3 LECTURES ON "DELEUZE AND BIOLOGY"

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INTENDED AUDIENCE

To be delivered at the 2nd "Deleuze Camp" in Cardiff, Wales, in August 2008. The intended audience is composed of students and scholars of Deleuze who are non-specialists in philosophy of biology (as I am!). Thus these are introductory lectures with a good deal of simplification and exaggeration. I wish to thank Dominique Homberger, Vince LiCata, John Larkin, Chuck Dyke, and Alistair Welchman for critical and clarifying comments. They have helped immensely, and the remaining infelicities are solely my responsibility.

PLAN OF THE LECTURES

Lecture 1: a brief narrative of the development of gene-centered views of heredity and development, up through current "evo-devo."

Lecture 2: a tour of current critical issues and positions calling some aspects of the received view into question. We'll see a move from gene-centered positions to ones where genes play important but not central roles: that is, positions in which they are seen as parts of networks which include "epigenetic" elements: elements outside the genome.

Lecture 3: what Deleuze can add to discussions about (philosophy of) biology.

OUTLINE OF LECTURE 1

INTRODUCTION
- The great questions of biology
- Some biological terminology

A BRIEF HISTORY
- Foucault on natural history and biology
- Darwin's "Copernican Revolution"
- The modern synthesis
- The molecular revolution
- Evo-devo

LECTURE 1
THE CONSTRUCTION OF THE STANDARD VIEW

INTRODUCTION

THE GREAT QUESTIONS OF BIOLOGY

The great challenges of biology are to think repetition and difference in biological processes occurring on different temporal and spatial organizational scales.

Spatial / organizational scales

Molecular	cellular	organ	organic systems	organisms	groups	ecologies
DNA RNA Proteins etc	Membranes Cytoplasm Mitochondria Ribosomes etc	Heart Liver etc	Nervous Endocrine Digestive etc	Bacteria Plants Animals Humans etc	Colonies Demes* Packs Societies etc	Local Regional Planetary

*Demes = reproductive communities

As the term "organizational" should alert you to, we as Deleuzeans have to be concerned as well with transformation, with the "plane of immanence" that allows change. Hence we have to think of the beings on the above spatial / organizational scale as the products of processes, or more radically, as processes themselves (which our everyday perceptions and scientific procedures freeze / reify). Thus we have to ask, what are the characteristic temporalities of these processes? How do they relate to each other?

We can identify four temporal / processual scales: developmental, organismic, reproductive, and evolutionary. What enables and polices repetition? What allows for and constrains difference? What is important difference? How do processes on the different scales interrelate?

Temporal / processual Scales

	Developmental	Organismic	Reproductive	Evolutionary
	Diachronic (months)	Synchronic (seconds, days, months)	Diachronic (generations)	Diachronic (geological)
	Embryology	Physiology	Heredity	Evolution
Repetition	Regular patterns of development	Systematic function as restoration of set points: homeostasis	Children resemble parents	Conservation of sex, body plans, species
Difference	Developmental plasticity	Multiple norms of "health"	Children differ from parents	novelty / disparity*

*Gould: diversity = number of species; disparity = difference in basic organization.

SOME BASIC TERMINOLOGY

Biological disciplines.

> History-centered: classification can be called “taxonomy,” but now, after Darwin, it's also known as “*cladistics*," that is, classification with regard to evolution; *paleontology*; *genetics*.
>
> Organism-centered: *embryology*, *physiology*, *anatomy*, *ethology*, *ecology*. (These can be done with a gene-centered focus, but not necessarily.)

Ontogeny = development (developmental and organismic scales). Embryonic development, followed by “growth,” then “transformation” at puberty, etc.

> Should best be seen as one life-long process of change with different qualitative rhythms. Thus the "developmental" and "organismic" temporal scales are abstract analytical tools.

Phylogeny = descent and branching (reproductive and evolutionary scales).

> You can and should see ontogeny and phylogeny together. Bergson asks us to think these processes as durational: the whole of the past accumulates and makes up the “edge” of the present. Recall Bergons’s notion of the body in MM3: “the actual state of my becoming, that part of my duration in process of formation.” IOW, your body is the last stage in a continuous process of both ontogeny and phylogeny: both developmental and evolutionary history. IOW, life is continuous, from its origin: whatever it is, at whatever level of abstraction, that allows us to say the first living being was alive, enables us to say we are alive. (Autopoiesis says this is the recursive self-producing pattern in which metabolism produces a membrane that allows for metabolism. This is only at the cellular level; for the organism we need to talk about "organizational closure.")

Speciation = appearance of new species (evolutionary scale).

Genome = set of genes for a species.

Genotype = set of genes in any one individual.

Phenotype = concrete features of the individual: anatomy, physiology, behavior.

We're NOT going to define "gene" at this point. It will become clear why not.

A BRIEF HISTORY

FOUCAULT ON NATURAL HISTORY AND BIOLOGY

According to Foucault in *The Order of Things*, 18th century natural history is the classification of natural beings by the identity and difference of their properties.

It is a putting into clear words of a constrained vision of things. Its focus is two-fold: structure (visible pattern of surfaces and lines) and character (essential nature, that which enables it to be placed in an ordered table).

> The table was constructed either "systematically" by comparing a small set of features in every being, or "methodically" by exhaustively describing a key being, and then arranging all other beings in relation to the key. The table then is an ordered grid of differences.
>
> The table expresses an ideal of continuous and fixed spatial distribution of species. Gaps in it are due only to temporal series of accidents; the goal was to reconstruct the ideal distribution from the time-battered record.

For Foucault, natural history has no idea of evolution, because time is extrinsic to the being of plants and animals: "It is … impossible for *natural history* to conceive of *the history of nature*" (OT: 157).

> Time is only a series of accidents that fouls the actual record and creates an epistemic challenge to reconstructing the true atemporal order of things. As Foucault puts it in a memorable phrase:

Finally, and memorably, Foucault will say "biology did not exist before the 19th century, because life itself did not exist; all that existed were living beings" (127-128). "Life" here means an (invisible) functional system (vs. visible structure), so Cuvier is the decisive break.

So life and time are what are introduced in the 19th century.

> For us, what's important is that natural history is a system of what Deleuze calls "representation": the focus on the properties of products. By focusing on visible properties, it neglects temporal process and functional integration. It's focused on plants, whereas biology, with its historicity and dynamic organic functionality, is focused on animals (277).
>
> The transitional figure from natural history to biology is Lamarck, who posits organic structure as the fundamental means of determining character (= essential nature of a thing). Whereas Lamarck broke with the fundamental visibility of Classical natural history to posit organic function as the key underlying reality, he still kept the notion of character as representation of place of a species in a table of identities and differences.

> Cuvier is the decisive break. By positing organic function of organs as basis of taxonomy, Cuvier could relate functions (respiration, digestion, circulation, locomotion) rather than structural properties (size, shape, location, etc) of organs. Life thus becomes a functional system and a science of life, modern biology, is possible.
>
> We'll come back to this in Lecture 3, but for Cuvier, there was a "plan of organization" (*plan d'organisation*) for the organism in which organs were hierarchically ordered according to their role in overall functional unity.
>
> Three consequences of Cuvier's thought: 1) discontinuous forms; 2) connection w/ environment; 3) temporality.
>
> Time is the key to Foucault's claim that Cuvier is the modern and Lamarck the Classicist, even though Cuvier is a "fixist" and Lamarck a thinker of change and development.
>
> For Lamarck, species developed along predetermined lines in a continuous process so that a pre-established "ontological continuity" (275) is simply unfolded; thus in Foucault's view, Lamarck has time as external to the real being of living things: it's just the way in which the ideal table unfolds: the reality is pre-established.

For Cuvier, species fixism is a consequence of historical forces that have reached a stable state. The underlying reality for Cuvier was temporal. In other words, the end of history is still historical.

> As with Ricardo and Marx in economics, so with Cuvier and Darwin: they both share the idea that life is fundamentally temporal: it's just that Cuvier thought that historical forces had come together to form a permanent state of stability (as Ricardo and Marx thought would happen in the future for economics, with different spins, of course -- Gutting [190] notes that Foucault allows in an interview that Marx's social theory constituted an epistemological break, but not his economics).

As we will see, Darwin is much more radical in his historicity: life is always out of balance.

DARWIN'S "COPERNICAN REVOLUTION"

BASIC CONCEPTS

Evolution is change over time. There were other “evolutionists” before Darwin, who accepted historical change in living beings.

Darwin proposed *natural selection* (NS) as the main (but not only) mechanism for organismic and ecological order. Organismic order = adaptation of organs to each other to form functioning whole. Ecological order = adaptation of organism to its fellows and to environment.

> Darwin also mentions *sexual selection*, which is the topic of very interesting recent work by Elizabeth Grosz, as adding some "indetermination" to nature, that which is in excess of utility (= survival / reproduction).

There are three key concepts to NS: *variation, heritability* and *selection*. The concept of NS articulates organismic and reproductive / evolutionary time scales and accounts for spatial difference in distribution of organisms. It is silent on development.

Variation. The source of variation was thought by Darwin to be *accidental mutation*. Variation itself was thought to be *random* and *prevalent*. Variations are produced without reference to how they help the organism adapt to its environment, that is, without reference to “fitness” (see below).

> Lamarck thought that variation was driven by adaptation; as an organism struggled in its environment, its differential use of its organs drove a variation. Thus adaptive variation was “acquired” and this acquired variation could be passed down to offspring.

Heritability. Variations have to be able to be passed on to offspring for NS to work. But Darwin did not (could not) know the *mechanism* of heredity we now accept (at least DNA, but now for many biologists, epigenetic resources as well).

> Darwin held to a theory of "pangenesis," i.e., that we have "gemmules" or particles in our bodies that are modified by chance events. These modified particles allegedly migrated via blood to the reproductive cells and were then inherited by the offspring.
>
> So even though Darwin did not accept Lamarck's (adaptive) source of variation, he did think (accidently) acquired characteristics could be inherited. This puts him at odds with those of his followers ("ultra-" or "neo-" Darwinists [following Weismann]) who think only genetic materials [i.e., non-acquired] are inherited.

Natural selection. According to Darwin, selection is due to population pressures relative to the carrying capacity of the environment. A species would tend to fill its “niche” to the point where the [in]famous “struggle for survival” would kick in, creating a “selection pressure” as members of the same species struggle against each other for limited resources.

Darwin will thus famously say that he has applied Malthus to the natural world. Kropotkin in *Mutual Aid* will say this is an English perspective: in Siberia it's clear that in many species the members co-operate in the struggle against the environment. (Gould tried to rehabilitate Kropotkin in a little essay, "Kropotkin was no crackpot.") Darwin mentions such intra-species *co-operation,* but it's often underplayed by his successors who focus on intra-species *competition*.

> Many contemporary accounts provide for other ways in which selection occurs; what counts is differential reproduction, no matter how it's achieved.
>
> My colleague Dominique Homberger writes: this scenario needs considerable nuancing, as it presupposes a fixed environment against the "borders" of which immobile species press (a container image). But organisms are mobile and environments are not fixed ("niche construction" [see below] would need to be discussed here). This is not to deny that populations grow. Each population tends to produce more offspring that what would be necessary to replace the parent population. In other words, in general, sexually reproducing organisms produce more than two offspring over their life time. But the response to this population growth need not be "struggle"; it's often the case that offspring move out of the core territory of their parents to find [and / or "construct"] their own niche. There are of course no guarantees; the new niche may be less favorable than the core territory, and the "emigrants" may not be successful. (Cf. the Deleuzean notion of "deterritorialization.")
>
> Continuing with the popular story, the "struggle" means that the "best" would survive and reproduce more; or the "worst" would be eliminated and reproduce less. The problem here is the presumed individualism. Organisms cannot "reproduce" (or even "survive" in any biologically meaningful way) in isolation. Even if you could somehow identify the "best" organism, this would have to mate with a less "perfect" individual, so that the offspring would automatically be less than "best."

