength(minDist*allSep);
69      if(l.s.currentLength()>gateFactor*minDist && l.s.isOn()){
70        l.s.turnOff();
71      }
72      if(l.s.currentLength()<gateFactor*minDist && l.s.isOff()){
73        l.s.turnOn();
74        l.s.setDamping(10);
75      }
76   }
77
78   for (int i = 0; i < z.dietLinks.size(); i++) {
79     Link l = (Link)z.dietLinks.get(i);
80
81     float minDist = l.a.radius+l.b.radius;
82     l.s.setRestLength(minDist*dietSep);
83    if(l.s.currentLength()>gateFactor*minDist && l.s.isOn()){
84     l.s.turnOff();
85    }
86    if(l.s.currentLength()<gateFactor*minDist && l.s.isOff()){
87     l.s.turnOn();
88     l.s.setDamping(10);
89    }
90   }
91
92   for (int i = 0; i < z.stratumLinks.size(); i++) {
93     Link l = (Link)z.stratumLinks.get(i);
94     float minDist = l.a.radius+l.b.radius;
95     l.s.setRestLength(minDist*strataSep);
96    if(l.s.currentLength()>gateFactor*minDist && l.s.isOn()){
97     l.s.turnOff();
98    }
99    if(l.s.currentLength()<gateFactor*minDist && l.s.isOff()){
100    l.s.turnOn();
101    l.s.setDamping(10);
102   }
103  }
104 }
105 void addSpacersToNodes(){
106  for (int i = 0; i < z.animals.size(); i++) {
107    Animal a = (Animal)z.animals.get(i);
108
109    for (int j = i+1; j < z.animals.size(); j++) {
110      Animal b = (Animal)z.animals.get(j);
111      float attDist = a.radius+b.radius;
112
113       //make room for carnivores
114      if (a != b && a.diet.equals("carnivore") || b.diet.equals("carnivore") ){
115        Attraction tempAtt = ps.makeAttraction( a.p, b.p, attStrength*5, attDist*attDist/5 );
116        z.dietAtt.add(tempAtt);
117       }
118   }
119  }
120 }
121
122 void adjustSpacers(){
123  for (int i = 0; i < z.dietAtt.size(); i++) {
124    Attraction a = (Attraction)z.dietAtt.get(i);
125    a.setMinimumDistance(attDist/5);
126    a.setStrength(attStrength*5);
127
128    Particle one = a.getOneEnd();
129    Particle two = a.getTheOtherEnd();
130
131    float d = distance(one.position.x,one.position.y,two.position.x,two.position.y);
132    if(a.isOn()){
133     if (d>100){
134      a.turnOff();
135     }
136    }
137    if(a.isOff()){
138     if (d<100){
139      a.turnOn();
140     }
141    }
142  }
143 }
```

CELLULAR ORGANISATION

REFER TO "INTERNAL DIFFERENTIATION" IN
CHAPTER 2: CONSTRUCTING THE ZOO MACHINE

FIG 4.4
TERRITORIAL PARTITIONING

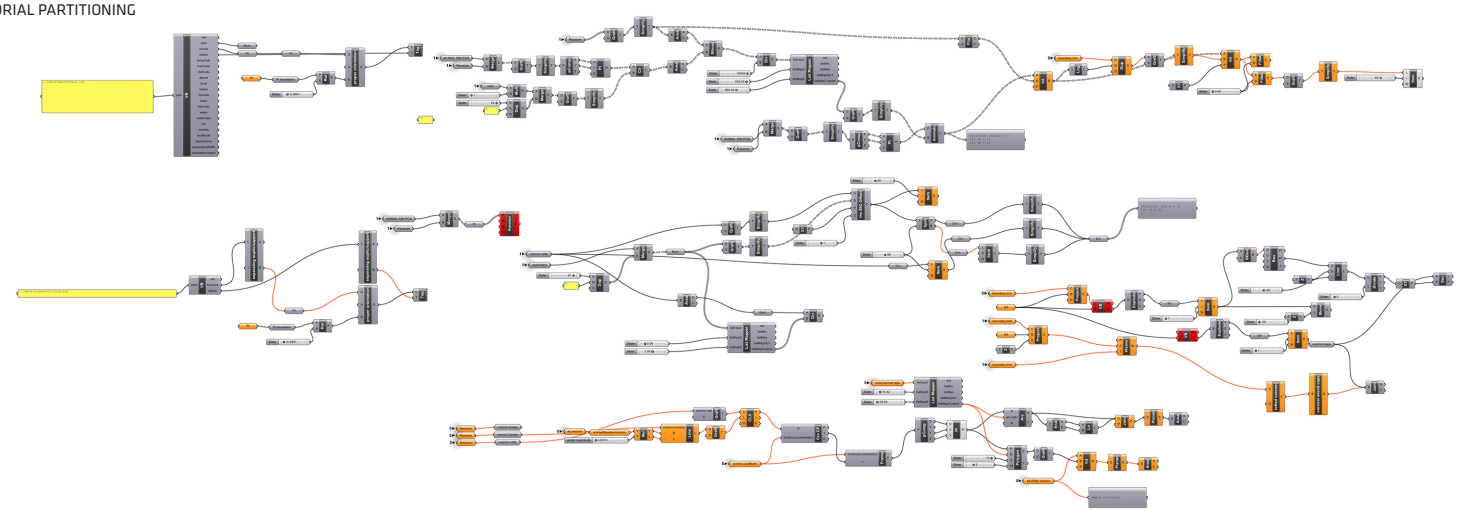
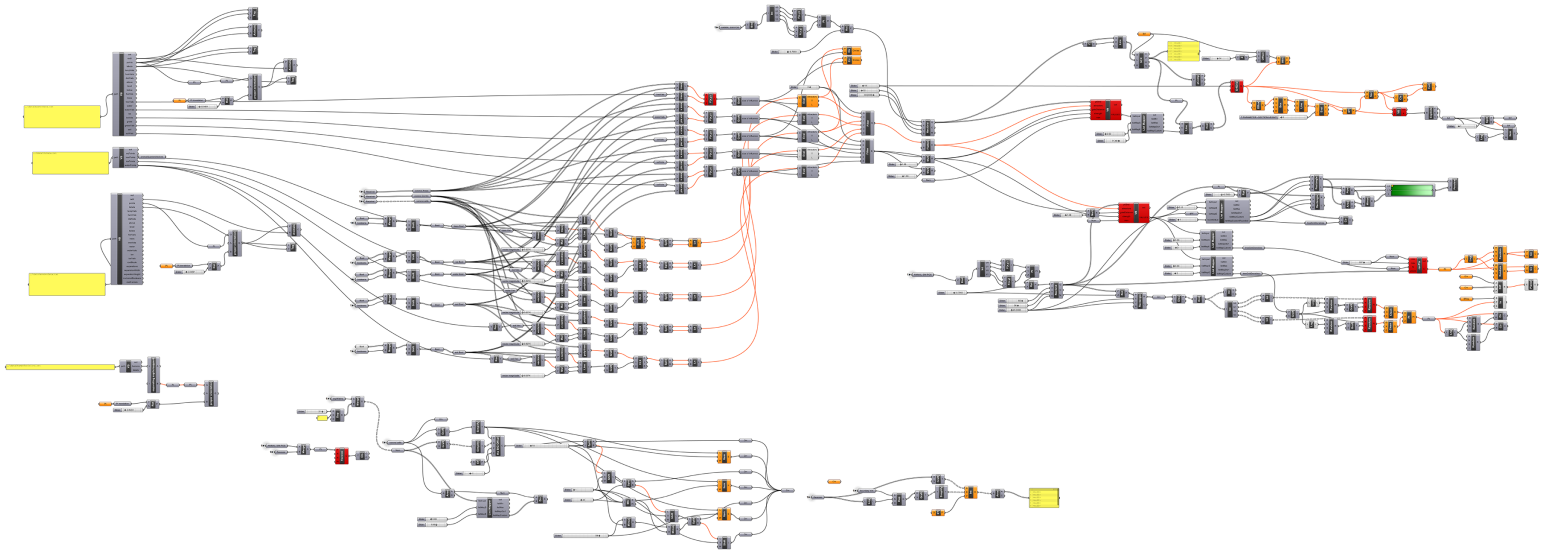


FIG 4.3
LANDCOVER SCHEMA



WET THREADS SIMULATION

REFER TO "THE BUNDLING SIMULATION" IN CHAPTER 2: CONSTRUCTING THE ZOO MACHINE

