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Winogradsky Rothko: Bacterial Ecosystem as Pastoral Landscape

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Abstract

Made in the dimensions of a Mark Rothko painting, a steel and glass frame was filled with mud and water. By applying a microbiology technique developed by a 19th-century soil scientist, Sergei Winogradsky, pigmented bacteria that existed in the mud and water composed a landscape. As bacteria colonize their optimal zones, they change their environments by depleting their resources and releasing by-products. As a bacterial species reaches its carrying capacity, the environment no longer hospitable to the original colonizer may now be the optimal environment for a potential successor to that zone resulting in an evolving color-field of living pigments. The appearance/disappearance of color indicates both procurement and loss of finite material resources; the agents that act out upon the landscape and synthesize change become acted upon by their consequentially changed world. For this article, the ecological industry of the figure and field of *Winogradsky Rothko* serves as a point of departure for thinking toward a notion of ecological rationality.

Keywords

bacteria • decomposition • ecological rationality • exponential function • figure • landscape • living pigments • Rothko • transformation • Winogradsky

> Separate 'things,' 'forms,' 'objects,' 'shapes,' etc., with beginnings and endings are mere convenient fictions: there is only an uncertain disintegrating order that transcends the limits of rational separations.
>
> (Robert Smithson, 1968[1996]: 112)

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Bacteria are the original synthesizers. Although bacteria are simple single cell organisms, they are a biological force adapting to and accessing minute resources in severe climates such as the Arctic or the deep sea. This adaptability has made bacteria the most genetically diverse and abundant (in mass and number) organisms. In their chemical and physical resource cultivation, they impact both their micro and macro ecosystems. On the macro scale, for example, bacteria generated oxygen stores that contributed to the creation of the ozone layer. The ozone layer was critical in reducing harmful effects of sunlight on evolving DNA. Bacteria also created greenhouse gases to warm the earth so that the climate was ripe for evolution of higher organisms. Even now, bacteria are profound players in the contemporary terrestrial economy.

Bacteria thrive if conditions are favorable; they mutate, migrate, die, or lie senescent if conditions are not favorable. They consume, reproduce, deplete their resources, and release waste products. As bacteria express themselves (i.e. live), they alter their habitat. They synthesize new environments or landscapes, thereby producing new ecological niches for other organisms. As such, they offer a field for mapping the rhythms and patterns constitutive of life.

As a formally trained biologist for more than 10 years, I continually observe transitions in the organic and inorganic world. I am compelled by the dynamic flux between matter and energy as it plays out in the destruction and creation of what is, as it informs how life is conserved, mutated, transmitted, or lost. I like looking for patterns that help explain the world. In particular, I am attracted to decomposition. I am intrigued by the 'offensive' smell, the 'violence' of re-appropriation, the applause for the glorified hedonism/agency of the 'creative', and the embarrassed, the fallen, the visceral 'ugliness' of rot – there is beauty in these moments. De/composition represents beginnings, change, contingencies of cause and effect, interconnectedness, possibility. Sometimes I feel trapped in the stasis of 'reality'. Perhaps decomposition is where my hope for the world lies.

I began creating art as a non-linear, non-languaged way to express the power of science. A scientific graph does not capture the complex process it represents; it only sums up the resultant pattern of particular constituents in a process. This concentrated abstraction of information is incredibly important because it gives us a conceptual framework within which to understand something bigger than our immediate perception. For example, plotting the growth of human population uses data of only those living at a particular time. That number is the net result of births and deaths. The point on the graph does not provide context regarding how many births there were or how many deaths. Nor does it explain the causes of death, location, or resultant change in square feet of earth per person – these would all be separate graphs. The graphed point only corresponds to the number of those living at a particular time, and taken with other points shows a trend or pattern.

A graph of change plotted along the axis of time simply shows layers of historical information. Henri Bergson (2001[1913]) speaks of the limits to our naming and enumerating: 'an algebraic equation always expresses something

Figure 1 *Winogradsky Rothko* (2004), two weeks after installation. Note initial pigment bands at the mud/water interface. Vertical streaks are from methane or oxygen bubbles created by biologic activity. Photo by Cathy Crane, 16 August 2004.

already done' (p. 119). In its pastness, it cannot capture 'the very essence of duration and motion, as they appear to our consciousness' (p. 119). The graph cannot express that which is 'unceasingly being done' (p. 119). My art strives to re-materialize processes that have been abstracted by the field of science so that the phenomena can be felt. To witness the process, an individual becomes wrapped in the perpetual experience of an evolving continuum.