Fitness. The key to NS is the assumption that some heritable variants would affect "fitness" (= number of offspring produced per generation). The more a heritable variant helped an organism leave behind live and fertile offspring, the more that variant would accumulate across generations (or, alternatively, the more "bad" variants hurt fitness, the more those traits would disappear – although new variants are always appearing).

> Biological "fitness" just measures reproductive success. Thus being the "best" doesn't measure some overall adaptation to an environment. Rather, organisms just need to be "good enough" (and not be unlucky) to interact successfully enough with the environment to survive long enough to reproduce. In other words, selection produces viability rather than optimality.
>
> Once it reproduces, an organism's "fitness" is out of its hands, as it were: it now depends on the survival and reproduction rates of its offspring.

> Grosz notes that in sexual selection traits are considered in terms of sexual "fitness" as access to partners and number of matings. Reproduction is not necessary.

Thus you could measure evolution as the change in distribution of adaptive or positively fitness-affecting heritable variants or "traits" in a population across generations. At some point in this process a new species appeared via the accumulation of differing traits (evolution scale) and geographic isolation.

> This "accumulation" need not be strictly quantitative. Theoretically, a single mutation may do the trick if it prevents interbreeding between populations that have been separated from each other and, thus, were prevented from interbreeding.
>
> There are no inherently "bad" or "good" variants. Variants are "bad" or "good" depending on interaction with an environment. For example, a particular variant may be bad in the arctic environment, but very good in a tropical desert environment.

CONSEQUENCES OF DARWIN

Dynamicism of life: life is always out of balance due to multiplicity of beings and species all adjusting to and changing their environments (the "environment" of a species includes other species which serve as prey and predators).

Differenciation of species: constant branching and diversification. Not a Chain of Being, but a growing tree. (NOT a picture of tree, but a real, live, growing, branching, tree. AND a tree without a fixed nature, but one whose branching pattern is itself evolving!)

Multiple temporal scales: evolutionary / geological vs historical / anthropomorphic. A great displacement of the human.

Irreality of species: "species" is really just a name of a snapshot of a process of diversification. Darwin is a *nominalist* with regard to species: it's a convenient name for a synchronic coagulation or a diachronic snapshot but it doesn't hook on to an "essence."

> Let's think in terms of synchronic and diachronic diversity.
>
> With respect to *synchronic diversity*, where do you draw the line between two variants of a species and two different species? (This is somewhat analogous to the dialect vs language issue in linguistics.) Here species are like coagulations of a viscous liquid, whose spreading out on a surface you have arrested.
>
> With regard to *diachronic diversity*, we have to remember our two temporal scales. Relative to our life span, to our *organismic* temporal scale, you might say that a species has a fixed identity (albeit with diversity of traits) – that's if you solve the synchronic "variant vs species" problem noted above. But relative to the *evolutionary* scale, they are just snapshots of a process.

> According to Gould, Darwin was a “slow gradualist” with regard to the rhythm of evolutionary change: that is, there was only a single rhythm, and speciation takes a long time. Others {Gould and Eldredge} propose “punctuated equilibrium,” that is, a variety of rhythms of speciation, some faster than others. So while speciation is a term for the appearance of novelty, or an “event,” in some periods, there is a faster frequency of events. With this and other considerations, Sterelny and Griffiths want to recuperate reality of species.

Population thinking: Means or types are abstractions from a population of concrete individuals with a distribution of traits.

> Thus there is no ideal height for a tiger; there is a distribution of heights in the tiger population. Each height is a “variant”; there might be a statistical “norm” (= “mean”) of those variants (just like there might be a statistical “mode” and “standard deviation”) but there is no “normative” norm, if you know what I mean: there is no “ideal” height that the “best” or “perfect” tiger is. And just as we can measure the distribution of variants synchronically (within the same generation), we can also track changes in that distribution diachronically (across generations). The statistical nature of means or norms entails that although the bulk of the natural distribution will approximate to the mean, no single individual need ever achieve the exact mean.
>
> One thing I'm trying to do is to introduce population thinking into cognitive science, to replace "the" cognitive subject (even in embodied-embedded mind).

DARWIN'S UNANSWERED QUESTIONS

A big question raised by Daniel Dennett: what other systems are evolutionary in Darwin's sense (i.e., involving variation, heritability, and selection)? IOW, what is the extent of the "multiple realizability" of "Darwin's Dangerous Idea"?

Darwin did not have the correct *mechanism for heredity*, nor was he able to discuss the *mechanisms of development*. So there were unanswered questions both for development (ontogeny) and for heredity (phylogeny), and for how they relate (what the new schools of evo-devo and devo-evo study).

Into this gap between heredity and development steps the concept of the *gene*. We will follow the analyses in Evelyn Fox Keller's wonderful book, *The Century of the Gene* (Harvard, 2000).

First we discuss heredity in the "modern synthesis." Then both heredity and development in the "molecular revolution." Then how they relate to each other in "evo-devo." This will complete our sketch of the standard, widely shared, view, at least of organisms. We won't be able to consider ecology and how it relates to organisms, but we will come back to this topic in lecture 3.

THE MODERN SYNTHESIS

DARWIN did not have the correct mechanism for heredity. So while Darwin could account for evolution as the selection of inherited adaptive variations (i.e., difference) on the evolutionary scale, he could not account for stability (i.e., repetition) on the reproductive scale.

WEISMANN proposed "determinants" as self-reproducing elements sequestered in a "germ-plasm" that is transferred intact between generations. Notice here two assumptions: (1) That fixed material units were passed on, and (2) that organisms are just epiphenomena of the underlying flow of germ-plasm.

> KAP shows connection to Bergson, to ultra-Darwinists, and to Deleuze.

MENDEL'S LAWS of heredity were rediscovered in early 20th century. The key discovery is that each parent could transmit a trait, rather than blending with the contribution of the other parent. Here we have the famous dominant and recessive traits.

> There was a big debate over continuous variation (as measured by "biometricians") vs. discrete traits in phenotype.

GENES were at first just abstract functional units thought to account for traits. They were just markers of heredity. There was no real sense of

1. what their physical structure was,
2. how they were passed on to the next generation,
3. how they conserved their structure in that passage,
4. or how they worked in development.

POPULATION GENETICS: showed how the continuous variation of traits in populations could be the result of the action of many discrete genes.

MODERN SYNTHESIS = population genetics plus Darwin's concept of evolution by NS. Evolution became thought of as the change in the distribution of genes in populations across time. But note that this is just the statistical "bookkeeping" of evolution. Evolution by NS is, in the words of Massimo Pigliucci, "a physical interaction between organisms and their environment, which partially determines the statistical patterns at the population level that biologists have access to (partially because individuals can die or reproduce for reasons independent of their physical fitness)." (http://life.bio.sunysb.edu/ee/pigliuccilab/Lectures_files/lecture-selection.pdf).

Notice that embryology, ethology and the other organism-centered biological disciplines do not play a role in the modern synthesis.

THE MOLECULAR REVOLUTION

WATSON AND CRICK did not "discover" DNA nor even link it to genes. It had already been shown that DNA comprised the physical structure of genes.

What they did do, in their famous *double helix* 1953 breakthrough, was to deduce a chemical structure for DNA (as braided strings of nucleotides).

The combination of these two advances meant that genes were understood to be *contiguous strings of nucleotides* located on the chromosomes. And these strings of nucleotides code for protein.

STRUCTURE CONTROLS FUNCTION. So DNA's *structure* (string of nucleic acids) was supposed to account for its *function* (coding for proteins: which are strings of amino acids).

Let's see how this works. DNA is *transcribed* into RNA which is then *translated* into protein.

Here's the process:

1. DNA in nucleus is separated (two strands pull apart).
2. An enzyme (RNA polymerase) copies the bottom strand in complementary mRNA (messenger RNA). This is the process known as *transcription*.
3. The mRNA is transported out of the nucleus into the cytoplasm.
4. On the ribosome, the tRNA (transfer RNA) binds to mRNA by recognizing triplet codons on the mRNA.
5. The tRNA adds an amino acid monomer, correlative to the triplet codons of the mRNA, to the protein polymer chain under construction. This is the process known as *translation*.
6. The protein chain, when complete, drops off the ribosome and goes on to play its role in the cell.

We will see that the process is even more complex than this, as the *primary* mRNA transcript has to be *spliced and edited* to form the *mature* mRNA transcript that goes to the ribosome.

THREE OF THE FOUR SCALES. So, we can see that by controlling protein production DNA can account for cell construction and function. So it has taken care of the *organismic* scale.

> Here there is a huge assumption of what we can call, for want of a better term, "methodological individualism." To have a true molecular reduction of organismic level physiology, to say nothing of ecological relations, we have to assume that we can account for organism level functions by aggregation of individual cell functions. AND that we can account for individual cell function by aggregation of individual protein functions. AND that we can account for individual protein function by aggregation of individual gene function (which is itself reducible to gene structure). All these assumptions will be challenged. More tomorrow when we discuss genetic reductionism.

What about *heredity*? DNA is passed on in sperm (cytoplasm was thought to be genetically irrelevant), so it can take care of the *reproductive* scale, and it accounts for *evolution* (as accumulation of mutations / change in distribution of alleles across generations).

> Remember, heredity is repetition and difference (or "descent with modification") on the reproductive and evolutionary scales: that is, faithful reproduction of a genetic inheritance while generating mutational variability to be screened by selection.

The CENTRAL DOGMA encapsulates the structure controls function logic in a molecular reprise of Weismann's "segregation of the germ-plasm" thesis. In *protein synthesis*, it said that DNA codes for RNA ("transcription") which codes for protein ("translation"). There's no influence on proteins back to DNA, so it's a one-way process of "information" flow from DNA to protein. Thus with regard to *heredity*, the source of variation can only be random genetic mutation, not mutation "directed" by "epigenetic" events (that is, mutation that comes up the wrong way on the one-way street from protein to DNA). In other words, nothing outside the genome can be passed on, so we can say the central dogma forbids epigenetic inheritance.

DEVELOPMENT: THE FINAL FRONTIER. Okay, you say, we now see how DNA can control cell construction and function (organismic scale) and how it can account for repetition and difference in phylogeny, on both reproductive and evolutionary scales. Its structure (sequence of nucleic acids) accounts for its function (coding for protein).

But what about development? It was left out of the modern synthesis. Can it be integrated with molecular biology? If it is to be, a big question must be answered: How can a linear sequence control a temporal process?

Development requires *anatomical arrangement* and *cell differenciation*: from a single cell, we develop an inside and outside, a top and bottom, a front and a back, and we develop many kinds of cells. All this spatial and qualitative change must be done in the correct order. That is, genes must be expressed (turned on and off) in the right order.

To solve this problem, JACOB AND MONOD propose a GENETIC PROGRAM: they distinguish *structural genes* (coding for protein) from *regulatory genes* (turning structural genes on and off). The actual details of their "operon model" for the regulation of gene expression in the protein synthesis of bacteria need not concern us. The important thing is that with the distinction of structural and regulatory genes, and the notion of a "genetic program," that development could be seen as genetically controlled.

It's the very ambiguity of the term "genetic regulatory mechanism" that is problematic. It's really a mechanism of gene regulation in which cell conditions [e.g., the presence of lactose] play a key role. But calling it a "genetic regulatory mechanism" and talking about a "program" implies that the locus of control is genetic rather than distributed. Hence the gene-dominant reading is a misunderstanding right from the start, though one enabled by Jacob and Monod's rhetoric (Keller 2000: 79).