```
//A Processing simulation to orchestrate the visitor's pathways between exhibits. It proceeds from the
        FDL simulation, taking each space's vectors and species specific properties and translating them
        into a system composed of fixed particles connected by springs of free moving particles which
        are allowed to gather together
import peasy.org.apache.commons.math.*;
import peasy.*;
import peasy.org.apache.commons.math.geometry.*;
import processing.opengl.*;
import upsdnPhysics.*;
import processing.pdf.*;

ParticleSystem ps;
ArrayList free = new ArrayList();
ArrayList attractions = new ArrayList();
Particle fixedP;

Animal[] animals;
Hair[] hairs;
Human[] humans;

//attraction properties
float aDist = 1000; //8
float aStrength = 5000; //50

//spring properties
float sLength = 1;
float sStrength = 1;
float sDampening = 1;

float gateDist = 70;
float crossSize = 3;

float radius = 350;
int divisions = 16;

boolean displayNodes = false;
boolean toggle = false;
boolean record = false;
boolean xPhysics = true;
boolean optimize = false;
boolean adjust = false;

char x;
float neighbourhood = 100;
int particlesNo, attractionsNo;
int bFactor=2;

PeasyCam camera;

void setup() {
  size(1026,830, OPENGL);
  camera = new PeasyCam(this, 500, 500, 0, 450);
  ps = new ParticleSystem( 0, 0.1 );
  initAnimals();
  ps.addCustomForce(new Turbulence());
}

void draw(){
  if (record) {
    beginRecord(PDF, "frame-####.pdf");
  }
  if(xPhysics){
    ps.tick(0.1);
  }
  background(0);
  for(int i =0; i<animals.length; i++){
    animals[i].draw();
  }
  for(int i =0; i<humans.length; i++){
    humans[i].draw();
  }

  for (int i = 0; i < hairs.length; i++) {
    hairs[i].draw();
  }

  if (record) {
    exportGeometry();
  }

  if(optimize){
    if(xPhysics){
      xPhysics = false;
    }
    optimizePaths();
  }
  if(adjust){
    adjustForces();
  }
}

//initialization of Animal objects and "hairs" connecting them
void initAnimals(){
  Table hairPlayInit = new Table("hairPlayInit.txt");
  int rowCount = hairPlayInit.getRowCount();
  animals = new Animal[rowCount];

  Table hairPlayInitHumans = new  Table("humanPositions.txt");
  int rowCountHumans = hairPlayInitHumans.getRowCount();
  humans = new Human[rowCountHumans-8];
```

```

Particle[] fixed = new Particle[rowCount+rowCountHumans-8];
 hairs= new Hair[0];

 for (int j=0; j<rowCount; j++){
  float x = hairPlayInit.getFloat(j,0);
  float y = hairPlayInit.getFloat(j,1);
  float z = hairPlayInit.getFloat(j,2);
  String label = hairPlayInit.getString(j,3);
  String specialType = hairPlayInit.getString(j,4);
  String stratum = hairPlayInit.getString(j,5);
  String temp = hairPlayInit.getString(j,6);
  String humidity = hairPlayInit.getString(j,7);
  String diet = hairPlayInit.getString(j,8);
  animals[j] = new Animal(x,y,z,label, specialType, stratum, diet, temp, humidity);
  fixed[j] = animals[j].p;
 }

 for (int j=0; j<rowCountHumans-8; j++){
  float x = hairPlayInitHumans.getFloat(j+8,1);
  float y = hairPlayInitHumans.getFloat(j+8,2);
  float z = hairPlayInitHumans.getFloat(j+8,3);
  String label = hairPlayInitHumans.getString(j+8,0);
  humans[j] = new Human(x/5,y/5,z/5,label);
  fixed[j+rowCount] = humans[j].p;
 }

 for (int j = 0; j < humans.length; j++) {
  for (int i = 0; i < animals.length; i++) {
   PVector ptDifference = PVector.sub(humans[j].position, animals[i].position);
   animals[i].setProximity(ptDifference.mag());
  }

  Arrays.sort(animals, new AComparator02());
  for(int i =0; i<9; i++){
   Hair tempStrand = new Hair(animals[i].p, humans[j].p, x);
   hairs = (Hair[])append(hairs, tempStrand);
   animals[i].countConnections();
   humans[j].countConnections();
  }
 }

 for (int i = 0; i < animals.length; i++) {
  Animal focusAnimal = animals[i];

  for (int k = 0; k < animals.length; k++) {
   PVector ptDifference = PVector.sub(focusAnimal.position, animals[k].position);
   if (i!=k){
    animals[k].setProximity(100000);
   }
   else{
    animals[k].setProximity(ptDifference.mag());
   }
  }

  Arrays.sort(animals, new AComparator02());

  for (int j = 0; j < animals.length-1; j++) {
   if(!neighbours(focusAnimal, animals[j])){
    if(!focusAnimal.label.equals(animals[j].label)){
     if(focusAnimal.connected<4){
      float distance = PVector.dist(focusAnimal.position, animals[j].position);
      if(distance<65  && focusAnimal.stratum.equals(animals[j].stratum)){
       x= 'b';
       Hair tempStrand = new Hair(focusAnimal.p, animals[j].p, x);
       hairs = (Hair[])append(hairs, tempStrand);
       focusAnimal.countConnections();
       focusAnimal.neighbours = (Animal[])append(focusAnimal.neighbours, animals[j]);
       animals[j].neighbours = (Animal[])append(animals[j].neighbours, focusAnimal);
      }

      else if( focusAnimal.connected<5 && animals[j].connected<5 && distance<100 && focusAnimal.temp.equals(animals[j].temp) && focusAnimal.humidity.equals(animals[j].humidity) && !neighbours(focusAnimal, animals[j])){
       x= 'c';
       Hair tempStrand = new Hair(focusAnimal.p, animals[j].p, x);
       hairs = (Hair[])append(hairs, tempStrand);
       focusAnimal.countConnections();
       focusAnimal.neighbours = (Animal[])append(focusAnimal.neighbours, animals[j]);
       animals[j].neighbours = (Animal[])append(animals[j].neighbours, focusAnimal);
      }

      else if( focusAnimal.connected<5 && animals[j].connected<5   && distance<100 && animals[i].diet.equals(animals[j].diet) && !neighbours(focusAnimal, animals[j])){
       x = 'a';
       Hair tempStrand = new Hair(focusAnimal.p, animals[j].p, x);
       hairs = (Hair[])append(hairs, tempStrand);
       focusAnimal.countConnections();
focusAnimal.neighbours = (Animal[])append(focusAnimal.neighbours, animals[j]);
       animals[j].neighbours = (Animal[])append(animals[j].neighbours, focusAnimal);
      }
     }
    }
   }
  }
 }

 particlesNo = ps.numberOfParticles();

 Particle a, b;
 for(int i = 0; i<particlesNo; i++){
  a = (Particle)ps.getParticle(i);
  PVector vA = new PVector(a.position.x, a.position.y, a.position.z);

  for(int j = i+1; j<particlesNo; j++){
   b = (Particle)ps.getParticle(j);
   PVector vB = new PVector(b.position.x,b.position.y, a.position.z);

   float distance = PVector.dist(vA, vB);
   Attraction tempAtt = ps.makeAttraction(a, b, distance/3, distance/12);
   attractions.add(tempAtt);
   if(distance>25){
    tempAtt.turnOff();
   }
  }
 }
 attractionsNo = ps.numberOfAttractions();
}

//sequence for adjusting the forces between free moving particles
void adjustForces(){
 Attraction a;
 Particle b, c;
 for(int i = 0; i<attractionsNo; i++){

  a = (Attraction)ps.getAttraction(i);
  b = a.getOneEnd();
  c = a.getTheOtherEnd();

  PVector vA = new PVector(b.position.x, b.position.y, b.position.z);
  PVector vB = new PVector(c.position.x, c.position.y, c.position.z);

  float distance = PVector.dist(vA, vB);
  if (distance<25 && a.isOff()){
   a.turnOn();
  }
```

```
    if (distance<25 && a.isOn()){
      a.setStrength(distance/2);
      a.setMinimumDistance(distance/2);
    }
    else if(distance>25 && a.isOn()){
      a.turnOff();
    }
  }
}

class AComparator implements Comparator {
  int compare(Object o1, Object o2) {
    float d1 = ((PVector) o1).mag();
    float d2 = ((PVector) o2).mag();
    return (d1<d2) ? -1 : (d1==d2) ? 0 : 1;
  }
}
class AComparator02 implements Comparator {
  int compare(Object o1, Object o2) {
    float d1 = ((Animal)o1).proximity;
    float d2 = ((Animal)o2).proximity;
    return (d1<d2) ? -1 : (d1==d2) ? 0 : 1;
  }
}

void optimizePaths(){
  for(int i = 0; i<hairs.length; i++){
    for(int j=1; j<hairs[i].cPts.length-1; j++){