Winogradsky Rothko (2004) is a rectangular steel and glass vessel (32¾" wide × 56" high × 2½" deep) containing a column of mud and water that undergoes pigmented transformations as colorful bacteria respond to their resources (Figures 1 to 3). *Winogradsky Rothko* mobilizes a living palette across an ecological landscape. Over time, various bacteria sequentially use (and consequentially transform) their habitat. The change in color is an indicator of transition in biophysical states, illuminating the bacterial industry within the bounded field of mud and water.

Though difficult to see individually, bacteria use pigment to harvest light energy. As a species of bacteria successfully reproduces and colonizes its optimal zone, it changes the environment by depleting resources and creating toxic by-products. When a colonizing species experiences exponential growth and reaches its carrying capacity (limits to its population growth), the now inhospitable environment becomes the optimal environment for a successor that might experience a similar growth and decay pattern. Thus, we see a slow display of biologic transitions – an infinitely evolving color-field of living pigments – bounded by a finite resource.

The transforming color-field I cultivated in *Winogradsky Rothko* was predicated on the rise and fall of organisms as they made use of and exhausted their preferred habitat. The individual pigments culminate in a kind of pointillism as the organisms grow from individual to colony, thereby illustrating a co-evolution of living cultures and habitats. In *Winogradsky Rothko*, bacteria are simultaneously figures in a landscape and catalytic agents in an ecosystem.

The living organisms manufacturing the pigment are simultaneously the subject and substance of 'painterly' objectification – both object and medium, both a work of art itself and a working of autopoiesis. This duality is singular in *Winogradsky Rothko* – the color-field image is literal. What it is in its becoming is what it means. Transitions seen in the three-dimensional field of color indicate sequential manifestations of synthetic structuring. These structures are built from the basic molecules of a finite ecosystem. Construction and deconstruction of the molecular building blocks produce an ongoing integration and disintegration of form. Therefore, there is not one color-field, but a series of color-fields. *Winogradsky Rothko* is a sequence of real-time, real-space negotiations performed by bacteria within a vertically oriented frame of finite natural resources. This work explores reiterations of cause and effect in order to make visible a universal of our three-dimensional world. The agents that act out upon the world and synthesize change become acted upon by their consequentially changed world.

Figure 2 *Winogradsky Rothko* (2004), six weeks after installation. Photo by Johnna MacArthur, 11 September 2004.

In creating *Winogradsky Rothko*, I was interested in three main things: (1) watching the live performance of ecosystem transformation as embodied by living pigments; (2) visualizing the exponential function – color as indicator of the growth/decay of successive species as they reach their resource limits; and (3) creating a piece of public art that could only be 'possessed' by serial viewing – because this 'painting' was always changing.

Winogradsky and Rothko

Imagine a time when bacteria were conceptually invisible, they were not even conceived of in the mental framework of mankind – think in terms of doctors, food preparation, hygiene, etc. People knew that milk spoiled, that patients died, and that soil changed but the mechanisms were not understood. In the late 1800s, scientists began accumulating important discoveries about bacteria. A Russian microbiologist, Sergei Winogradsky, stumbled upon color as an indicator of change in soil chemistry. He started by simply observing soil and water in a clear tube. One day, he saw a splotch of color that hadn't been there before. He stuck a pipette down into the colored section and looked at it under a microscope. There he saw micro-organisms. This simple system, now called the Winogradsky Column, has been responsible for important achievements in understanding the biology of bacteria and their impact on biological and chemical cycles in soil.

I learned about the Winogradsky Column one summer when I was a marine biology teaching assistant. On a field trip, the students and I filled clear two-liter pop bottles with mud from a freshwater/seawater mudflat on the coast of New Hampshire, USA. We brought the mud back to our wetlab, stirred in a bunch of eggs, grated some blackboard chalk, shredded some *Union Leader* newspapers, and covered the slurry with plastic wrap. We watched our own version of the Winogradsky Column for six weeks of the summer program. Little horizontal bands of color appeared and disappeared.