> Keller quotes Jacob and Monod: "the discovery of regulator and operator genes … reveals that the genome contains not only a series of blue-prints [for gene – protein coding: JP] but a coordinated program of protein synthesis and the means of controlling its execution." Keller continues in her own words: "In Jacob and Monod's view … genes may need to be activated, but other genes—regulator genes—were there to do the job. [even though those regulator genes are sensitive and respond to cellular conditions: JP] The net effect of Jacob and Monod's description of a gene-based mechanism of regulation was to put genes back in the driver's seat and traditional expectations of genetic control back on track" (Keller 2000: 80).

It was already known how, via the structure controls function logic (sequence determines coding), DNA accounts for repetition and difference on three of our scales: organismic, reproductive, and evolutionary. Now with the operon model and the notion of a genetic program, it could account for development as well.

EVO-DEVO

Until a series of fascinating discoveries in the 1980s, studies of genes in the evolutionary and developmental sciences were separate. Biologists knew that DNA was the basis of both evolution and development, but they didn't know how the hereditary gene and the developmental gene related to each other. How did the genes that control development evolve? And how did such evolved genes account for the difference in developmental pathways that yield both diversity of species and disparity of basic bodily plans? These were unanswered questions.

Biologists assumed that disparate biological orders had disparate developmental genes. The discovery that enabled the field of evo-devo was *homeotic genes*. A specific string of DNA with a homeotic function is called a *homeobox*. These structure development, acting as genetic switches controlling transcription factors regulating gene expression (turning them on and off). There is in fact a hierarchy of such genes, with some turning on and off others that in turn still others on and off in temporally ordered "cascades" of gene expression. They are essential in the development of basic body plans. Certain homeotic genes, called *hox genes*, are expressed in the order in which they are found in the chromosome and thus control body segmentation (first the top, then the middle, then the bottom, for instance).

What was shocking about homeotic genes is that they are found in many different orders, conserved from before the arthropod / mammal division. A famous one is "eyeless." When transplanted from a mouse into a fly, it induces an eye formation. Think about that for a minute: a mouse gene that works in a fly! A mammal gene that works in an insect! Obviously there's something very strange going on here, something that contradicts the idea that different orders have different genes. Evidently they have the same genes. But here's the catch: the eye that forms is a fly eye. It's the fly context that determines what kind of eye is formed.

So if large parts of the genome are conserved over vast periods of time and shared by widely divergent kinds of living beings, that is, if disparate organisms share developmental genes, what is the source of their disparity?

The answer is the evolution of different regulatory gene networks that change the pattern of expression of the genes and hence control developmental pathways. So evo-devo is very much gene-centered. Evolution is change in gene networks controlling development.

> Sean Carroll, in his excellent popular science book, *Endless Forms Most Beautiful: The New Science of Evo-Devo* (NY: Norton, 2005), writes: "Around 3 percent of [our DNA] … is regulatory. This DNA determines when, where, and how much of a gene's product is made…. Regulatory DNA is organized into fantastic little devices that integrate information about position in the embryo and the time of development. The output of these devices is ultimately transformed into pieces of anatomy that make up animal forms. This regulatory DNA contains the instructions for building anatomy, and evolutionary changes within this regulatory DNA lead to the diversity of form" (12).

IOW, it's all about the different developmental music (differences in rhythm and melody and harmony) that can be played on the same inherited keyboard. But who writes the score? And who does the playing?

As we will see, these are huge questions of "political physiology." Does DNA constitute a program that uses the raw materials of the cell to construct the organism? That is, is DNA the keyboard and score, and the cellular mechanisms only the paid musicians? Or should we think a more "democratic" scenario in which DNA plays an important, but not dictatorial, transcendent, role? Can we conceive a musical group in which there is no director, but the musicians rewrite the inherited score as they go along, responding to cues from each other and from the "audience" (environment), bringing out previously unexpressed potentials, forming new music as they go? (The French is better here: "audience" = ceux qui assistent.) (Hat tip to Gene Holland and his work on jazz improvisation as Deleuzean music.)

Let's end the lecture here. Tomorrow we'll see how the very progress of molecular genetics has undermined the picture of dictatorial DNA and given rise to a series of fascinating contemporary issues and positions.

> Evelyn Fox Keller tells a very interesting story in *The Century of the Gene* of how advances in molecular biology of DNA has tended to undermine the very notion of the gene. In other words, as we understand more how DNA *functions* in cells and organisms, how it partakes in complex multi-level networks of gene expression (when and where genes are turned on and off), the less important becomes the notion of gene *structure*, that is, the spatial location of nucleic acids.

LECTURE 2
CONTEMPORARY ISSUES AND POSITIONS

OUTLINE OF LECTURE 2

- Issues
  - Physiology and Development
    - Genetic determinism and reductionism
    - Genetic reductionism in physiology: structure dictates function
    - Genetic reductionism in development: the genetic program
  - Heredity and Evolution
    - Unit of selection
    - Adaptation
    - Niche-construction and "co-evolution"
- Contemporary Stances
  - Standard positions
    - Ultra-Darwinism
    - Evo-devo
  - Critical positions
    - Devo-evo (developmental evolutionary biology)
    - DST (Developmental Systems Theory)
    - Autopoiesis / enaction
    - Process structuralism
    - Serial endosymbiosis

ISSUES

PHYSIOLOGY AND DEVELOPMENT

GENETIC DETERMINISM AND REDUCTIONISM

First, we have to remember that the model I'm presenting of genetic determinism / reductionism is indeed a straw man for biologists, but unfortunately, and for many social-political reasons, has become -- and remains -- the standard popular view in mainstream media and in the minds of most educated but not specialized people. It may be that the crude ideas presented here never existed in the writings of real biologists, as opposed to being popular misconceptions right from the start. Just as, for example, nothing like "post-modernism" as some scary nihilism about the impossibility of meaning or reference ever existed except as a misunderstanding right from the start.

In any event, here we go.

Determinism is an *ontological thesis*: genes are the sole source of order of (they determine) physiological and developmental processes.

> No one has ever upheld such an absolute position if by that one means epigenetic conditions have no influence whatsoever, that developmental and physiological processes are determined the way a stone is determined to fall by gravity. The real target of critique is what Susan Oyama and the DST crowd call "interactionism," that is, the idea that there are two classes of developmental resources, genetic and epigenetic, and that genes provide the information or blue-print or plan or program, and that the epigenetic resources are the materials or background upon which and / or in which genes act. The real question is locus of control rather than absolute determination.

Reductionism is both an *epistemological* and *ontological issue*. An epistemological question: can the discourse about physiology and development be reduced to (or translated into) discourse about genes? Also, can Mendelian genetics be reduced to molecular biology? Ontologically speaking, this last question becomes: does DNA provide the mechanism that realizes Mendelian genetics?

> My LSU colleague John Larkin writes that practicing biologists think of reductionism as asking the question: can the portion of physiology and development due to genetic control be considered separately from the portion due to environmental / outside influences? A point of clarification: molecular processes always include genetic (DNA / RNA) and epigenetic (intranuclear and cytoplasmic) factors. However, many biologists will limit the extent of inherited epigenetic factors (they have to be inherited to play a role in evolution and development considered together) to intranuclear and cytoplasmic factors, and consider extra-cellular and extra-somatic factors to be "outside." The most radical DST position will be to include the extra-cellular and extra-somatic factors as epigenetic inheritance in a maximally extended "developmental system" (hence the name) or "life-cycle."
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> Now however one stands on the question of the extent of epigenetic inheritance, the key question is the separation and control question, which is a matter of "interactionism" as defined above. That is, a DST question would be: all biologists today admit epigenetic factors play a role, but, whatever their extent, are they controlled by epistemologically separable genetic factors?

We're going to see that determinism / reductionism is in trouble.

GENETIC REDUCTIONISM IN PHYSIOLOGY
STRUCTURE DICTATES FUNCTION

We remember the structure dictates function logic: a contiguous string of DNA (structure) codes for a string of amino acids in protein (function).

Well, not so fast. As we're going to see, following Keller's presentation in *The Century of the Gene*, the very progress of molecular biology has undermined that early picture. (In the last lecture we'll see the way Deleuze can help us make sense of this progress / undermining.)

For now, let's see why the process of transcription and translation is no longer thought to be linear and solely under genetic control (i.e., via regulator genes).

Here's the transcription / translation process at the time of the central dogma:

1. DNA in nucleus is *separated* (two strands pull apart).
2. *Transcription*: An enzyme (RNA polymerase) copies the bottom strand in complementary mRNA (messenger RNA).
3. The mRNA is *transported* out of the nucleus into the cytoplasm.
4. On the ribosome, the tRNA (transfer RNA) *binds* to mRNA by recognizing triplet codons on the mRNA.
5. *Translation*: The tRNA adds an amino acid monomer, correlative to the triplet codons of the mRNA, to the protein polymer chain under construction.
6. The protein chain, when complete, *drops off* the ribosome and goes on to play its role in the cell.

Extra steps. However, between steps 3 and 4, complex processes of splicing and editing go on. Thus the *primary* mRNA transcript at step 3 has to be *edited and spliced* to form the *mature* mRNA transcript that goes to the ribosome in step 4.

Why these extra steps? Well, it turns out that proteins sometimes need separated strands of DNA for their synthesis. Often there are big chunks of inactive or "junk" DNA (technically, "introns" for "intragenic region" or "intervening sequence") between the strings of active DNA ("exons" or "expressed DNA"). So the introns have to be cut out (edited) from the primary mRNA transcript and the exons have to be strung together (spliced) to form the mature mRNA transcript.

> Note that unexpressed DNA can evolve by drift (mutation) and other processes, independent of natural selection. This is because NS only works on phenotypes. (NS is about real world interactions, even if they can be tracked by gene shifts.) The variation in unexpressed DNA can be a reservoir for developmental plasticity, as we will see in discussing West-Eberhard.

Another twist: exons can be spliced together in different orders! This is called "alternative splicing." It means you can get more than one mature mRNA transcript from the same primary mRNA transcript (that is, from the same DNA string).

So here's *the real process*:

1. DNA in nucleus is separated (two strands pull apart).
2. An enzyme (RNA polymerase) *transcribes* the bottom strand in complementary mRNA (messenger RNA).
3. The primary mRNA transcript is transported out of the nucleus into the cytoplasm.
    a. The introns are excised
    b. The exons are spliced together
4. On the ribosome, the tRNA (transfer RNA) binds to mRNA by recognizing triplet codons on the mRNA.

5. The tRNA adds an amino acid monomer, correlative to the triplet codons of the mRNA, to the protein polymer chain under construction. This is the process known as *translation*.
6. The protein chain, when complete, drops off the ribosome and goes on to play its role in the cell.

Thus there is no longer a one-to-one correspondence of DNA sequence and synthesized protein. We have now one gene (DNA string) = many (mRNA transcripts) = many proteins.

> There are lots of other genetic mechanisms we haven't mentioned. For example, there are "proofreading" mechanisms involved in transmission / inheritance of DNA [i.e., in meiosis] and there are mechanisms of "frame-shifting" in binding from the mature mRNA transcript to the tRNA, in which the triplet codon boundary (that which is read by the tRNA) can shifted up one or two nucleic acids. Thus the "same" mature mRNA transcript can produce different proteins via frame-shifting. (Previously we talked about the production of different mature mRNA transcripts.)

Control of editing and splicing. And here's the important point: what controls the editing and splicing? *It depends on the state of the cell at any one time*. Thus control has migrated from DNA (structural plus regulatory genes) to the complex system in which DNA plays a (certainly very important) role, but no longer a controlling role.

> We can call this something like "functional dynamics of gene expression," though in one sense, you could also call it "dynamics of gene formation and expression," since the process of editing and splicing "forms" the gene as functional part of the system from the gene as string of DNA.