      PVector ptA = new PVector(hairs[i].cPts[j].position.x, hairs[i].cPts[j].position.y, hairs[i].
          cPts[j].position.z);
      PVector[] closestPts = new PVector[0];

      for(int k = 0; k<hairs.length; k++){
        PVector[] kPts = new PVector[0];
        PVector kClosestPt = new PVector();

        if(k!=i){
          for(int l=1; l<hairs[k].cPts.length-1; l++){
            PVector ptB = new PVector(hairs[k].cPts[l].position.x, hairs[k].cPts[l].position.y,
            hairs[k].cPts[l].position.z);
            PVector ptDifference = PVector.sub(ptA, ptB);
            kPts = (PVector[]) append(kPts, ptDifference);
          }
        }

        if(kPts.length>0){
          Arrays.sort(kPts, new AComparator());
          kClosestPt = kPts[0];
          closestPts = (PVector [])append(closestPts, kClosestPt);
        }
      }

      Arrays.sort(closestPts, new AComparator());
      float distance = ptA.dist(closestPts[0]);

      if(distance<200){
        PVector vec = closestPts[0];
        vec.mult(-0.1);
        PVector newPos = PVector.add(ptA, vec);
        line(ptA.x, ptA.y, ptA.z, newPos.x, newPos.y, newPos.z);
        hairs[i].cPts[j].position().set(newPos.x, newPos.y, newPos.z);
        hairs[i].cPts[j].makeFixed();
      }
    }
  }
}

void exportGeometry(){
  saveFrame("frame-####.png");
  endRecord();
  record = false;

  PrintWriter output1 = createWriter("beziers.txt");
  PrintWriter output2 = createWriter("lines.txt");

  for (int i = 0; i < hairs.length; i++) {
    if(hairs[i].cPts.length>2){
      output2.print(hairs[i].cPts[0].position.x +","+ hairs[i].cPts[0].position.y +","+  hairs[i].
          cPts[0].position.z +"," +(hairs[i].cPts[1].position.x + hairs[i].cPts[0].position.x)/2 +","+
          (hairs[i].cPts[0].position.y + hairs[i].cPts[1].position.y) /2 +","+ (hairs[i].cPts[0].position.z
          + hairs[i].cPts[1].position.z) /2);

      int numCPts = hairs[i].cPts.length;

      for (int j = 1; j < hairs[i].cPts.length-2; j++) {
        output1.print((hairs[i].cPts[j-1].position.x+hairs[i].cPts[j].position.x)/2 +","+ (hairs[i].
          cPts[j-1].position.y+hairs[i].cPts[j].position.y) /2 +","+ (hairs[i].cPts[j-1].position.
          z+hairs[i].cPts[j].position.z) /2 +","+hairs[i].cPts[j].position.x +","+hairs[i].cPts[j].
          position.y +"," +hairs[i].cPts[j].position.z +"," +hairs[i].cPts[j].position.x +","+ hairs[i].
          cPts[j].position.y +"," +hairs[i].cPts[j].position.z +","+ (hairs[i].cPts[j+1].position.x +
          hairs[i].cPts[j].position.x)/2 +","+ (hairs[i].cPts[j+1].position.y + hairs[i].cPts[j].position.y)
          / 2 +","+ (hairs[i].cPts[j+1].position.z + hairs[i].cPts[j].position.z) / 2+",");
      }
      output1.println((hairs[i].cPts[numCPts-3].position.x+hairs[i].cPts[numCPts-2].position.x)/2
          +","+ (hairs[i].cPts[numCPts-3].position.y+hairs[i].cPts[numCPts-2].position.y) /2
          +","+ (hairs[i].cPts[numCPts-3].position.z+hairs[i].cPts[numCPts-2].position.z) /2
          +","+hairs[i].cPts[numCPts-2].position.x +","+hairs[i].cPts[numCPts-2].position.y +","
          +hairs[i].cPts[numCPts-2].position.z +"," +hairs[i].cPts[numCPts-2].position.x +","+
          hairs[i].cPts[numCPts-2].position.y +"," +hairs[i].cPts[numCPts-2].position.z +","+
          (hairs[i].cPts[numCPts-2].position.x + hairs[i].cPts[numCPts-1].position.x)/2 +","+
          (hairs[i].cPts[numCPts-2].position.y + hairs[i].cPts[numCPts-1].position.y) / 2 +","+
          (hairs[i].cPts[numCPts-2].position.z + hairs[i].cPts[numCPts-1].position.z) / 2);
      output2.println(","+ hairs[i].cPts[hairs[i].cPts.length-1].position.x +","+ hairs[i].cPts[hairs[i].
          cPts.length-1].position.y +","+ hairs[i].cPts[hairs[i].cPts.length-1].position.z +","+
          (hairs[i].cPts[hairs[i].cPts.length-2].position.x + hairs[i].cPts[hairs[i].cPts.length-1].
          position.x )/2 +","+ (hairs[i].cPts[hairs[i].cPts.length-2].position.y + hairs[i].cPts[hairs[i].
          cPts.length-1].position.y )/2 +","+ (hairs[i].cPts[hairs[i].cPts.length-2].position.z +
          hairs[i].cPts[hairs[i].cPts.length-1].position.z )/2);
    }
  }
  output1.flush();
  output1.close();
  output2.flush();
  output2.close();
}
void keyPressed(){
  if(key=='d') displayNodes=!displayNodes;
  if(key=='t') toggle=!toggle;
  if (key == 'r') record =! record;
  if (key == 'x') xPhysics =! xPhysics;
  if (key == 'o') optimize =! optimize;
  if (key == 'a') adjust =! adjust;
  if (key == '[') bFactor++;
  println(bFactor);
  if (key == ']') bFactor—;
  println(bFactor);
}

public class Turbulence implements Force {
  int ForceX, ForceY;
  float nScale = 1;
  float timeScale = 1;
  float amp = 1;
  float sample = 0.47;
```

```
  public void apply(){

    for(int i = 0; i<particlesNo; i++){
      Particle p = (Particle)ps.getParticle(i);

      ForceX  += ((noise(p.position.x/nScale, p.position.y/nScale, float(frameCount)/timeScale))-
          sample)*amp;
      ForceY += ((noise(p.position.x/nScale, p.position.y/nScale + 1000, float(frameCount)/
          timeScale))-sample)*amp;

      p.force().add( ForceX, ForceY, 0 );
    }
  }
  boolean isOn(){
    return true;
  }
  void turnOff(){
  }
  boolean isOff(){
    return false;
  }
}

boolean neighbours(Animal a, Animal b){
  for(int i = 0; i<a.neighbours.length; i++){
    if(a.neighbours[i] == b ){
      println(a.label +" and "+ b.label +" are neighbours yes");
      return true;
    }
  }
  println("No, "+ a.label +" and "+ b.label +" are not neighbours yet");
  return false;
}
```

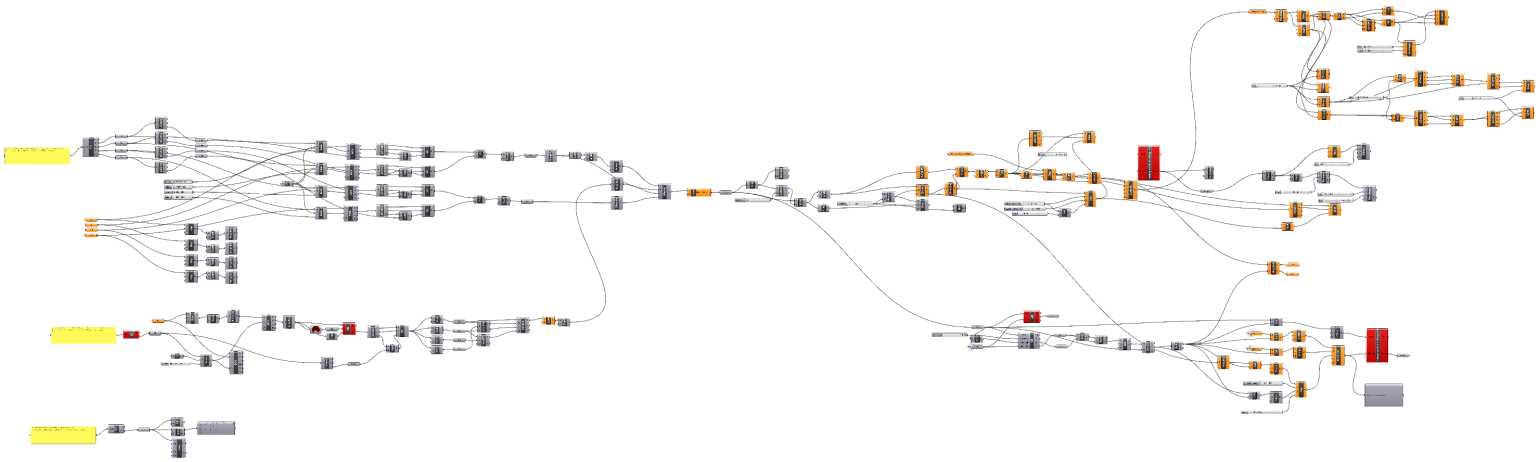
```
class Hair{
  Particle pA, pB;
  PVector a, b;
  Particle[] cPts;
  Spring[] segments;
  char type;
  float z;
  int numP;