Somewhere along the way, I remembered as a child, taking a field trip to the Hood Museum in Hanover, NH, USA where I saw my first Mark Rothko painting, *Orange and Lilac over Ivory* (1953). I remember thinking it looked like a big open window, the kind you see in summer, warm and cool.

For me, the abstract Rothko pattern – translucent layering of horizontal color – is everywhere in the world. For example, gravity sets up a vertical armature that layers ecosystems. Without the energy that animates life, everything succumbs to the pull of gravity. The dust settles, the tree falls and materials line up in horizontal bands. In the case of soil, layers of chemistry across a soil landscape provide a variety of homes for diverse bacteria. These niches are suitable to various bacteria at various times as the natural resources undergo infinite structural changes by biologic activity.

Understanding this phenomenon, I set up the conditions of *Winogradsky Rothko* so that the horizontal banding of bacteria would manifest a

Figure 3 *Winogradsky Rothko* (2004), 12 weeks after installation. Photo by Johnna MacArthur, 21 October 2004.

pigmented pattern similar to a Rothko. Since I was working with only two physical variables – mud and water – Rothko's *Untitled* (1949) (32¾" × 56") was selected for its banding proportions and pigment tones that I felt the living palette would be able to mimic. The frame was made of steel so the outside edge would change, limning the image in reds and oranges. The water pressure required a 1⅛" thick glass face that gave the piece a slight green tint.

On 1 August 2004, the piece was hung by airline cable on a curved brick wall of Emerson Hall on the campus of Cornell University in Ithaca, NY. Buckets of mud, scum, and water were collected from a nearby pond. The mud was pressed through ¼ inch wire mesh and funneled into a thin opening at the top of the steel and glass container. The piece was hung directly opposite Mann Library (the main agricultural science library) along a well-traveled throughway. To prevent pigment bleaching, it was positioned to receive no direct sunlight other than a small triangle of sun which lit it in the late afternoon. It was removed on 1 November 2004. In principle, *Winogradsky Rothko* can evolve continually.

Niche Transformation

> . . . bacteria can acquire DNA sequences not only from each other but also from humans, for example, effecting a transfer of DNA from the animal kingdom to the bacterial kingdom. Some microbiologists have suggested that there are really no bacterial species at all but rather a sort of continuum of flowing genes over a huge amount of space and time. (Dexter Dyer, 2003: 10)

Recently, I note a delicate kind of existential crisis – that of doing and being undone. I see it happen all around me. Some call it flux, flow, change, transformation, nature. I call it expression – communication as action, as crossing from inside to outside to inside, as genealogy, as transmission. For bacteria, this process of living involves, for example, stripping electrons off molecules such as sulfur. When an electron is ripped off sulfur, the molecular chemistry of the sulfur is altered. Consequently, the chemistry of the surrounding environment is also altered. The beauty in this 'living destruction' is that one organism's waste product is another organism's food resource.

For example, a phototrophic purple bacteria might oxidize hydrogen sulfide (H_2S) to sulfate (SO_4^{-2}). Another bacteria such as *Desulfovibrio* will reduce SO_4^{-2} back to H_2S. The sulfur cycle is a lot more complicated than this simple reciprocal relationship drawn in Figure 4, but the point here is that these finite resources get tossed back and forth between electron states by the action of bacteria. The soil column is an extensive network of chemical reactions.

Not only do these chemical cycles affect the micro-ecosystems of bacteria, on a macro-scale they dramatically impact global climate. Without bacterial