Separating the concepts of structural and functional genes. Think of it this way: we have to learn to separate the *heredity gene* or *structural gene* (as contiguous string of DNA passed down in reproduction) from the *functional gene* (end-product of transcription processes "forming," from separated strings of DNA, a gene which plays a role in protein synthesis).

> If you want to be dialectical about it, you could say that now function determines structure. That is, the function of the protein to be formed dictates the formation of the mature mRNA transcript. That is, the structure of the mature mRNA transcript, the structure of the functional gene, is dictated by the function of the protein to be formed. As you can no doubt anticipate a daring person might say that there's a teleology or even intentionality at work here. Obviously there are big philosophical issues in saying that!

Regulation of protein function. But the story is not over yet. Not only are different proteins formed from the "same" gene (that is, to repeat, different mature mRNA transcripts can be formed from the same primary mRNA transcript), but *proteins function in different ways, according to the cellular context in which they find themselves*. This change in protein function is due to changes in their structure; this is known as "allostery." So now we have, instead of "one protein = one function," the case that "one protein = many functions."

Consequences. So we've gone from "one string of DNA = one gene = one protein = one function" to "one string of DNA (structural / hereditary gene) = many (functional) genes (many mature mRNA transcripts) = many proteins = many functions."

> Of course the first equation is an ideal case: everyone always acknowledged the possibility of errors at each stage (i.e., errors in transmission of DNA in heredity, then transcription or translation errors). Still, the point is that the classic reference point was always a linear, self-contained process by which cell function (and further on, phenotypic traits) could be understood as reducible to proteins produced by genes as DNA strings.
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> Mike Wheeler puts it this way: we have to give up the idea that "genes code for traits," and be satisfied with the notion that individual mature mRNA transcripts code for individual proteins. But we can't go simply from hereditary genes (DNA strings) to functional genes (individual mature mRNA transcripts), nor can we go from proteins to traits.
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> That's because there's a big assumption here that we can account for individual cell function by aggregation of individual protein functions (in other words, a denial of emergent cell function).
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> We've seen the disappointment of all those determinist / reductionist assumptions, since we've seen how gene formation and expression depends on cell dynamics which are part of larger networks. (In fact, even the stability of the hereditary gene or DNA sequence is influenced by external events in what's called "stress-induced mutagenesis": in crisis situations, mutation rates increase. This capacity has itself evolved in what's called the "evolution of evolvability.")
>
> But let's talk about development before we talk any more about heredity – anticipating West-Eberhard's views on developmental plasticity as inducing genetic variation.

GENETIC REDUCTIONISM IN DEVELOPMENT
THE GENETIC PROGRAM

So far we have spoken about individual cell metabolism. But the process of development includes cell differenciation: we have lots of different types of mature cells. Thus gene expression has to follow a temporal pattern.

At first, hopes were high that Jacob and Monod's operon model, which depended on the regulatory vs structural gene distinction, meant that gene expression and hence development could be controlled from inside the genome, by a "genetic program." But now biologists acknowledge the role that *epigenetic* factors play in development.

What are these epigenetic factors? Working our way outward from DNA, we note that it is packaged and coiled on the chromosomes. This packaging, DNA and chromosomal proteins together, is called *chromatin*. Chromatin plays an important role in gene expression.

Next we find the *cytoplasm*. In earliest development, the fertilized egg. The chemical gradients in the egg turn out to be very important in development. There are also lots of connections between cytoplasm and chromatin. Control is being dispersed.

> One of the keys to this new view of the importance of the cytoplasm is nuclear transplantation. It used to be thought that you couldn't clone from an adult nucleus because the genome copy carried in an adult cell was irrevocably changed by the process of cell differenciation so that it lost its "totipotency." But after Dolly the sheep, we can now see definitively that what counts is the relationship of nucleus and cytoplasm, not the (allegedly changed) state of the nucleus.

This is the most conservative position to take, that epigenetic factors are limited to chromatin and cytoplasm. As we'll see in discussing DST, some people propose other factors, extracellular and even extrasomatic.

But even if we stick to intracellular elements as the limits of our epigenetic factors, we have to recognize that cell position in development plays a role in cell differenciation. Hence gene regulation networks are dynamic and multifactorial; they are no longer simply genomic. Hence development is key to seeing limits of genetic determinism / reductionism.

So here we have critically examined the assumption behind genetic determinism / reductionism of what we can call, for want of a better term, "methodological individualism." To have a true molecular reduction of organismic level physiology, to say nothing of ecological relations, we have to assume that we can account for organism level functions by aggregation of individual cell functions. AND that we can account for individual cell function by aggregation of individual protein functions. AND that we can account for individual protein function by aggregation of individual gene function (which is itself supposedly reducible to gene structure). AND that a genetic program has to control the development of all these mature structures.

All these assumptions have been challenged. Instead of DNA as master molecule (as localized and transcendent to the process) it plays a functional role (as immanent to the distributed process). DNA is part of networks that are dynamic and that themselves change over time throughout the development process (which we can see as lifelong, as involving different rhythms).

HEREDITY AND EVOLUTION

UNIT OF SELECTION

GENE CENTERED SELECTION

What is it that is targeted by NS? Darwin thought it was the organism. But with the molecular revolution, genetic selectionism came to the fore, popularized by Richard Dawkins (*Selfish Gene*, 1976; *Extended Phenotype*, 1982).

Here we find Dawkins' famous distinction of replicators and vehicles, with all his famous phrases: organisms as "lumbering robots," etc. Dawkins is after "active germ-line replicators": genes as units of heredity and development. The replicator has to be "active" because it has to have a phenotypic effect, since that organism-level trait will be the proximate target of NS – though genes as chunks of DNA ("germ-line") are the ultimate target. In this way, Dawkins is promoting a "molecular Weismannism."

David Hull substitutes the term "interactor" for "vehicle": "interactor" doesn't imply subordination to replicator and can be used in discussing higher levels of interaction (Sterelny and Griffiths 1999: 56).

Genetic selectionism does not imply that organisms qua interactors are irrelevant. In fact, they are the ways in which genes are selected: phenotypic effects cause differential replication of genes via survival and reproduction of organisms. Nor are organisms mere epiphenomena of genes. However, it is a "gene's eye view" of evolution.

CRITICISMS OF GENETIC SELECTIONISM

(Relying here on Sterelny and Griffiths 1999.) There's a key assumption of a simple path to gene expression in genetic selectionism. That is, phenotypes are what are screened in NS, and via their phenotypic effects, genes are the ultimate target.

But we have seen that gene expression is anything but simple. We have seen that once put into functional networks in developmental processes, structure no longer dictates function. In other words, there is a separation of the hereditary gene as string of DNA and the functional gene as end product of transcription process of editing and splicing. So even if gene structure as chunk of DNA is passed on in heredity, gene function in development is not equal to a contiguous string of DNA.

So if phenotype is what is selected for (and gene selectionists agree with this), then any complexity or multiplicity, any deviation from one gene – one phenotype expression, will derail gene selectionism.

It's no good to shift the target and say that the functional gene is the target of selection because it has no stable molecular base that is inherited. There's no sense in saying that the end products of complex cellular processes are "replicators."

So while the hereditary gene as string of DNA is a replicator, it has such variable phenotypic effects that it is invisible to selection and cannot be the target of selection. And the functional gene that does have reliable phenotypic effects is not a replicator.

> As if the multiplicity of gene expression argument weren't enough, genetic selectionism also has to deal with *gene interaction* and with *hitch-hiker genes*.
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> Gene interaction is a big problem for genetic selection since genes never work in isolation: they work together in groups. How is a gene's effect on phenotype to be isolated so it can be targeted by selection?
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> Another problem is "hitch-hiker" genes: selection *for* organisms with certain traits (a phenotype) will cause selection *of* genes *correlated* with those phenotypes, even if there is very little or no causal contribution of those carried along genes to the selected for phenotypes. This means that a lot of genetic variation will be "invisible" to selection. But the thesis of genetic selectionism is that genes are the ultimate target of selection.

We'll deal with two other problems for genetic selectionism in the next section, on contemporary postions. These problems are *epigenetic inheritance* [in the DST section] and *organism level selection* [in the "developmental plasticity" section].

GROUP SELECTION

Here there are two issues: emergence and altruism.

A big question here is *emergence*. If groups can have functional organization in the same way individuals do, that is, if groups can be emergent individuals, then groups can also be "vehicles" for selection (if they have variation, heredity, and selection pressures, of course). For example, groups that cooperate better may have out-reproduced those which did not.

With co-operation, we get lots of debates about *altruism* here. Some see it as the key to groups functioning as emergent individuals and hence allowing for group selection.

But the gene-centered folks talk about “kin selection” as a way of providing a genetic reduction of altruistic behavior and thus disallowing group selection. If you sacrifice yourself for a kin, at least part of your genotype, the “altruistic” part that determines or at least influences self-sacrifice and that is [probably] shared with that kin, is passed on.

> It's very important here not to confuse proximate [psychological] explanations [motivation] and ultimate [genetic] explanation. You really do love the kin you help, even when it hurts your fitness but helps theirs. Thus you're not "really" *motivated* by

> genes here, though some say your behavior can be *explained* (ultimately) by genes (encoding altruistic / loving behavior). Richard Joyce, *Evolution of Morality* is good here.

Allied with kin selection is the notion of "inclusive fitness," which is individual fitness (number of offspring) plus the effect the organism's behavior has on other organisms' fitness (number of offspring of those helped: or more precisely, the "percentage" of those offspring that can be attributed to the helping behavior).

> Dominique Homberger writes: "Altruism has rarely anything to do with the macho notion of "self-sacrifice". Some biologists maintain that what we call altruism is actually fairly common and can be seen in motherly (of fatherly) behavior towards offspring and young animals in general (adoption and even trans-specific adoptions of deserted youngsters are observed fairly regularly, and herding animals can be seen eating side by side (in contrast to hummingbirds who will chase away other hummingbirds from a feeder even if they themselves cannot eaten more). Most animals are to some degree social beings and as such, they feel good about pleasant interactions (e.g., reproduction, raising young, playing, feeling safe in company, etc.). Altruism, of course, is very important for the survival of highly social animals, such as social insects, naked moles, hyraxes, prairie dogs, and most of all human beings. Given their very precarious anatomy and physiology, human beings are very vulnerable as individuals (i.e., without tools and alone by themselves, human beings are unlikely to survive for very long in any truly wild environment). For human beings, hence, becoming one of the most "successful" species was possible only because of their highly developed social skills and altruistic interactions, which have been documented early on, such as the presence of handicapped and chronically sick individuals in graves of Neanderthals."

There's a lot to talk about in altruism and co-operation with Kropotkin and political physiology and naturalism.

ADAPTATION

Probably the most famous critique of *complete* adaptationism is Gould and Lewontin's "Spandrels of San Marco" article: some traits we see today were never selected for, but are just "spandrels," that is, the accidental product of other selected traits.

We shouldn't confuse spandrels with what Gould calls "exaptation," that is, the shift of function of a mechanism during the course of evolution.

> We are very familiar with exaptation from the "genealogical" strain in philosophy (Nietzsche, Foucault, Deleuze): the current function of something is no absolute or foolproof clue to its origin, or in other words, that a structure can assume different functions over the course of its history, as it is subsumed in different "assemblages." This would hold for both biological and social history according to these thinkers.

> Gould and Lewontin's spandrels and exaptation arguments carries only against rampant or complete adaptationism, not adaptationism *per se*. After all, we haven't seen much change in the double-helix structure of DNA since it evolved! Once NS finds something that works, that something is conserved.
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> We also have to remember the debates about the role such a complete adaptationism plays in Gould and Lewontin's *bête noir*, Evolutionary Psychology.