  //very important to simulation...
  int numPfactor = 14; //was 12 before

  Hair(Particle pA, Particle pB, char type){
    this.type = type;
    this.z = pA.position.z;

    PVector a = new PVector(pA.position.x, pA.position.y, pA.position.z);
    PVector b = new PVector(pB.position.x, pB.position.y, pB.position.z);

    float tempDistance = a.dist(b);
    numP = ceil(tempDistance/numPfactor)+1;
    cPts = new Particle[numP];
    cPts[0] = pA;
    cPts[cPts.length-1] = pB;

    for(float i = 1; i<cPts.length-1; i++){
      cPts[int(i)] = ps.makeParticle(1, (1-i/cPts.length)*a.x+b.x*(i/cPts.length), (1-i/cPts.length)*a.
          y+b.y*(i/cPts.length), (1-i/cPts.length)*a.z + b.z*(i/cPts.length));
      free.add(cPts[int(i)]);
    }
    segments = new Spring[cPts.length-1];
    for(int i = 0; i<segments.length; i++){
      PVector tempA = new PVector(cPts[i].position.x, cPts[i].position.y, cPts[i].position.z);
      PVector tempB = new PVector(cPts[i+1].position.x, cPts[i+1].position.y, cPts[i+1].position.z);
      float distance = PVector.dist(tempA, tempB);
      segments[i] = ps.makeSpring(cPts[i], cPts[i+1], sStrength, sDampening, distance*sLength);
    }
  }

  void draw(){
    switch(type){
    case 'a':
      stroke(255, 0, 0);
      break;
    case 'b':
      stroke(0, 255, 0);
      //keeps hair on one plane
      for (int i = 0; i<cPts.length;i++){
        float x = cPts[i].position().x();
        float  y = cPts[i].position().y();
        cPts[i].position().set(  x,  y,  this.z );
      }
      break;
    case 'c':
      stroke(0, 0, 255);
      break;
    }

    strokeWeight(0.5);

    if(!toggle){
      if(cPts.length>2){
        line(cPts[0].position.x, cPts[0].position.y, cPts[0].position.z, (cPts[1].position.x+cPts[0].
            position.x)/2, (cPts[0].position.y+cPts[1].position.y) /2, (cPts[0].position.z + cPts[1].
            position.z) /2);
        for(int i = 1; i<cPts.length-1; i++){
          PVector A = new PVector((cPts[i-1].position.x+cPts[i].position.x)/2, (cPts[i-1].position.
              y+cPts[i].position.y) /2, (cPts[i-1].position.z + cPts[i].position.z) /2);
          PVector B = new PVector(cPts[i].position.x, cPts[i].position.y, cPts[i].position.z);
          PVector C = new PVector((cPts[i+1].position.x+cPts[i].position.x)/2, (cPts[i+1].position.
              y+cPts[i].position.y) /2, (cPts[i+1].position.z + cPts[i].position.z) /2);

          PVector handle1 = new PVector(B.x-A.x, B.y-A.y, B.z-A.z);
          float hLength1 = handle1.mag();
          handle1.normalize();
          handle1.mult(hLength1/bFactor); //25 is nice

          PVector handle2 = new PVector(B.x-C.x, B.y-C.y, B.z-C.z);
          float hLength2 = handle2.mag();
          handle2.normalize();
          handle2.mult(hLength2/bFactor);

          bezier(A.x, A.y, A.z , A.x+handle1.x, A.y+ handle1.y, A.z+ handle1.z  , C.x + handle2.x ,
              C.y + handle2.y, C.z + handle2.z , C.x, C.y, C.z);
        }
        line(cPts[cPts.length-1].position.x, cPts[cPts.length-1].position.y, cPts[cPts.length-1].
            position.z, (cPts[cPts.length-2].position.x+cPts[cPts.length-1].position.x )/2, (cPts[cPts.
            length-2].position.y+cPts[cPts.length-1].position.y )/2, (cPts[cPts.length-2].position.
            z+cPts[cPts.length-1].position.z )/2);
      }
    }

    if(toggle){
      beginShape();
      curveVertex(cPts[0].position.x, cPts[0].position.y, cPts[0].position.z);
      curveVertex(cPts[0].position.x, cPts[0].position.y, cPts[0].position.z);
      for (int i = 1; i<cPts.length-1;i++){
        curveVertex(cPts[i].position.x, cPts[i].position.y, cPts[i].position.z);
      }
```

```
    curveVertex(cPts[cPts.length-1].position.x, cPts[cPts.length-1].position.y, cPts[cPts.length-1].position.z);
    curveVertex(cPts[cPts.length-1].position.x, cPts[cPts.length-1].position.y, cPts[cPts.length-1].position.z);
    endShape();
   }

   if(displayNodes){
    fill(255);
    strokeWeight(0.5);
    for(int i = 1; i<cPts.length; i++){
      line(cPts[i].position.x-crossSize, cPts[i].position.y, cPts[i].position.z, cPts[i].position.x+crossSize, cPts[i].position.y, cPts[i].position.z);
      line(cPts[i].position.x, cPts[i].position.y-crossSize, cPts[i].position.z, cPts[i].position.x, cPts[i].position.y+crossSize, cPts[i].position.z);
    }
    noFill();
   }
  }
}
```

```
class Animal{
 float x, y, z;
 String label, specialType, stratum ,diet, temp, humidity;
 PVector position;
 Particle p;
 int connected=0;
 float proximity;
 Animal[] neighbours = new Animal[0];

 Animal(float x, float y, float z, String label, String specialType, String stratum, String diet, String temp, String humidity){
  this.label = label;
  this.specialType = specialType;
  this.diet = diet;
  this.temp = temp;
  this.humidity = humidity;
  this.stratum = stratum;
  this.p = ps.makeParticle(1, x, y, z);
  this.p.makeFixed();
  position= new PVector( x, y , z);
 }
 void draw(){
  if(connected>0){
    stroke(255,99,0); }
  else{
    stroke(255,99); }
  strokeWeight(0.1);
  fill(255,50);
  pushMatrix();
  translate(0,0,position.z);
  ellipse(position.x, position.y, 3, 3);
  popMatrix();
  noFill();
 }
 void countConnections(){
  connected++;
 }
 void setProximity(float distance){
  proximity = distance;
 }
}
```

```
class Human{
 float x, y, z;
 String label;
 PVector position;
 Particle p;
 int connected=0;

 Human(float x, float y, float z, String label){
  this.label = label;
  this.p = ps.makeParticle(1, x, y, z);
  this.p.makeFixed();
  position= new PVector( x, y , z);
 }

 void draw(){
  stroke(255,99);
  strokeWeight(0.1);
  fill(255);
  pushMatrix();
  translate(0,0,position.z);
  ellipse(position.x, position.y, 5, 5);
  popMatrix();
  noFill();
 }

 void countConnections(){
  connected++;
 }
}
```

FIG 4.5
WET THREADS MANIPULATION



WET THREAD PROCESSING

REFER TO "VISITOR PATHWAYS"
IN
CHAPTER 2: CONSTRUCTING THE ZOO MACHINE