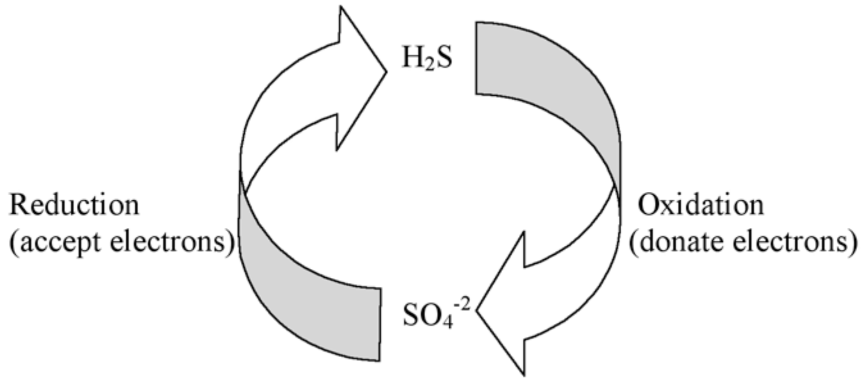

Figure 4 Simple sulfur cycle.

action, the earth would be uninhabitable. For example, some species of bacteria were among the first organisms to impact the earth's climate by off-gassing methane, a potent greenhouse gas. Greenhouse gas production made earth habitable for subsequent organisms that needed a warmer environment for their evolution. As the bacterial pioneers of genetic diversity evolved on the face of the earth, they changed the earth. They constructed new molecules, new ecosystems, and, consequently, new genetic capacity for adapting to their changing environments. Bacteria are a force of synthetic genius.

In *Winogradsky Rothko*, the bacteria synthesize their existence with an effectively infinite source of sunlight in a finite ecosystem of mud and water. Most bacteria only manufacture photosynthetic pigments as a coping mechanism when they are at the earth's surface. Often, this phototrophic system is not sufficient to support bacterial replication. A single bacterium surviving on its pigment is invisible to the naked eye – that is why we don't see colorful bacterial mats in the landscape often. Most bacteria have other more efficient mechanisms to harvest energy when buried in the soil column from molecules such as sulfur as described earlier. Species evolve to access resources in discrete niches.[1]

Winogradsky Rothko develops a living body of knowledge by materializing growth in a finite ecosystem. An otherwise invisible phenomenon – of singular becoming plural, of non-existent becoming perceived, of one becoming two, two becoming four, four becoming eight – is seen. The manifestation of exponential growth by a successful community is visualized by the surplus color![2] As a group of bacteria reaches its carrying capacity (collectively, the population has depleted the available resources and has created waste products), it fades away and is replaced – reincorporated – by a predecessor lying senescent in that zone. This successor thrives on the new molecular formulas/structures/waste left by the previous organism. As these organisms are limited by available resources, they materialize the pattern of the exponential function.

Empirical Revelation – the Power of Two

> The greatest shortcoming of the human race is our inability to understand the exponential function. (Bartlett, 2008)

A graph of the exponential function is a map of growth and decay. In general, an exponential pattern can go unnoticed for generations before the culminating impact of its sequential doublings becomes observable. The exponential function is the summative outcome of 'normal' behavior – what our parents did, what our neighborhoods are doing, what our children will do (unless something changes this pattern of behavior). Climate change, population growth, AIDS, and consumption are status quo problems of exponential nature. The change seems imperceptible in day-to-day life until it reaches a critical level when the culminating force of the doublings becomes abundantly clear. The exponential function is self-similar change (1, 2, 4, 8, 16, or the reverse). As one element grows, implicitly another recedes; the exponential function has a mirror image.

A good way to illustrate the exponential function is with the story of the poor boy who returns a lost princess to the king (Figure 5). When asked by the king for any gift in trade, the boy only asks for a grain of rice to be doubled across each square of a chessboard (64 doublings). The king, knowing he has eight million bundles of grain (with one trillion grains per bundle), exclaims: 'That is *all* you want for returning my daughter?'

But by the end of the simple doubling (1, 2, 4, 8, 16 . . .) across 63 squares, the poor boy has the king's wealth in rice. For the first 55 squares, the king is beaming because this request has barely made a dent in his stores. By the 61st square, the king still has ¾ of his grain but by the 63rd square, the king is completely broke and encourages marriage between his daughter and the boy since he can no longer fulfill his end of the deal nor feed his daughter. By simple doubling, the king experienced exponential loss of his finite resources and the boy exponential gain.