NICHE-CONSTRUCTION AND "CO-EVOLUTION"

In all these adaptation debates there are also very interesting questions about "niche construction." The theory of niche-construction proposes that an organism does not passively submit to the pressures of a pre-existing environment, but actively constructs its niche: its own activity will change the environment and hence affect the selection pressure. The notion of "niche construction" is closely related to the notion of "co-evolution" in which the activity of one species will affect the fitness of another species, and vice versa. The two (or more!) species then "co-evolve." The simplest example of this is the "arms race" of predator-prey, but there are other modes of co-evolution.

CONTEMPORARY STANCES

STANDARD POSITIONS

ULTRA-DARWINISTS

Dawkins / Dennett / EO Wilson (sociobiology) / Pinker (Evolutionary Psychology). We have dealt with this in the above treatment of genetic selectionism.

EVO-DEVO

We spoke of this yesterday. To recap: evo-devo is the study of molecular development and its evolution. A big discovery is homeotic genes. These structure development, acting as genetic switches controlling transcription factors regulating gene expression (turning them on and off). They are essential in body plans. Hox genes, a subset of homeotic genes, are expressed in the order in which they are found in the chromosome and they control body segmentation, for instance. They are found in many different orders, conserved from before arthropod / mammal division. A famous one is "eyeless." When transplanted from a mouse into a fly, it induces an eye formation. But here's the catch: the eye that forms is a fly eye. It's the fly context that determines what kind of eye is formed.

Evo-devo is still gene-centered. Let's move beyond the gene.

CRITICAL POSITIONS

AUTOPOIESIS / ENACTION

Maturana and Varela. Combined with DST in Evan Thompson, *Mind in Life* (Harvard, 2007). Sense-making. Autonomous systems. Jonas / Spinoza connection.

Varela is perhaps best known for his early collaboration with Humberto Maturana in developing the concept of autopoiesis.

> This work, published in Spanish in 1973, and made known to the Anglophone community by a 1974 article and then by a 1980 monograph, is a classic of “second-order” or “neo” cybernetics. In our terms, it is marked by a notion of “synchronic emergence,” which is conducted in static part / whole terms. The concept of autopoiesis was developed to provide a horizon of unity for thinking living entities, rather than the haphazard empiricism of the “list of properties” model usually adopted (“reproduction, metabolism, growth …”). In other words, Maturana and Varela were trying to isolate an essence of life, an essence which would provide a viewpoint on life that is “history independent” (Varela, Maturana and Uribe 1974: 187).

We must distinguish organization (essence) and structure (historical accident). Organization is the set of all possible relationships of the autopoietic processes of an organism. Structure is that selection from the organizational set that is actually at work at any one moment (Maturana and

Varela 1980: xx, 77, 137-38; see also Hayles 1999: 138 and Rudrauf et al, 2003: 31).

Changes in the environment with which the system interacts are known as “perturbations” of the system. The system interacts only with those events with which it has an “interest” in interacting, that is, those events that are relevant to its continued maintenance of autopoietic organization (e.g., nutrients). These events of interaction form a process of “structural coupling” that leads to structural changes in the system.

These changes, as reactions to the perturbation, either re-establish the baseline state of the system (they re-establish the homeostasis of the system) or result in the destruction of the system qua living (Maturana and Varela 1980: 81). Homeostatic restoration thus results in conservation of autopoietic organization.

> From this essentialist viewpoint, the origin of life must be a leap into another register, a *metabasis eis allo genos* (“the establishment of an autopoietic system cannot be a gradual process; either a system is an autopoietic system or it is not” [Maturana and Varela 1980: 94]). From the autopoietic perspective, questions of diachronic emergence have to be thought in terms of “natural drift,” whose relation to autopoietic essential organization is problematic, as we will see. In any event, clearly autopoietic organization is synchronic emergence in which the whole arises from a “network of interactions of components” (Varela, Maturana and Uribe 1974: 187).
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> For Maturana and Varela, autonomous systems have sufficient internal complexity and feedback that "coupling" with their environment "triggers" internally-directed action. This means that only those external environmental differences capable of being sensed and made sense of by an autonomous system can be said to exist for that system, can be said to make up the world of that system (Maturana and Varela 1980: 119). The positing of a causal relation between external and internal events is only possible from the perspective of an "observer," a system that itself must be capable of sensing and making sense of such events in <u>its</u> environment (81).
>
> The biological basis of the judgments "good" and "bad." This basic value polarity is well noted in affective neuroscience, and is in fact grounded in basic organic capacities for affective cognition. Witness the single-celled organism's ability to make sense. "Sense" has, perhaps fittingly, a three-fold sense: sensibility, signification, and direction. (There is an archaic sense of the English word "sense" meaning "direction," as in "the sense of the river." This sense is still present in French, as in, among other uses, the expression <u>sens unique</u> for "one-way street.")
>
> A single-celled organism can sense food gradients (it possesses sensibility as openness to the environment), can make sense of this difference in terms of its own needs (it can establish the signification "good" or "bad"), and can turn itself in the right sense for addressing its needs (it orients itself in the right direction of movement). This fundamental biological property of sense-making is one reason why the Cartesian distinction of mental and material has no purchase in discussions of sense-making. There is no "mental" property (in the sense of full-blown reflective consciousness) attributable

to the single-celled organism, but since there is spontaneous and autonomous sense-making, there is no purely "material" realm either in these organisms either. Affective cognition in humans is simply a development of this basic biological capacity of sense-making.

PROCESS STRUCTURALISM

Goodwin, Kauffman: self-organizing physical processes in development (morphogenesis) constrain NS by providing another source of order. Key notion is a phase space of body plans and organ development. Much of it is off-limits due to constraints imposed by self-organizing physical processes.

Kauffman also talks about the properties of regulatory gene networks for cell differentiation (DeLanda ISVP 54-55). K can predict surrounding transformation space for any one cell based on its history / neighborhood by looking at nearby attractors in gene network model. Note that DeLanda overestimates the "open space" for evolution this creates (58).

SERIAL ENDOSYMBIOSIS

Macro-evolution: Margulis: mutation not the only source of creativity / innovation in evolution. The most important source is symbiosis. Most famous example: Mitochondria as previously independent aerobic bacteria engulfed by anaerobic (proto-nucleated) bacteria. Symbiosis short-circuits the strict Darwinist doctrine of mutation and selection of slight adaptations.

Needed because of the "oxygen holocaust" produced by spread of blue-green algae which produced oxygen as by-product of their metabolism. Oxygen is highly corrosive: it combines with anything and "burns" it. The ingested aerobic bacterium received nutrients from the host while the host received energy from the aerobic activity of the bacterium.

DEVO-EVO
DEVELOPMENTAL / PHENOTYPIC PLASTICITY

Mary Jane West-Eberhard, *Developmental Plasticity and Evolution* (Oxford, 2003). West-Eberhard calls her work "developmental evolutionary biology," which we can call "devo-evo."

Evo-devo to date has a genetic / molecular focus: how have regulatory gene networks evolved? But what about the organism? After all, there are many ways to skin the developmental cat: organisms are plastic, meaning that they can produce many different phenotypic expressions in response to different environments even with same genetic makeup. In other words, development is *flexible*. But it is also *robust*: even with different genetic makeup, organisms still follow similar developmental pathways.

Now evo-devo found that large parts of the genome are conserved over vast periods of time and shared by widely divergent orders. So if disparate organisms share genes, what is the source of their disparity? The answer is different developmental networks that change the pattern of expression of the genes. But how do those different developmental networks evolve?

W-E proposes that genetic control mechanisms can be exposed to selection by the phenotypic adaptation of organisms to new kinds of environment. For her, this phenotypic adaptation, what she calls "plasticity," ultimately drives evolution.

W-E has three points to make:

1. Environmental induction is a major initiator of evolutionary change (genes are followers, not leaders [as they would be if mutation were the major initiator of change.)
2. Evolutionary novelties result from reorganization of preexisting phenotypes and incorporation of environmental elements (novel traits are not de novo results of mutation).
3. Phenotypic plasticity can facilitate evolution by immediate accommodation and exaggeration of change (phenotypic plasticity is not mere noise obscuring genetic patterns).

In other words, DPE is a book on developmental evolutionary biology – that is, evolutionary biology with reference to development – thus paying attention to "variation and selection w/in populations, speciation, developmental plasticity, and the origin of behavioral, physiological and life history traits." Rather than evo-devo as developmental biology with an evolutionary reference, that is, concerned with "regulatory genes, body plans and morphology, as seen in a few model organisms."

> For W-E, there is a restricted sense of development today: lab science (marriage of embryology and molecular biology) where development means "gene expression and tissue differentiation, primarily during early development, and primarily in multicellular organisms." For W-E, development must include "the ontogeny of all aspects of the phenotype, at all levels of organization, and in all organisms." Thus we have to look to "the environment as agent of development, not just selection, in the evolution of all forms of life."

W-E does not deny NS, but claims it will favor the spread of a particular environmentally-induced phenotypic variant when it has positive effects on individual fitness, that is, when it is adaptive.

Now you may want me to stop right here, because this sounds Lamarckian. It's not though, W-E emphasizes, because there is no direct influence of environment on genotype. In other words, Lamarck thought that adaptive phenotypic changes were the source of variants that could be inherited (in contemporary terms, adaptive phenotypic changes produce genetic variation). But that's not West-Eberhard's scheme. What she says is that some adaptive phenotypic change is the result of developmental plasticity calling upon previously hidden, i.e., unexpressed, genetic variation. In other words, neither the phenotype nor the environment produces genetic variation.

The above sketch needs to be made more precise. The key concept for West-Eberhard is "genetic accommodation."

The process goes like this: a new phenotype develops (developmental plasticity) by being induced via a genetic mutation or an environmental difference. What has happened in the latter case is that the new environment has brought forth an untapped potential of the pre-existing genetic variation.

This is a key assumption of W-E's argument: unexpressed genetic variation that was previously screened from selection by developmental robustness, that is, the fact that there are many genetic pathways to the same phenotypic expression.

> It makes sense given our previous discussion that not all genetic variation is expressed; remember that genetic expression depends on cellular / environmental conditions. We have to also remember that such unexpressed genetic variation can be inherited, but that's okay, given gene interaction and hitch-hiker genes: lots of genes can get inherited without being selected for – this is only a problem for gene selectionists.

The key and controversial assumption is that this new phenotype is adaptive. The notion of adaptive phenotypic accommodation is called the "two-legged goat effect" from the example of a goat born with two legs which changed lots of things in its phenotype to survive to reproductive age (though it didn't, in fact, reproduce). The principle is that organisms can adaptively change in response to mutations or environmental changes, and that these adaptive changes can become genetically accommodated (again, this sounds Lamarckian, but really isn't).

This change in phenotype creates new selection pressures (because selection is all about interaction of phenotypes; remember, genetic changes simply keep track of real world interactions). The new phenotype starts to spread (as long as, in the case of environmentally induced change, the new environmental conditions reliably recur).

Then the new selection pressures go to work on the regulatory gene networks of the pre-existing unexpressed genetic variation (this is why it's not Lamarckian). The new selection pressures can cause the spread of phenotypes which rely upon the expression of the previously unexpressed genes, so that it (the new phenotype) can eventually become a fixed expression (that is, the regulatory gene networks can be selected for), even when the original environmental novelty is no longer present.

If the trait appears without recurrence of the environmental stimulus, there is "genetic assimilation" (going back to Waddington's work). "Genetic accommodation" is the general case in which the trait appears with or without the environmental stimulus. If it occurs only with the environmental stimulus, it's said to be an "environmentally sensitive" trait expression. In this latter case, what gets selected for is, conservatively speaking, the regulatory gene network, or, radically speaking, the life cycle that includes

> the extended network encompassing the recurrent environmental stimulus and the regulatory gene network.