```
Private Sub RunScript(ByVal crv As List(Of OnCurve), ByVal inPts As List(Of On3dPoint), ByRef
        A As Object, ByRef B As Object)
  Dim d1 As Double = Double.MaxValue
  Dim min1 As Int32 = -1
  Dim closest As New list(Of On3dPoint)
  Dim closestVals As New List(Of Double)
  For j As int32 = 0 To crv.Count - 1
    For i As Int32 = 1 To inPts.Count() - 1
      Dim t As New Double
      crv(j).GetClosestPoint(inPts(i), t)
      Dim cPt As New On3dPoint
      cPt = crv(j).PointAt(t)
      Dim d As Double = inPts(i).DistanceTo(cPt)
      If (d < d1) Then
        d1 = d
        min1 = i
      End If
    Next
    closest.add(inPts(min1))
    Dim u As New Double
    crv(j).GetClosestPoint(inPts(min1), u)
    closestVals.Add(u)
  Next

  A = closest
  B = closestVals

End Sub
```

```
Private Sub RunScript(ByVal path As String, ByRef A As Object, ByRef At As Object, ByRef B As
        Object, ByRef Bt As Object)
  If (Not IO.File.Exists(path)) Then Return

  Dim lines As String() = IO.File.ReadAllLines(path)

 If (lines Is Nothing) Then Return
  Dim beziersA, beziersAt, beziersB, beziersBt  As New List(Of On3dPoint)

  For Each line As String In lines
  Dim parts As String() = line.Split(",".ToCharArray())
    Dim x1 As Double = Convert.ToDouble(parts(0))
    Dim y1 As Double = Convert.ToDouble(parts(1))
    Dim z1 As Double = Convert.ToDouble(parts(2))
    beziersA.Add(New On3dPoint(5 * x1, -5 * y1, 5 * z1))
    Dim x2 As Double = Convert.ToDouble(parts(3))
    Dim y2 As Double = Convert.ToDouble(parts(4))
    Dim z2 As Double = Convert.ToDouble(parts(5))
    beziersAt.Add(New On3dPoint(5 * x2, -5 * y2, 5 * z2))
    Dim x3 As Double = Convert.ToDouble(parts(6))
    Dim y3 As Double = Convert.ToDouble(parts(7))
    Dim z3 As Double = Convert.ToDouble(parts(8))
    beziersB.Add(New On3dPoint(5 * x3, -5 * y3, 5 * z3))
    Dim x4 As Double = Convert.ToDouble(parts(9))
    Dim y4 As Double = Convert.ToDouble(parts(10))
    Dim z4 As Double = Convert.ToDouble(parts(11))
    beziersBt.Add(New On3dPoint(5 * x4, -5 * y4, 5 * z4))
  Next
  A = beziersA
  At = beziersAt
  B = beziersB
  Bt = beziersBt
End Sub

```

```
Private Sub RunScript(ByVal curves As List(Of OnCurve), ByVal threshold As Double, ByVal
        crvLength As List(Of Double), ByVal centres As List(Of On3dPoint), ByRef A As Object,
        ByRef B As Object, ByRef C As Object)
  Dim i, j As New Integer
  Dim tVals As New List(Of Double)
  Dim bools As New list(Of Boolean)
  Dim lengths As New List(Of Double)
  Dim closestPtsList As New List(Of On3dPointArray)
  Dim closestPtParam As New Double
  Dim ptArray, closestPts, applicableCentres, testCentres As New On3dPointArray
  Dim crvPt As New On3dPoint
  For i = 0 To curves.Count - 1 Step 1
    If crvLength(i) > threshold Then
      Dim p0 As New On3dPoint(curves(i).PointAtStart())
      Dim p1 As New On3dPoint(curves(i).PointAtEnd())
      For j = 0 To centres.Count - 1
        If centres(j) <> p0 And centres(j) <> p1 Then
          ptArray.Append(centres(j))
        End If
      Next
      If crvLength(i) > threshold Then
        For  j = 0 To ptArray.count - 1
          curves(i).GetClosestPoint(ptArray(j), closestPtParam)
          'I don't want swells at the beginning or end of the curve
          If closestPtParam <> 0 And closestPtParam <> 1
            crvPt = curves(i).pointat(closestPtParam)
            closestPts.Append(crvPt)
            applicableCentres.append(ptArray(j))
            'Else If closestPtParam <> 0 Or closestPtParam <> 1 Then
            ' ptArray.Remove(j)
          End If
        Next
      End If
      closestPtsList.Add(closestPts)
    End If
  Next

  A = tVals
  B = applicableCentres
  C = closestPts
End Sub
```

ATTRACTOR PATTERN

REFER TO "ENVELOPE" IN
CHAPTER 2: CONSTRUCTING THE ZOO MACHINE

```
//An attractor pattern which allocates values to each point in an array - in this case a grid - based on their porximity to a list of attractors. In this version, only if the distance between attractor and point is under a given value, here simply called "distance". A gaussian or normal function is implemented here to get an easing in and out of each attractor's zone of influence.
Sub RunScript(ByVal ptGrid As List(Of On3dPoint), ByVal attractors As List(Of On3dPoint), ByVal gateDistance As List(Of Double), ByVal strength As List(Of Double), ByVal max As Double)

  Dim intensityValues As New List(Of Double)
  Dim i As Integer
  Dim j As Integer

  For i = 0 To ptGrid.Count - 1 Step 1

    Dim intVal As New Double
    intVal = 0.0

    For j = 0 To attractors.Count - 1 Step 1
      Dim distance As Double
        distance = attractors(j).DistanceTo(ptGrid(i))

      If distance < gateDistance(j) Then
        intVal = intVal + strength(j) * exp(-((distance) ^ 2 / (2 * gateDistance(j) ^ 2))) / (gateDistance(j) * sqrt(2 * PI))
      End If

    Next

    intensityValues.Add(intVal)
  Next

  VALUES = intensityValues

End Sub
```

FIG 4.6
ENVELOPE PANEL ARTICULATION

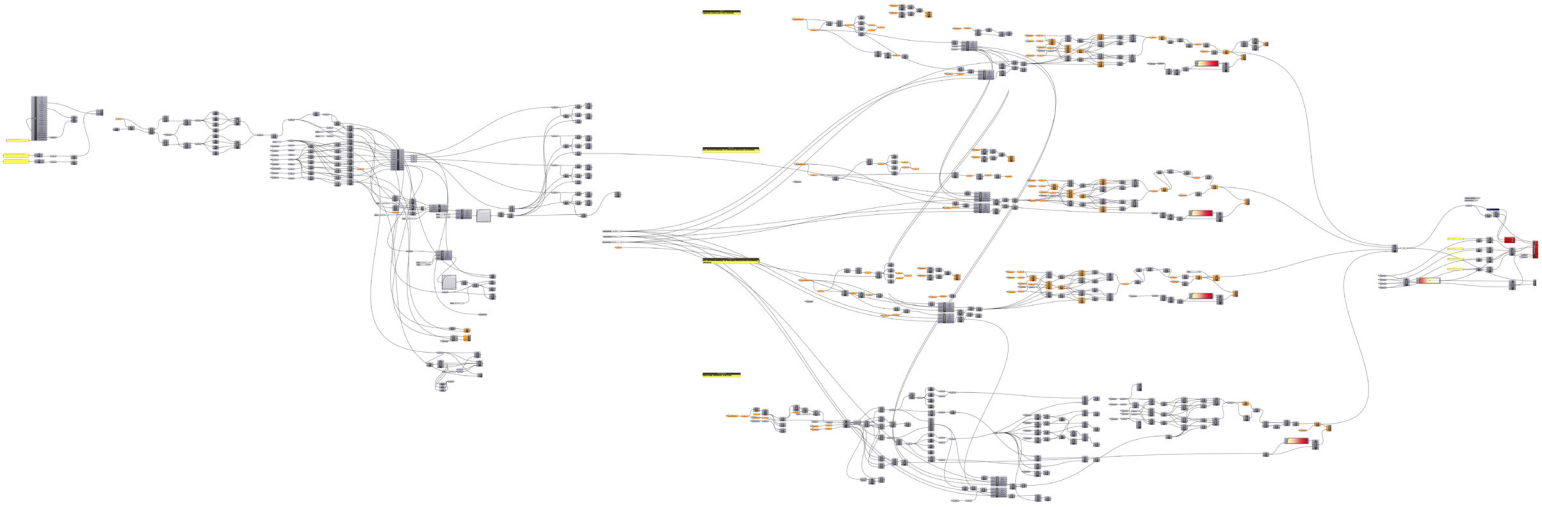
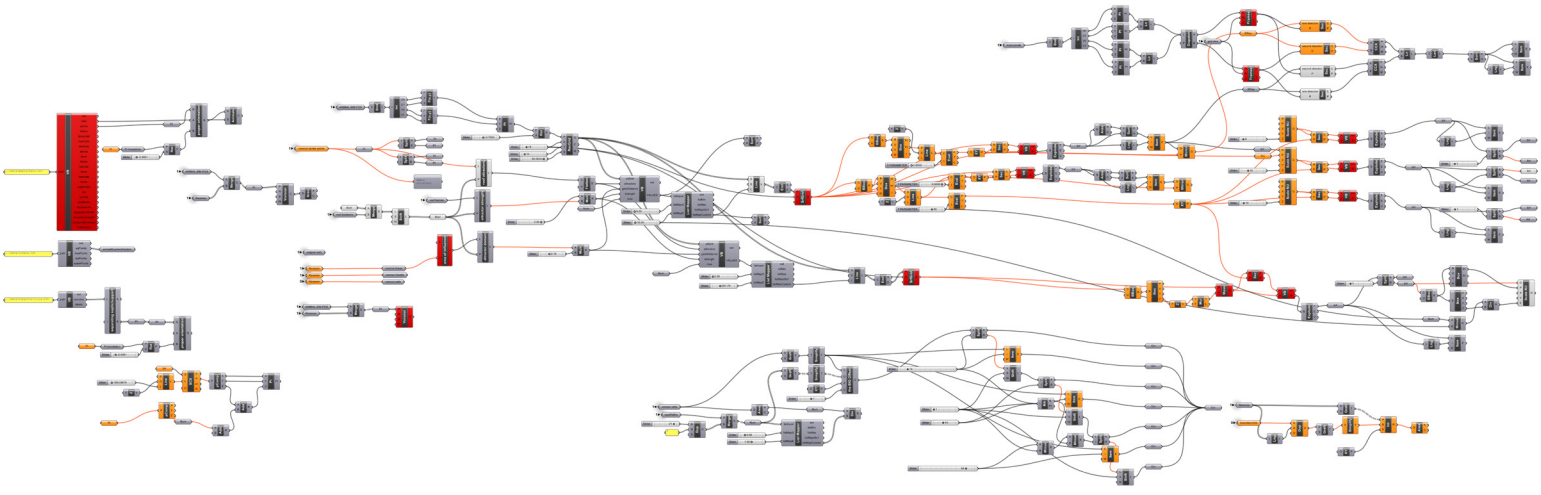


FIG 4.7
ENVELOPE GEOMETRY



TRIANGULATION SCHEMA

REFER TO "ENVELOPE"
IN
CHAPTER 2: CONSTRUCTING THE ZOO MACHINE