The 'fact' of the exponential function is that there is relatively little time to respond when the curve becomes noticeable. As shown in Figure 5, the simple doubling pattern can go for more than 55 generations before the exponential function begins to be observable in the graph of the king's rice. Just two doublings from being broke, the king still has 75 per cent of his resources. The relatively short 20-minute doubling time of bacteria (coupled with the pigments) is precisely what makes the bacterial drama of the exponential visible in *Winogradsky Rothko*. We see species populate an ecozone as a single bacterium reproduces by doubling. This doubling is exponential growth coupled to exponential depletion of available resources. When the resources are no longer sufficient, the species gives way to a successor. The successor exponentially populates the region by feeding on the waste products of its predecessor. We can see this transition by a change in color.

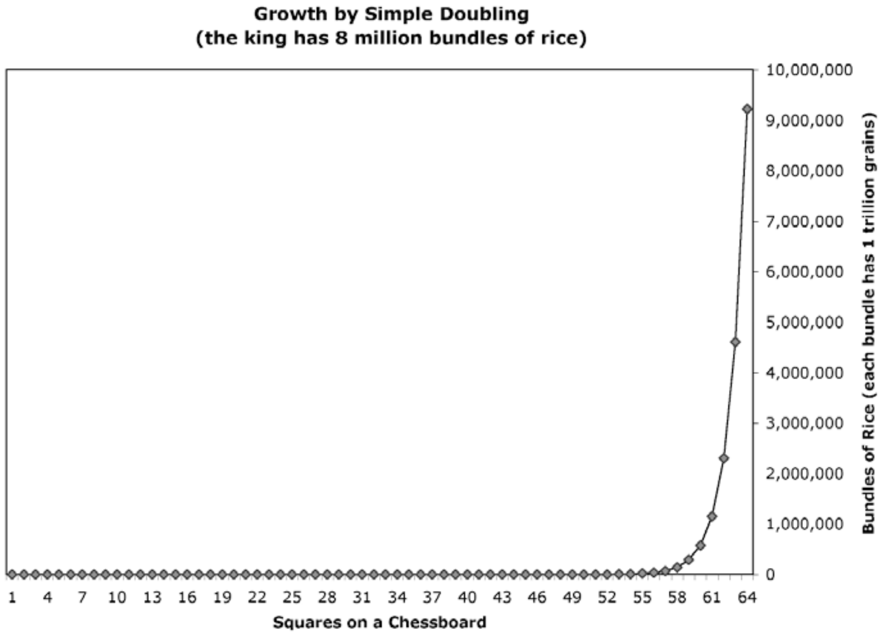

Figure 5 Graph of exponential growth.

The *Winogradsky Rothko* embodies the process of the exponential function in a way a graph cannot. The exponential function makes for a very simple graph – it is easy to name when you see it. So easy, that the pound-in-your-heart implication embedded in the graph is lost and it is simply named: 'Oh, that is exponential.' To most, it is a factual word without cultural embodiment. It is a word lacking a literalization to bring it forth from the abstract. What is the implication of 'giving' cultural meaning to 'made' abstract facts? How do we culturally qualify the quantified? There are more than six billion people, each standing on his or her changing 2 square feet of earth with his or her own perspective on what is going on.

Meanwhile, the contemporary economic system thrives on infinite growth. Infinite growth would be possible if we lived in an infinite world, but we don't. In ecology, the term *carrying capacity* is used to define the maximum population of a given organism that a particular environment or habitat can sustain (this includes biological and technological limits).

Awareness of the consequences of exponential growth is not recent. In fact, Darwin (1859[1872]) cites the exponential function in the context of natural selection in the *Origin of Species*: 'There is no exception to the rule that every organic being naturally increases at so high a rate, that, if not destroyed, the earth would soon be covered by the progeny of a single pair' (p. 53).[3] And yet, modern civilization has not come to terms with the social, cultural, and political significance of the exponential function: that our *normal* behavior will be changed with or without our thinking consent, with or without our ability to use the information embodied in the multiple expressions of the exponential function.

The doubling of a population mirrors the doubling of resource depletion. As a species advances on the ecosystem creating a network of chemical synthesis, spreading out from the originator, it both exponentially grows in number and simultaneously depletes its resource base.