So, to recap, when an adaptive phenotypic change has a genetic component, the regulatory gene networks (or, radically speaking, the life cycle that includes the extended network encompassing the recurrent environmental stimulus and the regulatory gene network) for this adaptive phenotypic variant (networks that were only "virtual," that is, only potentials of the pre-existing but unexpressed genetic variation) will now be selected (if the environmental change reliably recurs), so these gene networks are thus "followers", as opposed to "leaders" in evolution. Instead of being the sole causal factors, they are often just "bookkeeping."

DEVOLOPMENTAL SYSTEMS THEORY (DST)

Anti-genetic determinism: the "parity principle" of DST states that there are *multiple developmental resources of which DNA is only one*. Genes are certainly important, but they are immanent parts of networks.

> No one has ever upheld an absolute determinist position if by that one means epigenetic conditions have no influence whatsoever, that they are determined the way a stone is determined to fall by gravity. The real target of critique is what Susan Oyama and the DST crowd call "interactionism," that is, the idea that there are two classes of developmental resources, genetic and epigenetic, and that genes provide the information or blue-print or plan or program, and that the epigenetic resources are the materials or background upon which or in which genes act. The real question is locus of control rather than absolute determination.
>
> Thus the DST critical position is to uphold a "parity thesis" in which genes are considered one among many developmental resources; they are an important, indeed essential, part of a developmental process, but they are immanent to the process and cannot be said to "control" it in any transcendent way. At stake is a deep question of "political physiology."
>
> Nor can we parcel out the "portion" of genetic control. DNA plays a role in the extended network regulating developmental and physiology, but we cannot conclude from this that development and physiology are "partially under genetic control." They are under the control of the extended system of which DNA plays a part. Let's put it this way: in a prison, guards play a role in the extended system of prisoner control (but so do wardens, physicians, clerks, and TV cameras, microphones, doors, bars, walls, etc.), but we shouldn't say that prisoners are "partially under guard control."
>
> A crucial point is "information." Oyama holds that the idea the DNA contains pre-existing information as bundles of physically encoded meaning able to direct development is false; instead, "information" has to be seen as a process (in-formation:) in

> which the direction of developmental stages emerges in that very process. Thus the title of her book, *The Ontogeny of Information*. Francisco Varela expresses this idea with the phrase "laying down a path in walking." We can consult Simondon in *L'Individu et sa genèse physico-biologique* for in-formation as a process vs information as a unit.

DST proposes *the life cycle* as at least one of the units of selection (pluralist position) or as the unit of selection (strong position). They are also big proponents of niche-construction as providing a robust sense of extra-somatic inheritance (i.e., epigenetic inheritance very widely construed).

With the emphasis on *niche-construction* as part of epigenetic inheritance, DST brings ecology into direct relation with development and with evolution, that is, with evo-devo and devo-evo. We might even call a DST and devo-evo synthesis "eco-devo-evo."

> Many practicing biologists reject the DST position as unworkable, as getting too close to an unmanageable holism -- where do you draw the line once you're extra-somatic? Sure, in principle, the entire universe is reflected in each Whiteheadean "organism" or Leibnizian monad, but you can't do science that way -- science is about extracting a few factors and measuring their interaction as dependent and independent variables. So a key question is: is DST "just philosophy"? Or can you operationalize it, render it scientific? Can you form testable hypotheses from it? The DST people will point to already ongoing research projects following their principles.

Some key DST books: Richard Lewontin: *The Triple Helix* (niche-construction); Susan Oyama: *The Ontogeny of Information* (multiple developmental resources); Jablonka and Lamb: *Evolution in Four Dimensions* (genetic, epigenetic, behavioral, symbolic inheritance).

THE BIG PICTURE IN BIOLOGY

Eco-devo-evo: Synthesis of W-E and DST

Provides for multi-level, interlocking, distributed system for cell / organ / system / organism / life cycle development & function in an evolutionary perspective

IOW, the big bio-picture: repetition and difference on all the spatial-organization and temporal-processual scales of life.

LECTURE 3
DELEUZE'S CONTRIBUTIONS

OUTLINE OF LECTURE 3

Why bother?
Development in *Difference and Repetition*
Evolution in *A Thousand Plateaus*

WHY BOTHER?

The first thing to ask is why bother translating the biology we've covered into Deleuzean terms? Why not just stay with the conceptual schemes of West-Eberhard and DST, producing an eco-devo-evo synthesis in their own terms? It's certainly a lot of work to get into their conceptual system, as exemplified by the work we had to do to grasp the notion of "genetic accommodation," for instance. And I take it we all will acknowledge how much work it takes to grasp the difference between individuation and dramatization in DR, for instance, or epistrata and parastrata in ATP!

Well, there are two benefits I can see, one technical and professional and the other of general interest.

Technical / professional. The concept of the *virtual* enables us to think potentiality in distributed / differential systems (such as that of the extended gene regulatory system), just as the concept of *actualization* enables us to think the "multiple realizability" of such systems. As these are important concepts in analytic philosophy of biology / philosophy of science, Deleuze allows some ground for dialogue, some common vocabulary.

General interest: Deleuze and DG offer a conceptual scheme that allows us to treat inorganic, organic, and social being with the same concepts. In both DR and ATP, which will be our foci, D and DG strive for a *naturalism*, that is, the refusal of humans as a "kingdom within the kingdom," as Spinoza would have it. Of course, here naturalism cannot be confused with a reductionist or eliminative "materialism," which is better named a "mechanism." Nature includes freedom and creativity as much as it contains mechanism. "Machinism" is not mechanism. In fact, for Deleuze, mechanism is a residue of machinism: creativity comes first, then routinization. (A preview: this is a good slogan for genetic accommodation and for serial endosymbiosis!)

> Deleuzean naturalism is the topic of an early piece on D's biophilosophy by Howard Caygill in KAP's essay collection of 1996. Caygill criticizes D for sentimentally including a human level selection (active joyful encounters) and avoiding Darwin's inhuman selection. A common fear, as we see here in Caygill, is that we thus brutalize ethics and politics by naturalizing. But this is a monolithic view of nature. Darwin is not just about competition. As Kropotkin shows, there's plenty of co-operation in nature as well. I think we can capture this with DG's distinction of stratification and consistency.

> Nature is multiple, so both sides of human nature, the destructive and constructive, the State and the nomad, the creative and the repetitive (obviously these do not always line up) are natural.

We can also ask: How can biology help us with Deleuze?

Genetic accommodation via environmental induction of developmental plasticity and phenotypic adaptivity gives us a concrete model of counter-effectuation

DEVELOPMENT IN *DIFFERENCE AND REPETITION*

THE CONDITIONS OF GENESIS OF REAL EXPERIENCE

We know that with DR, D wants to change the Kantian formula for transcendental philosophy from the search of "conditions of possibility for any rational experience" to the search for "conditions of the genesis of real experience."

The full formula he comes up with is: "indi-drama-differen*t/c*iation" (246 / 317).

Let's read this from right to left.

We know of the t / c distinction from Chapter 4.

Differentiation = differential structure of Ideas or "multiplicity." Idea = set of differential elements, differential relations, and their singularities.

Differenciation = divergent actualization of Ideas resulting in set products with extensive properties: spatial and qualitative.

Then we come upon "drama" for "dramatization." Dramatization of Ideas occurs in intensive spatio-temporal individuation processes.

And finally we see the lead term, "indi" for "individuation. This is the most important term! As we will see, Deleuze will insist that individuation has priority over actualization / differenciation and it determines which differential relations are to be actualized. It's the priority of individuation that prevents the virtual from being Platonized, as allegedly consisted of pre-existing Ideas. In fact, Ideas are determined or even invented by individuation processes. And this priority fits with the biology we've learned so far.

One of D's favorite examples of such an individuation process in DR is embryo development.

THREE ONTOLOGICAL MODES

Deleuze can be read as positing three ontological registers: the actual (organism), the intensive (impersonal individuation [and dramatization: though Deleuze often just says "impersonal individuation"]: embryological or more generally ontogenetic development), and the virtual (pre-individual singularities in differential-distributed genetic-environmental networks).

Let's spell out the use of virtual here a bit. We recall the difference between functional genes as end-products of the transcription process and hereditary genes as strings of DNA on the chromosomes. In other words, the functional genes are only virtually there – their mode of being is virtual – in the hereditary genes.

They have to be actualized through a distributed process in which regulatory gene networks are activated in "dialogue" with epigenetic conditions (intranuclear: mythelation patterns, chromatin markings; cytoplasmic gradients; "positional information" during morphogenesis [temporal-spatial relation of cells to each other]; and even more, perhaps extra-somatic conditions [a particular ambient temperature controlled by niche-construction, for instance; or more complex "scaffolding" operations including exposure to language and other symbolic systems].

Now all these distributed systems are "differential" in Deleuze's sense:

1. the elements are defined reciprocally ["a gene" is what it is only in the network of genes [it only codes for a protein because of its relative position in an arbitrary genetic code], "a cell position" is what it is in a field of cells [there's no absolute space-time co-ordinates at play, only relative cell position], "a niche" is what it is only in the network of niches [ecosystems are precisely systems] – or in other words, there is no such thing as "a gene" or "a cell position" or "a niche"];
2. the relations are differential (it's all about linked rates of change: how fast does X element arrive relative to the rate of arrival of Y: the famous delta X / delta Y: it's only given determinate values in the actualization process)
3. and the relations contain singularities as remarkable points or thresholds for qualitative change. The singularities as thresholds means the functional genes are "multiply realizable" / divergent actualization from the same DNA string: remember instead of "one string of DNA = one gene = one protein = one function" to "one string of DNA (structural / hereditary gene) = many (functional) genes (many mature mRNA transcripts) = many proteins = many functions."

So one connection of Deleuze and biology can certainly be to propose virtuality as the ontological status of functional genes. This would certainly bring some clarity to gene discourse.

FOUR-FOLD ORDER OF REASONS

But it's a even more complex than just three modes or registers, for we have to distinguish "individuation" as the field of individuation from "dramatization" as the process of individuation. Thus, "the egg provides us a model for the order of reasons: differentiation-individuation-dramatization-differenciation (organic and specific)" (251 / 323; translation modified to restore original word order of parentheses).

Following Simondon, Deleuze will distinguish the *field* of individuation (the egg / the BwO / the metastable field), which retains the name "individuation," from "dramatization" as the *process* of individuation (morphogenesis / (embryonic) development / "spatio-temporal dynamisms). So both the field and the process are "impersonal," whereas the virtual / differential-distributed genetic-environmental system is "pre-individual." (which makes the actual into the "personal")

> If you want a comparison, in the meteorological register, the *field* of individuation is composed of the pre-conditions (the bands of different temperature and pressure in air and water) to the morphogenesis of wind currents or storms, which are the spatio-temporal dynamisms, the *process* of individuation.

Here is how it is presented in DR:

THE PRIORITY OF INDIVIDUATION

Intensity is determinant in actualization. It dramatizes, it is expressed in spatio-temporal dynamisms. So individuation is named the "essential process of intensive quantities" and also called "signal/sign systems." Deleuze recalls how for Simondon: individuation presupposes metastable state, that is, 2 orders of magnitude btw which are potentials (signal). These potentials constitute an objective problematic field, and individuation is act of solving problem, that is, the actualization of a potential = establishing communication btw disparates (sign). Thus the individual (as intensity, as "impersonal") is coupled to a *pre-individual* virtual field of differential relations and singularities. Thus individuation is the answer to the question "who?" not the essentialist "what is?"

"Individuation precedes differenciation in principle … every differenciation presupposes a prior intense field of individuation. It is because of the action of the field of individuation that such and such differential relations and such and such distinctive points (pre-individual fields) are actualized" (247).

"As a result" of the priority of individuation, we see the formation of quality, number, species and parts of individuals. In other words, differenciation is a relation to other differences and allows "generality" (placement of an individual in a species and genus) (247). That's why it's crucial to correct the translation and put "organique et spécifique" *after* differenciation.