```
Private Sub RunScript(ByVal triangles As OnCurve, ByRef A As Object)

  Dim new_polylines As New List(Of OnPolyline)
  Dim polyline As New OnPolyline()
  Dim i,j, k As Int32

  For i = 0 To triangles.Count - 1

    Dim triangle As OnCurve
    triangle = triangles(i)
    Dim knots(), mids() As Double
    triangle.GetSpanVector(knots)

    For j = 0 To 2

      Dim vertices, midPoints As List(Of On3dPoint)
      Dim tempPt As On3dPoint
      tempPt = triangle.PointAt(knots(j))
      vertices.Add(tempPt)

      If j = 0 Then
        mids(0) = knots(0) - knots(2)
      Else
        mids(j) = knots(j) - knots(j - 1)
      End If

      For k = 0 To 2
        tempPt = triangle.PointAt(mids(k))
        midPoints.Add(tempPt)
      Next

    Next

  Next

  A = midPoints

End Sub
```

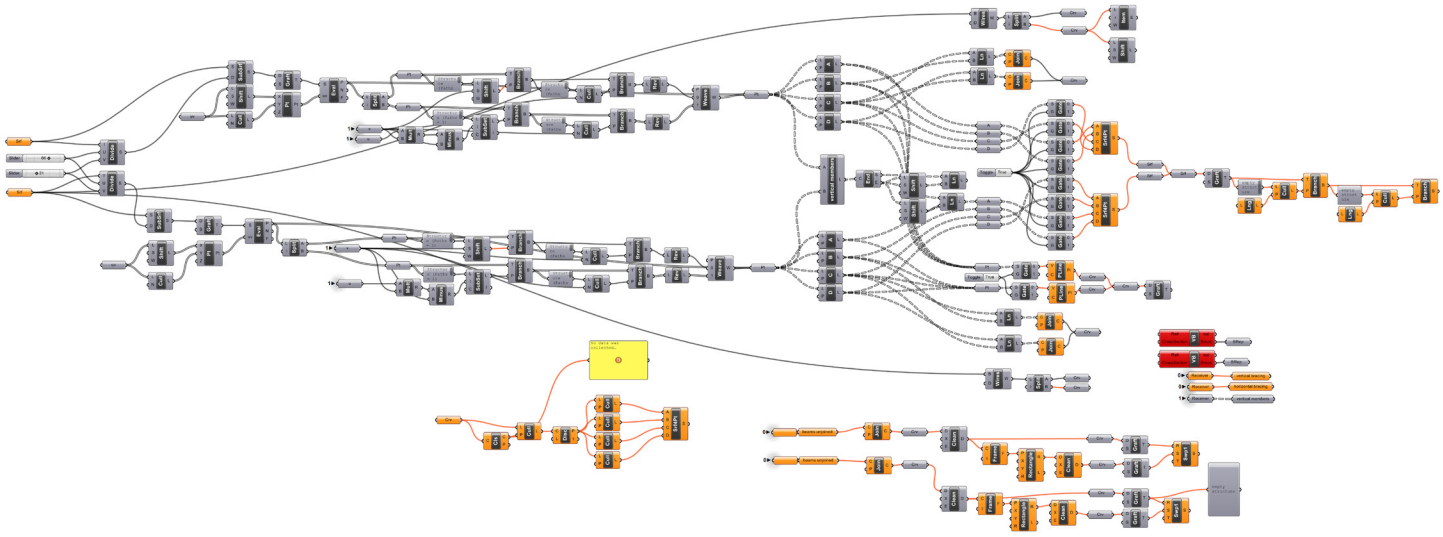
```
Private Sub RunScript(ByVal vertices As List(Of On3dPoint), ByVal midpts As List(Of
        On3dPoint), ByRef A As Object)

  Dim new_polylines As New List(Of OnPolyline)

  For i As int32 = 0 To 2
```

```

      Dim polyline As New OnPolyline()
      polyline.Append(midpts(i))
      polyline.Append(vertices(i))

      If i = 2 Then
       polyline.Append(midpts(0))
      Else
       polyline.Append(midpts(i + 1))
      End If

      new_polylines.Add(polyline)

    Next

  A = new_polylines

End Sub
```

```
Private Sub RunScript(ByVal vertices As List(Of On3dPoint), ByVal midpts As List(Of
        On3dPoint), ByRef A As Object)

  Dim new_polylines As New List(Of OnPolyline)

  For i As int32 = 0 To 2

    Dim polyline As New OnPolyline()
    polyline.Append(midpts(i))
    polyline.Append(vertices(i))

    If i = 2 Then
      polyline.Append(midpts(0))
    Else
      polyline.Append(midpts(i + 1))
    End If

    new_polylines.Add(polyline)

  Next

  A = new_polylines

End Sub
```

```
Private Sub RunScript(ByVal vertices As List(Of On3dPoint), ByVal midpts As List(Of
        On3dPoint), ByRef A As Object)

  Dim new_polylines As New List(Of OnPolyline)
  Dim polyline As New OnPolyline()

  polyline.Append(midpts(0))
  polyline.Append(midpts(1))
  polyline.Append(midpts(2))
  polyline.Append(midpts(0))

  new_polylines.Add(polyline)