Self-similar change works both ways (1, 2, 4, 8, 16 *or* the reverse). That is, self-similar change can be changed – the growth (which is a rate) can be slowed, stopped, or reversed. The exponential function is simply a pattern that describes a rate generated from normal doubling behavior; change in normal behavior alters the rate of change and the pattern.

The exponential function is a pattern that applies to just about everything in this world. We can reason with the incredibly simple abstraction of the exponential function, or we can let it reach finite limits. Something beautiful will inevitably become of us because the conditions on earth are marvelously receptive to the mutability of life. Life is movement, including its cessation. To understand the exponential function is to understand a scientific construction that describes a fact of behavior, time, and place.

Landscape of Ecological Rationality

> I think of my pictures as dramas; the shapes in the pictures are the performers. They have been created from the need for a group of actors who are able to move dramatically without embarrassment and execute gestures without shame.
>
> On shapes:
>
> - they are unique elements in a unique situation.
> - they are organisms with volition and a passion for self-assertion.
> - they move with internal freedom, and without need to conform with or to violate what is probable in the familiar world.
> - they have no direct association with any particular visible experience, but in them one recognizes the principle and passion of organisms. (Rothko, 1947[1992, 2003]: 572)

Memories from science class reek of formaldehyde. Bodies *fixed* – denied their decomposition – so I might have the opportunity to understand the accumulated degrees of organization. With fixed bodies, I could attend to fixing names to organelles. Fixed bodies, fixed names. Biology is the science of life and life is anything but fixed. It is reflexive: life shapes itself in relation to its immediate exterior condition, thereby changing the exterior condition, and, once again, requiring life to adapt to its new condition. These individual expressions of life materialize a dynamic ecosystem.

Ecological landscapes are a network of materials embodied as beings (nodes/ figures) and material resource flows (edges/fields) constantly touching and adjusting the facts of the world, changing as the facts change, shifting in the reflexive arrangements of life and material reality. A form's function can