But we have to beware the "tendency to believe individuation is a continuation of the determination of species" (247).

Deleuze puts it very strongly: "any reduction of individuation to a limit or complication of differenciation compromises the whole of the philosophy of difference. This would be to commit an error, this time in the actual, analogous to that made in confusing the virtual with the possible" (247 / 318).

"Individuation does not presuppose any differenciation; it gives rise to it [*la provoque*]" (247 / 318).

INDIVIDUAL DIFFERENCE AND EMBRYOLOGICAL DEVELOPMENT

At this point, Deleuze must distinguish between the comparable difference between individuals, difference within a horizon of resemblance (i.e., representation), which can be classed in genus and species, and divergent difference or "individual difference," the difference thought by Darwin, the "differenciation of difference," that which does not track genus, but produces it via selection as stabilizing procedure. Making species turn around individual / diverging difference: this is Darwin's "Copernican Revolution" (247-249).

D now turns to embryos:

Embryo: organic de-differenciation. For von Baër: embryonic life goes from more to less general. However, this generality is not abstraction (differenciation as comparison), but is lived in the process of individuation / dramatization. Thus the experience of the embryo (remember the most basic shift of DR is from Kantian conditions of possibility of rational experience to Deleuzean genetic conditions of real experience) points to:

1) Differential relations or virtuality prior to actualization of species form (i.e., prior to differenciation, when compared to other forms).
2) "first movements" or "condition" of actualization: individuation as it "finds its field of constitution in the egg"

So, the lived generality of the embryo points beyond species to the individual (field of individuation and process of individuation) and pre-individual singularities. So even though the specific form of the embryo appears early, this is due to speed and slowness of individuation process, that is, to the "influence exercised by individuation upon actualization or the determination of the species." Thus a species is an "illusion" of play of individuation (249-250).

A PRESCIENT CRITIQUE OF GENETIC REDUCTIONISM

First, we are reminded again of the primacy of individuation over differenciation, and that the "embryo is individual as such caught up in field of its individuation" (250). After the famous "the world is an egg" (251) we read that "the nucleus and the genes designate only the differentiated matter – in other words, the differential relations which constitute the pre-individual field to be actualized; but their actualization is determined only by the cytoplasm, with its gradients and its fields of individuation" (251 / 323). Again, the virtual is "pre-individual," while the intensive is "impersonal." (thus the actual must be personal.)

We have seen this as the movement away from a genetic program to a distributed / differential network controlling development.

Recall here the Deleuzean principle of critique, the outlawing of the tracing relation between transcendental and empirical or virtual and actual: the non-resemblance of actualized species/parts to virtual differential relations / singularities / intensities. And the non-resemblance of both to the intensive processes of morphogenesis: the lived experience of the embryo – its twists and folds – do not resemble either the virtual network of relations among DNA strings and epigenetic factors or the actual structures and qualitatively different cell types of the adult organism.

The "principal difficulty" is that we have posed field of individuation formally and generally. It thus seems to depend upon the species. So we must conceive individuating difference as individual difference: no 2 eggs are identical.

We've traced the order of reasons from virtual differentiation through impersonal / intensive field of individuation to spatio-temporal dynamisms as process of individuation or dramatization to differenciation as formation of parts and species, that is, structures and qualitatively different cell types and functions.

COUNTER-EFFECTUATION

We've seen the relation of individuation and differenciation and the priority of the former. What about the relation between individuation and differentiation?

In other words, what about counter-effectuation? Is it a purely mental / philosophical act or is there a objectivity, a reality to it? Peter Hallward holds the former, which is why for him, Deleuze is theophantic and philosophy aims at de-materialization.

Concerning the relation between individuation and differentiation, Delezue writes: "individuation is the act by which intensity determines differential relations to become actualized, along the lines of differenciation and within the qualities and extensities it creates" (317F / 246E: "L'individuation, c'est l'acte de l'intensité qui détermine les rapports différentiels à s'actualiser, d'après des lignes de différenciation, dans les qualités et les étendues qu'elle crée.")

Writing a few pages later about the clear and confused nature of intensities, Deleuze tells us that the expression of Ideas in intensities "introduces a new type of distinction into these relations and between Ideas a new type of distinction" (i.e., from co-existing to relations of simultaneity or succession). He then writes: that "all the intensities are implicated in one another, each in turn both enveloped and enveloping, such that each continues to express the changing totality of Ideas, the variable ensemble of differential relations." He concludes that "each intensity clearly expresses only certain relations or certain degrees of variation. … those on which it is focused when it has the enveloping role" (*Difference and Repetition* 325 F / 252E).

Is there a way in which the selective "focus" by which intensities clearly express only certain relations will itself introduce changes into the realm of Ideas? Is counter-effectuation creative? That is, can one say that experimentation with intensive morphogenetic processes will link together new combinations of differential relations, thereby forming new Ideas? That it will express or determine new potentials of the virtual? That's what I take "determines the differential relations to be actualized" (which I prefer as a translation of "à s'actualiser") to mean in the extreme case of an Event or "emission of singularities": it renders them determinate in the sense of linking together previously unrelated relations. In pushing this interpretation, I want to avoid a Platonism in which the Ideas are already determined and so expression is mere copying of already made linkages of relations.

Now for the biology connection. Recall how developmental plasticity is the creativity of the phenotype and environment (NOT the genotype and environment). When an adaptive phenotypic change has a genetic component, the regulator gene networks (or more radically, the life cycle) for this adaptive phenotypic variant will now be selected (if the environmental change reliably recurs). Now these accommodated or now newly / creatively expressed regulatory gene networks

(again, more radically put, the life cycle provoking the extended system of regulatory gene network and recurrent environmental conditions) were only "virtual," that is, only potentials of the pre-existing but unexpressed genetic variation.

Here we see the meaning of W-E's phrase that gene networks are thus "followers" as opposed to "leaders" in evolution. Instead of being the sole causal factors, they are often just "bookkeeping." That is, it's the developmental plasticity and the phenotypic adaptivity (that is, intensive processes of individuation) that take the lead and bring out previously unexpressed potentials of hereditary DNA: brings out their potential to form the regulatory gene networks. But here's the crucially important point: the potentiality of the hereditary DNA is not a preformationism: there's no present / actual / homuncular / already-determined "unit" or "program" in the DNA that determines the actualization of the potential. The virtual is not "self-determining": it's determined, on the spot, each time, by the individuation process. (That's why Deleuze will say the condition is no bigger than the conditioned.)

It's the individuation process that takes the lead, that has to creatively produce a novelty, that has to introduce something new into the world. This priority of individuation is what W-E talks about as developmental plasticity and phenotypic adaptivity, and is a perfect example of the reality of creative counter-effectuation.

MISTAKEN CRITIQUES

Mark Hansen, in discussing DR, misses the details of DR 5. That is, at the biggest level, he fails typographically to distinguish differentiation as virtual from differenciation as actualization. And he fails to correctly identify intensity with the field and process of individuation, instead identifying intensity with the virtual. This leads to confusing sentences like: "Deleuze implies the existence of a domain of intensity that embodies this virtuality, thus effectively repudiating the primacy Bergson (and contemporary complexity theory) afford actualization as differentiation."

In detail, what he has done is conflate individuation as field of individuation with the virtual as differential. The intensive field of individuation is the egg. It is NOT the differential network of the genes (which we would now say includes epigenetic elements). The egg is the BwO or in Simondon's terms, the metastable field. It is impersonal, but the virtual is pre-individual. Thus Hansen is mistaken to say: "emergent actuals [e.g., the embryo as spatio-temporal dynamism or process of individuation or morphogenetic process] do not limit the virtual by means of an operation of negation [true], but rather express a concrete differentiation [there is no such thing; there are only concrete individuation processes taking the lead over differenciation] that remains in contact with the domain of intensity (or the virtuality) from which it emerges [false; this conflates egg as impersonal intense field of individuation with gene networks as virtual pre-individual differential realm]."

Peter Hallward also cannot appreciate the role of intensive processes as creative of biological novelty because he has assimilated a genetic reductionism to an exclusive privilege of the virtual and evacuation of all creativity from the actual. Hallward writes that “there is no more an interactive relation between this virtual or composing power and its actual or composed result

than there is *between* a given set of genes and the organism that incarnates them (52; emphasis in original).

But we have seen very few biologists would now say an organism "incarnates" genes.

CONCLUSION TO DR AND BIOLOGY

We have seen the strong anti-genetic reductionist views of contemporary critical biology. For West-Eberhard and DST, organisms do not "incarnate" genes. There is a distributed / differential system of feedback among genes and multiple epigenetic factors guiding development.

But not only that: in West-Eberhard's concept of genetic accommodation of environmental induction of novel phenotypic traits as a source of evolutionary potential (145; 499ff), we have seen counter-effectuation as a reality.

So, we have to see both distributed-differential gene-environment networks as virtual and we have to see genetic accommodation as counter-effectuation, as changing the virtual, as bringing forth previously unexpressed potentials, from intensive processes.

EVOLUTION IN *A THOUSAND PLATEAUS*

TRANSITION

Let's translate our DR take on devo-evo into ATP's terms of content and expression.

Here's how ATP handles genes:

Substance of content: amino acids
Form of content: order of amino acids in a protein chain
Form of expression: overcoding provided by tRNA (as part of gene expression network), which picks out an amino acid according to the triplet codons it gets from the mature mRNA transcript
Substance of expression: the completed protein (a new emergent functional structure)

The completed protein can then be the substance of content for cellular metabolism; the cell can then be substance of content for the organ, etc. So, e.g.,

Substance of content: the protein
Form of content: the order in which that protein is selected in building a cellular structure (e.g., the membrane
Form of expression: that part of gene expression network responsible for the cellular structure under construction, and is thus responsible for organizing the protein's role in the cellular metabolism
Substance of expression: the complete cell structure as it functions in cell metabolism (e.g., the completed membrane)

DIFFERENCE BETWEEN DR AND ATP

Whereas in DR we focused on genetic accommodation as counter-effectuation, here in ATP we focus on what W-E calls "environmental induction." This makes sense, as DR focuses on how individuation determines the actualization / differenciation of virtuality, whereas in ATP it’s all about different rhythms of intensive processes. In a way, it's a much "flatter" ontology in ATP: there's a way in which the notion of the virtual is hardly even present in ATP. It's more like the limit of the process of destratification or deterritorialization. I don't think you ever "reach" the virtual in ATP: you can get more or less flexible processes depending on how close you approach the limit of destratification / deterritorialization. But you can't live the virtual (so arguably there's no "real experience" of the virtual in ATP, though there are ways to be more flexible): you need to be always in a process (multiple processes) of individuation. But the "direction" of that process can change; you can head toward flexibility or toward repetition. But there's no a priori privilege of flexibility: it's all about pragmatic / cautious experimentation. "Real experience" as experimentation rather than Erlebnis. We don't have to fight out all the details here though.

MILIEUS, CODES, AND TERRITORIES

In discussing evolution in ATP, we have to talk about milieus and codes, strata and territories. Famously (or notoriously), ATP talks about "non-organic life."

> LIFE [*vie*]: (1) a certain set of beings (‘organisms’), that is, ‘a particularly complex system of stratification’ (336);
>
> (2) the creativity of complex systems, ‘a surplus value of *destratification* … an aggregate of consistency that disrupts orders, forms, and substances’ (336; italics in original).
>
> In the second sense, then, life is not limited to the organism form: ‘the organism is that which life sets against itself in order to limit itself’ (503). This notion of life as creativity, revealed by metallurgy and its sense of ‘a life proper to matter’, gives rise to ‘the prodigious idea of *Nonorganic Life*’ (411; italics in original).

Milieu = vibratory / rhythmic / coded material field (313) for bodies (strata) and territories (assemblages). They are "drawn" by rhythms from chaos. Milieu are heterogeneous. Territories form in the between of ever-shifting milieu.