  A = new_polylines

End Sub
```

FIG 4.8
STRUCTURAL GRID



BIBLIOGRAPHY

Allan, John, and Berthold Lubetkin. *Berthold Lubetkin : Architecture and the Tradition of Progress*. London: RIBA Publications, 1992. Print.

Allen, Stan. *Points + Lines : Diagrams and Projects for the City*. 1st ed. New York: Princeton Architectural Press, 1999. Print.

Altinisik, Melike, et al. *Morphê : MRGD*. Wien ; New York ; London: Springer, 2008. Print.

Aranda, Benjamin, and Chris Lasch. *Tooling*. 27 Vol. New York: Princeton Architectural Press, 2006. Print.

Balmond, Cecil, Jannuzzi Smith, and Christian Brensing. *Informal*. Munich ; New York: Prestel, 2002. Print.

Cosgrove, Denis E. *Mappings*. London: Reaktion Books, 1999. Print.

Czerniak, Julia, and Harvard University. Graduate School of Design. *CASE—Downsview Park Toronto*. Munich : London: Prestel, 2001. Print.

Foreign Office Architects, et al. *Phylogenesis : Foa's Ark*. Barcelona, Spain: Actar, 2004. Print.

Halprin, Lawrence. *The Rsvp Cycles; Creative Processes in the Human Environment*. New York, G. Braziller C1969:Print.

Hensel, Michael, Achim Menges, and Architectural Association. *Morpho-Ecologies*. London: Architectural Association, 2006. Print.

Hensel, Michael, Achim Menges, and Michael Weinstock. *Techniques and Technologies in Morphogenetic Design*. 180 Vol. London: Wiley-Academy, 2006. Print.

Hight, Christopher, and Chris Perry. *Collective Intelligence in Design*. profile no. 183, v. 76, no. 5 Vol. Chichester, England: Wiley-Academy, 2006. Print.

Lally, Sean, Jessica Young, and Rice University. School of Architecture. *Softspace : From a Representation of Form to a Simulation of Space*. 41 Vol. New York: Taylor and Francis, 2006. Print.

Lynn, Greg. *Animate Form*. New York: Princeton Architectural Press, 1999. Print.

Oosterhuis, Kas, and Lukas Feireiss. *The Architecture Co-Laboratory : GameSetandMatch II : On Computer Games, Advanced Geometries, and Digital Technologies*. Rotterdam: Episode Publishers, 2006. Print.

Otto, Frei, Winfried Nerdinger, and Technische Universität München. Architekturmuseum. *Frei Otto : Complete Works : Lightweight Construction, Natural Design*. Basel ; Boston: Birkhäuser, 2005. Print.

Rahim, Ali, and Hina Jamelle. *Elegance*. 185 Vol. Chichester, England: John Wiley, 2007. Print.

Rahim, Ali. *Catalytic Formations : Architecture and Digital Design*. London: Taylor & Francis, 2006. Print.

Rahim, Ali. *Contemporary Processes in Architecture*. 145 Vol. Bognor Regis, Eng.: Wiley-Academy, 2000. Print.

Rahim, Ali. *Contemporary Techniques in Architecture*. 155 Vol. London ; New York: Wiley-Academy, 2002. Print.

Reiser, Jesse, and Nanako Umemoto. *Atlas of Novel Tectonics*. 1st ed. New York: Princeton Architectural Press, 2006. Print.

Silver, Mike. *Programming Cultures : Art and Architecture in the Age of Software*. 182 Vol. London: Wiley-Academy, 2006. Print.

Spuybroek, Lars. *NOX : Machining Architecture*. New York: Thames & Hudson, 2004. Print.

Weinstock, Michael, Achim Menges, and Michael Hensel. *Emergence : Morphogenetic Design Strategies*. 169 Vol. Chichester: Wiley-Academy, 2004. Print.

Werkbund Bayern, and Museum Villa Stuck. *Frei Otto, Bodo Rasch : Finding Form : Towards an Architecture of the Minimal : The Werkbund shows Frei Otto, Frei Otto shows Bodo Rasch : Exhibition in the Villa Stuck, Munich, on the Occasion of the Award of the 1992 Deutscher Werkbund Bayern Prize to Frei Otto and Bodo Rasch*. Germany: Axel Menges, 1995. Print

ARCHITECTURE, THEORY

Ednie-Brown, Pia, and Alisa Andrasek. "CONTINUUM: A Self-Engineering Creature-Culture." *Architectural design* 76.5 (2006): 18-25. Print.

Ednie-Brown, Pia. "All-Over, Over-all: Biothing and Emergent Composition." *Architectural Design* 76.4 (2006): 72-81. Print.

Ednie-Brown, Pia. "Ethico-Aesthetic Know-how: The Ethical Depths of Processual Architecture". Eds. Kirsten Orr and Sandra Kaji-O'Grady.Sydney: 2007. Print.

Ednie-Brown, Pia. "The Will to Animation." *Architectural Design* 71.2 (2001): 64-73. Print.

Frichot, Helene. "Disjunctive Syntheses Of (Post) Digital Architecture And Life". Eds. Kirsten Orr and Sandra Kaji-O'Grady.Sydney: 2007. Print.

Ingraham, Catherine. *Architecture, Animal, Human : The Asymmetrical Condition*. Abingdon, Oxon ; New York: Routledge, 2006. Print.

Massumi, Brian. "Sensing The Virtual, Building The Insensible." *Architectural Design* 68 (Hypersurface).133 (1998): 16-24. Print.

Mitnick, Keith. *Artificial Light : A Narrative Inquiry into the Nature of Abstraction, Immediacy, and Other Architectural Fictions*. 1st ed. New York: Princeton Architectural Press, 2008. Print.

Wiscombe, Tom. "Emergent Models of Architectural Practice." *Perspecta, the Yale architectural journal*.38 (2006)Print.

Wiscombe, Tom. "Emergent Processes." *Oz, Journal of the College of Architecture, Planning, and Design Kansas State University* 27 (2005)Print.

BIOMIMICRY/ANIMAL ARCHITECTURE

Benyus, Janine M. *Biomimicry : Innovation Inspired by Nature*. 1st ed. New York: Morrow, 1997. Print.

Feuerstein, Günther. *Biomorphic Architecture : Menschen- Und Tiergestalten in Der Architektur = Human and Animal Forms in Architecture*. Stuttgart: Menges, 2002. Print.

Gould, James L., and Carol Grant Gould. *Animal Architects : Building and the Evolution of Intelligence*. New York: Basic Books, 2007. Print.

Pallasmaa, Juhani, and Suomen Rakennustaiteen Museo. *Eläinten Arkkitehtuuri*. Helsinki: Suomen Rakennustaiteen Museo, 1995. Print.

Turner, J. Scott. *The Extended Organism : The Physiology of Animal-Built Structures*. Cambridge, Mass.: Harvard University Press, 2000. Print.

COMPLEXITY THEORY

Buchanan, Mark. *Nexus : Small Worlds and the Groundbreaking Science of Networks*. 1st ed. New York: W.W. Norton, 2002. Print.

Grand, Steve. *Creation : Life and how to make it*. Cambridge, MA: Harvard University Press, 2001. Print.

Holland, John H. *Emergence : From Chaos to Order*. Reading, Mass.: Addison-Wesley, 1998. Print.

Johnson, Steven. *Emergence : The Connected Lives of Ants, Brains, Cities and Software*. London: Allen Lane The Penguin Press, 2001. Print.

Lewin, Roger. *Complexity : Life at the Edge of Chaos*. New York: Macmillan Pub. Co., 1992. Print.

Wolfram, Stephen. *A New Kind of Science*. Champaign, IL: Wolfram Media, 2002. Print.

COMPUTATION

Flake, Gary William. *The Computational Beauty of Nature : Computer Explorations of Fractals, Chaos, Complex Systems, and Adaptation*. Cambridge, Mass: MIT Press, 1998. Print.

Fry, Ben. *Visualizing Data*. Sebastopol, CA: O'Reilly Media, Inc., 2008. Print.

Reas, Casey, and Ben Fry. *Processing : A Programming Handbook for Visual Designers and Artists*. Cambridge, Mass.: MIT Press, 2007. Print.

Sierra, Kathy, and Bert Bates. *Head First Java*. 2nd ed. Sebastopol, CA: O'Reilly, 2005. Print.

Terzidis, Kostas. *Algorithmic Architecture*. Amsterdam ; Boston: Architectural Press, 2006. Print.

Terzidis, Kostas *Expressive Form : A Conceptual Approach to Computational Design*. London ; New York: Spon Press, 2003. Print.

www.processing.org

CULTURAL THEORY

Agamben, Giorgio. *The Open : Man and Animal*. Stanford, Calif.: Stanford University Press, 2004. Print.

Baudrillard, Jean. *Simulacra and Simulation*. Ann Arbor: University of Michigan Press, 1994. Print.

Berger, John. *About Looking*. 1 American — ed. New York: Pantheon Books, 1980. Print.

Calarco, Matthew. *Zoographies : The Question of the Animal from Heidegger to Derrida*. New York: Columbia University Press, 2008. Print.

De Landa, Manuel. *Intensive Science and Virtual Philosophy*. London ; New York: Continuum, 2002. Print.

De Landa. *A Thousand Years of Nonlinear History*. New York: Zone Books, 1997. Print.

Deleuze, Gilles, Félix Guattari, and Brian Massumi. *A Thousand Plateaus : Capitalism and Schizophrenia*. London: Continuum, 2004; 1987. Print.

Haraway, Donna Jeanne. *Simians, Cyborgs, and Women : The Reinvention of Nature*. New York: Routledge, 1991. Print.

Heidegger, Martin. *The Question Concerning Technology, and Other Essays*. 1st —. — ed. CN 419 Vol. Toronto: Fitzhenry & Whiteside, 1977, 1977. Print.

Kalof, Linda, and Amy J. Fitzgerald. *The Animals Reader : The Essential Classic and Contemporary Writings*. Oxford ; New York: Berg, 2007. Print.

Massumi, Brian. *Parables for the Virtual : Movement, Affect, Sensation*. Durham N.C. ; London: Duke University Press, 2002. Print.

Massumi, Brian. "Realer than Real: The Simulacrum According to Deleuze and Guattari", in Copyright, no.1, 1987, pp. 90-97. Web.

Wolfe, Cary. *Zoontologies : The Question of the Animal*. Minneapolis, MN: University of Minnesota Press, 2003. Print. s, 2004. Print.

ECOLOGY

Forman, Richard T. T., and Michel Godron. *Landscape Ecology*. New York: Wiley, 1986. Print.

Groombridge, Brian, et al. *Global Biodiversity : Status of the Earth's Living Resources : A Report*. 1st ed. London ; New York: Chapman & Hall, 1992. Print.

Grzimek, Bernhard. *Grzimek's Encyclopedia of Ecology*. New York: Van Notrand Reinhold, 1976. Print.

Schultz, Jürgen. *The Ecozones of the World : The Ecological Divisions of the Geosphere*. 2nd ed. Berlin ; New York: Springer-Verlag, 2005. Print.

FICTION

Abe, Kōbō. *The Woman in the Dunes. Translated from the Japanese by E. Dale Saunders. with Drawings by Machi Abé*. 1st American ed. New York: Knopf, 1964. Print.

Ballard, J. G. ***Concrete Island***. London: J. Cape, 1984. Print.

Borges, Jorge Luis, Donald A. Yates, and James East Irby. ***Labyrinths : Selected Stories & Other Writings***. New York: New Directions, 2007. Print.

Dick, Philip K. ***Do Androids Dream of Electric Sheep?***. London: HarperCollins, 1997. Print.

Fowles, John. ***The Collector***. Boston: Little, Brown, 1963. Print.

Self, Will. ***Great Apes***. London: Bloomsbury, 1997. Print.

PARADIGMATIC SOURCES

Breidbach, Olaf. ***Visions of Nature : The Art and Science of Ernst Haeckel***. Munich ; London: Prestel, 2006. Print.

Haeckel, Ernst Heinrich Philipp August. ***Art Forms in Nature : The Prints of Ernst Haeckel***. Munich ; New York: Prestel, 1998. Print.

Thompson, D'Arcy Wentworth, and John Tyler Bonner. ***On Growth and Form***. —. Abridg ed. Cambridge, Eng.: Cambridge University Press, 1961. Print.

Turing, Alan Mathison, and P. T. Saunders. ***Morphogenesis***. Amsterdam ; New York; New York, NY, U.S.A.: North-Holland; Distributors for the U.S. and Canada, Elsevier Science Pub. Co., 1992. Print.

Von Uexkull, Jakob. "A Stroll through the Worlds of Animals and Men: A Picture Book of Invisible Worlds." ***Semiotica*** 89.4 (1992): 319-91. Web.

von Goethe, Johann Wolfgang, and Douglas Miller. ***Scientific Studies***. 12 Vol. New York, N.Y.: Suhrkamp, 1988. Print.

ZOOS

Baratay, Eric, and Elisabeth Hardouin-Fugier. ***Zoo : A History of Zoological Gardens in the West***. London: Reaktion, 2002. Print.

Bell, Catharine E. ***Encyclopedia of the World's Zoos***. Chicago, IL, USA: Fitzroy Dearborn Publishers, 2001. Print.

Bonner, Jeffrey P. ***Sailing with Noah : Stories from the World of Zoos***. Columbia: University of Missouri Press, 2006. Print.

Cherfas, Jeremy, and British Broadcasting Corporation. ***Zoo 2000 : A Look Beyond the Bars***. London: British Broadcasting Corporation, 1984. Print.

Croke, Vickie. ***The Modern Ark : The Story of Zoos : Past, Present, and Future***. New York: Scribner, 1997. Print.

Dault, Gary Michael, and Volker Seding. *Captive : Animals & Artifice : The Zoo Photographs of Volker Seding = Captifs : Animaux Et Artifice : Les Photographies De Jardins Zoologiques De Volker Seding Textes De Gary Michael Dault ; Traduits De l'Anglais Par Marie-Claude Rochon*. Montréal: Les 400 coups, 2007. Print.

Fisher, James. *Zoos of the World*. London: Aldus, 1967. Print.

Guillery, Peter, and 20 Royal Commission on Historical Monuments. *The Buildings of London Zoo. [Royal Commission on the Historical Monuments of England]*. 1993:Print.

Hancocks, David. *A Different Nature : The Paradoxical World of Zoos and their Uncertain Future*. Berkeley: University of California Press, 2001. Print.

Hanson, Elizabeth. *Animal Attractions : Nature on Display in American Zoos*. Princeton, N.J. ; Oxford: Princeton University Press, 2002. Print.

Kirchshofer, Rosl. *The World of Zoos: A Survey and Gazetteer*. London: Batsford, 1968. Print.

London Zoo (London, England), and P. Chalmers Mitchell. *Illustrated Official Guide to the London Zoological Society's Gardens in Regent's Park*. 18th — ed. London: Zoological Society, 1920. Print.

Polakowski, Kenneth J., and University of Michigan. School of Natural Resources. *Zoo Design : The Reality of Wild Illusions*. Ann Arbor: University of Michigan, School of Natural Resources, 1987. Print.

Robinson, Phillip T. *Life at the Zoo : Behind the Scenes with the Animal Doctors*. New York ; Chichester England: Columbia University Press, 2004. Print.

Stevens, Peter, and Paignton Zoological and Botanical Gardens. *Fourth International Symposium on Zoo Design and Construction, Torquay, Devon, U.K., 14th-18th may, 1989*. Devon, U.K: Whitley Wildlife Conservation Trust, 1992. Print.

Zuckerman, Solly Zuckerman. *Great Zoos of the World : Their Origins and Significance*. Boulder, Colo.: Westview Press, 1980. Print.

ANIMAL DATA SOURCES

Boschert, Ken. "NetVet Veterinary Resources / Electronic Zoo Animal Species," 1994. http://netvet.wustl.edu/ssi.htm

ITIS. "Integrated Taxonomic Information System." ITIS, 2009. http://www.itis.gov/index.html

Metro Toronto Zoo. "Toronto Zoo > Animals > Fact Sheet." MTZ Website, 2009. http://www.torontozoo.com/Animals/

SI National Zoo. "Animal Index - National Zoo| FONZ." Smithsonian Institute National Zoo, 2009. http://nationalzoo.si.edu/Animals/AnimalIndex/

University of Michigan Museum of Zoology. "Animal Diversity Web." Animal Diversity Web, 2009. http://animaldiversity.ummz.umich.edu/site/index.html.

World Wildlife Fund. “WWF - WildFinder”. database. 2009.
http://gis.wwfus.org/wildfinder/.

LAKEVIEW

Brook McIlroy Inc & The City Of Mississauga. "Lakeview and Port Credit District Policies Review." City of Mississauga Website. Mississauga, 2008.

Danahy, John. "Lakeview Legacy Project." Lakeview Ratepayer's Assoication Website. Mississauga, 2008.
http://www.lakeviewresidents.com/files/LRA_LEGACY_PRESENTATION.pdf.

Ontario Power Generation. "Lakeview GS 43." Ontario Power Generation, 2005.
http://www.opg.com/power/fossil/brochures/lakeviewbrochure.pdf.

Toronto and Region Conservation. ***Arsenal Lands Master Plan Addendum***. Toronto: 2007.
1115_ALMPaddendumMarieCurtisP_2007 15.pdf.