Every living being has 4 milieus:

1. Exterior milieu: materials furnished by substratum (49)
2. Interior milieu: domain of homeostasis for the composing elements and composed substances (50)
3. Intermediary milieu: membranes (51): establishing possibility of *epistrata* as stable states (homeostatic set points)
4. Annexed or associated milieu (51) = enacted world = niche (*parastrata*)
    a. sources of energy different from food (respiration)
    b. discernment of materials (perception)
    c. fabrication of compounds (response / reaction)

Milieus are coded / repetitive – but the rhythm is always shifting in "transcoding" (313).

Rhythm is the difference between one code and another ("there is rhythm whenever there is a transcoded passage from one milieu to another, a communication of milieus, coordination between heterogeneous space-times" [313]). Thus the rhythm and the milieu are relational. "A milieu does in fact exist by virtue of a periodic repetition [i.e., a code], but one whose only effect is to produce a difference by which the milieu passes into another milieu" (314).

Codes = that which determines order (in a milieu, or as forming a body in content / expression).

Every code has a "*margin of decoding*" (53 / 322) from two factors: *supplements* (unexpressed genetic variation, that is, non-coding DNA) and *transcoding* or "surplus value of code" (transverse communication or serial endosymbiosis).

> *Supplements* are free matter for variation (53 / 322). Think of W-E's unexpressed genetic variation.
>
> *Transcoding* is between fragments of different codes, constitutes a new plane of "surplus value" (314). Von Uexkull sees this as melodies in counter point (nature as music). See also 53. Parastrata / rhizome / transverse communication / serial endosymbiosis.

Territorialization affects multiple milieus and rhythms. Territories themselves have exterior, interior, intermediary, and annexed mileus (as do bodies) (314).

> With territories, milieu components are no longer directional but now *dimensional*, that is, they are no longer merely functional, but now *expressive* (315). There are thus now qualities as *matters of expression*.
>
> For example, color in birds or fishes is *functional* when tied to an action (when it indicates readiness for one of the "4 Fs"), but it is *expressive* when it marks a territory.
>
> The difference is temporal: functional color shifts are transitory and tied to the action, while expressive color has a "temporal constancy and a spatial range" (315).

Territories depend on decoding: The key is the disjunction of code and territory (322): "the territory arises in a free margin of the code", that is, while in milieus there is transcoding, territories are associated with *decoding*.

There is free DNA as a "free matter for variation," but it's not enough for creative speciation. "it is very unlikely that this kind of matter could create new species independently of mutations" (322; see also 53). We can connect this to W-E's unexpressed genetic variation.

What does terrritorialization do? It has spatial / distribution and intensification effects.

1. It spreads organisms out, making them keep their distance from each other.
2. It *intensifies the relation of the organism and its milieus*. It speeds up evolution from having to wait for mutation: "Territorialization is precisely such a factor that lodges on the margins of the code of a single species and give the separate representatives of that species the possibility of differenciating [translation modified from "differentiating"]" (322 / 396).

CONNECTION OF ATP SO FAR WITH BIOLOGY

DST / niche-construction. So, in DST terms, "territorialization" is individual / variable "niche-construction." The evolutionary intra-populational or intra-specific variation takes place on the level of the individual niche-construction.

Devo-evo and environmental induction. Now to be the leading edge of evolution, territories have to be different from codes, that is, they have to be underdetermined by the genetic code. That it, there is developmental plasticity / phenotypic adaptivity: "it is because there is a disjunction

between the territory and the code that the territory can indirectly induce new species" and "territorial animals are much less coded than non-territorial animals" (322).

The term "induce" should remind us of what W-E says:

1. Environmental induction is a major initiator of evolutionary change (genes are followers, not leaders [as they would be if mutation were the major initiator of change.)
2. Evolutionary novelties result from reorganization of preexisting phenotypes and incorporation of environmental elements (novel traits are not de novo results of mutation).
3. Phenotypic plasticity can facilitate evolution by immediate accommodation and exaggeration of change (phenotypic plasticity is not mere noise obscuring genetic patterns).

A FEW MORE WRINKLES: EPISTRATA AND PARASTRATA

As if the discussion in the Refrain chapter weren't enough, there are some nuances in the Geology of Morals chapter we have to address.

First, two definitions

EPISTRATA: in the strata, stable states of bodies produced through territorialization and deterritorialization, ‘variations that are tolerated below a certain threshold of identity’ (50). In crystals, epistrata are ‘discontinuous states of metastability’, while on the organic stratum, epistrata are ‘interior milieus’ that provide materials to internal organs, thus regulating ‘the degree of complexity or differentiation of the parts of an organism’ (50); in disciplinary organizations, epistrata are tolerated deviances. Epistrata fragment a stratum, as each crystalline solution, organic life form, or social institution will have different thresholds of tolerance for deviation from a norm.

PARASTRATA: sets of affects on the organic stratum produced by processes of coding and decoding. Parastrata enable the construction of assemblages linking an organism to ‘associated milieus’ allowing for ‘respiration’ or capture of energy sources; ‘perception’ or discernment of materials; and ‘reaction’ or fabrication of compounds (51). Such associated milieus are closely related to organic forms (the distribution of traits in a population) and react upon margins of decoding in the organism (54-5).

Key sentence: "An organic form is not a simple structure, but a structuration, the constitution of an associated milieu. [IOW, niche-construction or enaction of a world.] An animal milieu, such as the spider web, is no less 'morphogenetic' than the form of the organism" (51). This is crucial: DG here see the subject of development / ontogeny as the organism in its niche, not just the organism in some simple physical bounded sense. Sure, there are physical self-organizing phenomena that are morphogenetic (Goodwin), but this is not the limit of the extent of morphogenesis, which extends to extra-somatic factors. This is not soft science: a social animal will die if deprived of contact (that is, part of what constitutes its niche is social contact with conspecifics) just as much as if denied of air (though of course the death takes longer).

We can't get into all the details of the relations of stratification and territorialization in ATP 3. But we have enough to examine an interesting article from Mark Hansen, whose shortcomings will help us see what is at stake in ATP.

MARK HANSEN'S CRITIQUE

HANSEN ON MORPHOGENESIS

In discussing ATP, Hansen misses several points. For one thing, he misses the intermediate levels of DG's exposition. He accuses them of only having a molecular reductionism and a cosmic expressionism. But this misses the epistrata as steady states above level of genes and below level of organism and the parastrata as emergent fields / niche-construction, that is, above the level of the organism but below that of the cosmos.

Hansen is correct that DG want to go above and below the level of organism, but he is wrong on both fronts: below the level of the organism there are W-E's "modular sub-units" (= steady state of interior milieu = "epistrata" and not just pure molecular innovation, but de-re-territorialization and "degrees of development" as relative speeds and slowness = developmental plasticity as producing phenotypic variation via environmental induction)

And above the organism there is DST's life cycle, that is, an emergent morphogenetic field producing viability constraints, but it is the organism in its niche (not just "organism" as Goodwin would have it). (associated milieu / parastrata / recurrent assemblage: de-re-coding and "forms" = genetic accommodation as changing genetic profile of a population by acting on previously unexpressed genetic variation: adaptation).

Yes, DG do include Magulis and symbioses (238), but Hansen underplays their role in micro-evolution. Cf. WE and entrenchment (501). On 239, DG say that "movement occurs not only, or not primarily [*surtout*], by filiative productions but also by transversal communications between heterogeneous populations." So DG don't deny evolution by filiation, they just want to focus on involution by transverse communication. Here there is no notion of which process is more important or whether we're talking long-term macro-evolution or short term micro-evolution. But the real action in micro-evolution is in the interplay of epistrata and parastrata, that is, coding and territorialization.

HANSEN'S FAILURE TO DISTINGUISH THE BIOLOGICAL AND POLITICAL ORGANISMS

Hansen writes: DG "redefine life as a thoroughly machinic process, one that expresses itself in heterogeneous conjunctions of singularities which are themselves heedless of biological constraints."

LIFE [*vie*]: (1) a certain set of beings (‘organisms’), ‘a particularly complex system of stratification’ (336); (2) the creativity of complex systems, ‘a surplus value of *destratification* …

an aggregate of consistency that disrupts orders, forms, and substances' (336; italics in original). In the second sense, then, life is not limited to the organism form: 'the organism is that which life sets against itself in order to limit itself' (503). This notion of life as creativity, revealed by metallurgy and its sense of 'a life proper to matter', gives rise to 'the prodigious idea of *Nonorganic Life*' (411; italics in original). (Note that 'living thing' [*le vivant*] is used as a neutral term with regard to the distinction between organism and non-organic life [313].)

Life includes both non-organic and organic life. The "machinic process" = non-organic life. They do not mean by this that organic life can ignore viability constraints. What they do mean is that living beings (les vivants) or "bodies" can be taken up into larger assemblages that shake up habits and inject some flexibility into the "organism" qua hierarchically subjected body politic. In other words, Hansen fails to distinguish the biological organism from the political organism. It's the latter that is the "judgment of God."

This mistake is revealed when Hansen writes: "the flexibility postulated by Geoffroy's "Principle of Connections" and by the types of symbioses Margulis discusses (e.g., between cells and mitochondria) only arises over large-scale macroevolutionary timescales, not in cases of individual somatic change of the sort that forms the object of D+G's ethology of becoming." But here he confuses the "somatic" (i.e., biological organism) with the political organism, which is the short-term subject of symbioses / becomings / assemblages, etc.

Again, "While Margulis may be right that we are, from the standpoint of macroevolution, mere hosts for microbial life, in the narrower frame we remain organized units which are, in some sense or other, the objects of nature's selectional processes." "We remain organized units" as biological organisms, but the political body's experiments work on the political organism, not the biological organism, which retains the viability constraint of autopoiesis.

Hansen: "It is one thing for D+G to draw on contemporary biology and on neglected historical pathways to underwrite creative involution as an alternative model of macroevolution and quite another thing to apply this model to the behavior of individuals or use it as the basis for a molecular dissolution of the organism." But of course DG apply creative involution to behavior! There's no problem here at all, since behavior is radically underdetermined by the biological organism's homeostatic / homeodynamic / autopoietic viability constraints. The biological organism is NOT the major target of becoming (although yoga, etc., can have physio effects.)

Hansen: "the BwO serves to furnish a limitless source of alternate organizational pathways that form the basis for, and thus guarantee the logical possibility of, the deterritorialization of the organism." Again, experimentation reaching the BwO mostly aims at the political organism; it's always subject to viability constraint of the biological organism. This is the theme of caution.

Hansen: "their ethology of becoming is--from the biological standpoint--nothing short of impossible." This is crazy. Ethology / behavior is radically underdetermined by biology (or at least in complex animals).

Hansen: "simply put, deterritorialization as a biological process can only take place relative to a concrete if flexible context and can only modify the ecology of the organism within certain structurally and situationally imposed bounds."

HOWEVER, even though you must separate the biological and political organism (that is, take advantage of the radical underdetermination of behavior by physiology), we have to acknowledge that you there is a bio component to social / political becoming via developmental / phenotypic plasticity / accommodation. E.g., neuroconstructivism. So while there are physiological constraints, the neuro-behavioral is pretty much wide open: although there are inherited forms here too: we are not blank slates, there is a human nature. But it's not the Darwinian competitive (alone), but there is also prosociality as revealed by wide-spread proto-empathic identification. In fact, I'd say prosociality is primary and you have to do a lot, you have to create extreme social conditions (neo-liberalism and shock) to break solidarity and bring competition to the fore.

There is some bio-flexibility of course: you can change your physiology by practice: exercise regimes. And these can influence by conditioning your behavior: manipulating thresholds of excitability. But by and large, it helps to emphasize the note of caution in ATP and that means recognizing the distinction of the biological and the political organism.

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