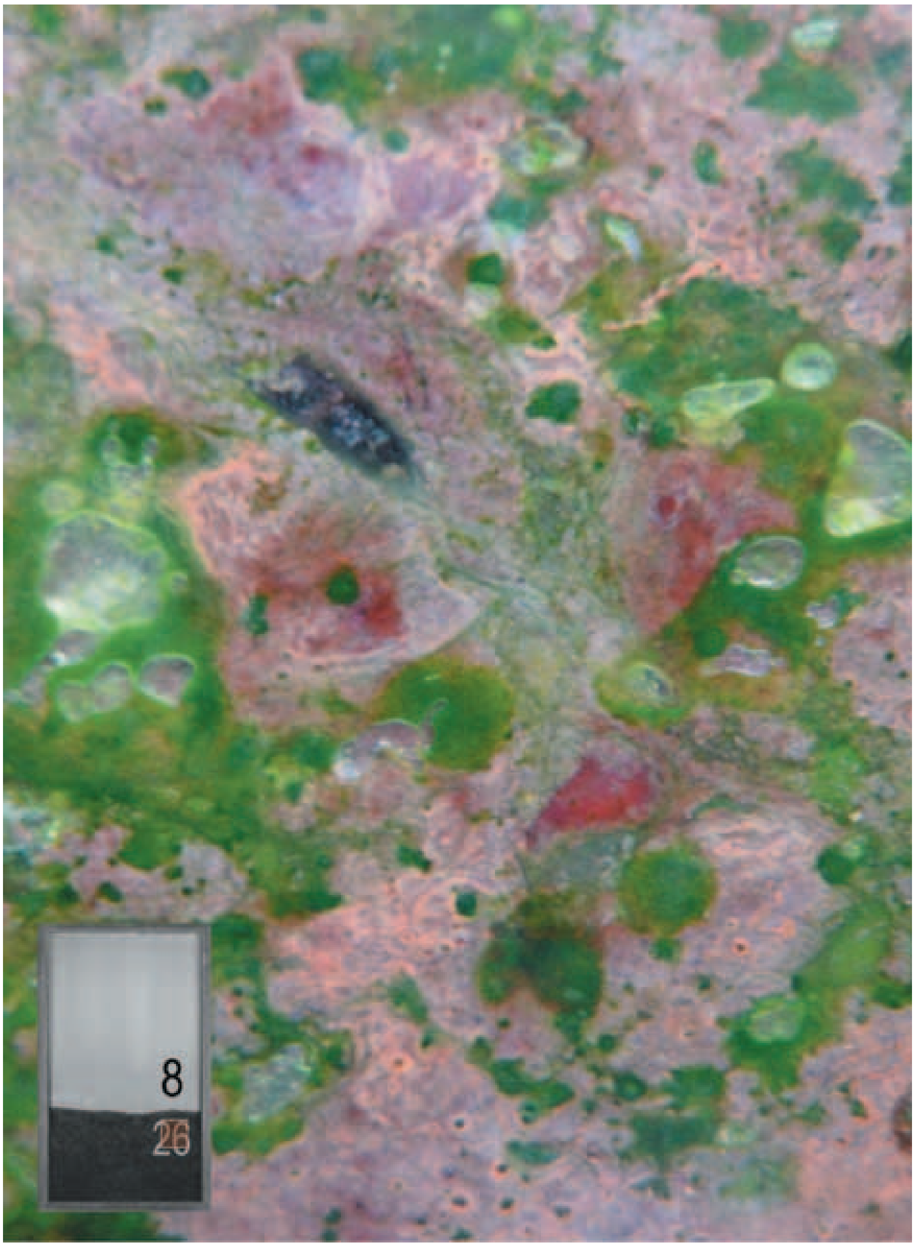

Figure 6

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Producing one pound of steel takes half the energy needed to produce one pound of nitrogen. My project used the same energy as producing 50 pounds of nitrogen that could have been allocated to an acre of agriculture. Meanwhile I've already seen a green variety overrun the beige/tan zone. And the red that colonized the dead worm is almost gone. In a finite world, the desire for change comes at the cost of something else (even when change is maintaining basic functions).

radically change given different conditions. So while materials may be finite, the basic building blocks may be employed for radically different purposes implying infinite expression. Nodes concentrate edges; edges re-circulate decaying nodes. Both figure and field are continually reconfigured from finite materials.

The *Winogradsky Rothko* frames the unfolding drama of changing relationships in a molecular landscape. Organisms aggregate base molecules to build higher order structures such as pigment. The individual pigmentation collects in color mosaics pointing to the construction of temporary communities. These are islands of expression – color is an indicator of the organized gathering of resources. This is resource cultivation. The color transition in *Winogradsky Rothko* signals an ecological reflexivity between the industry of a biological body and its environment that might inform our own ecological rationality.

Modern society lives very much in the now, which is drastically short term. Human understanding of geologic time or even a future generation is at best theoretical. Graphing concretizes variables (e.g. time, resources) so we can see beyond our immediate and finite sensibilities. I do not understand what six billion people really means. Drop that number by a few factors, and I still don't know what 10 million means. I can think of situations where I have seen 10,000 people (e.g. while walking in New York City), but I still don't understand what that means with respect to all the resources used just in hot-dog production for an event, to say nothing of resources harnessed to make 10,000 people's clothing.

How do we – a cultural mosaic of six billion individuals – begin to come to terms with a convention of seemingly infinite economic growth within a finite planet? Moreover, how will we begin to imagine and then form an equitable global society and cultivate an ecological rationality when our points of departure – what we perceive as real – produce for us multiple concomitant realities? While our decisions may seem rational in a local context, they may be irrational in a global context. In which case, how might we begin to bring these multiple realities into alignment so as to conceive equitability, sustainability?

Insofar as it tries to present situational cues that reflect a larger dynamic system that is our world, my art seeks to return concentrated data back into tangible experience so that biological logic becomes felt. To this end, the pigmented bacteria of the *Winogradsky Rothko* painted a transforming landscape that reflected the relationship between subject (agent/culture) and substance (environment/ecosystem) much as landscape artists explored and painted their findings in the new world.

In American landscape painting of the 1800s, there developed a tension between the pristine quality of the untouched land and the opportunity for mobilizing unexploited material wealth. Artists went on dangerous expeditions to capture and record the landscape. Landscape images ranged from utilitarian topographic maps, to wilderness mysteries, to pastoral narratives, to pre-industrial documentation.

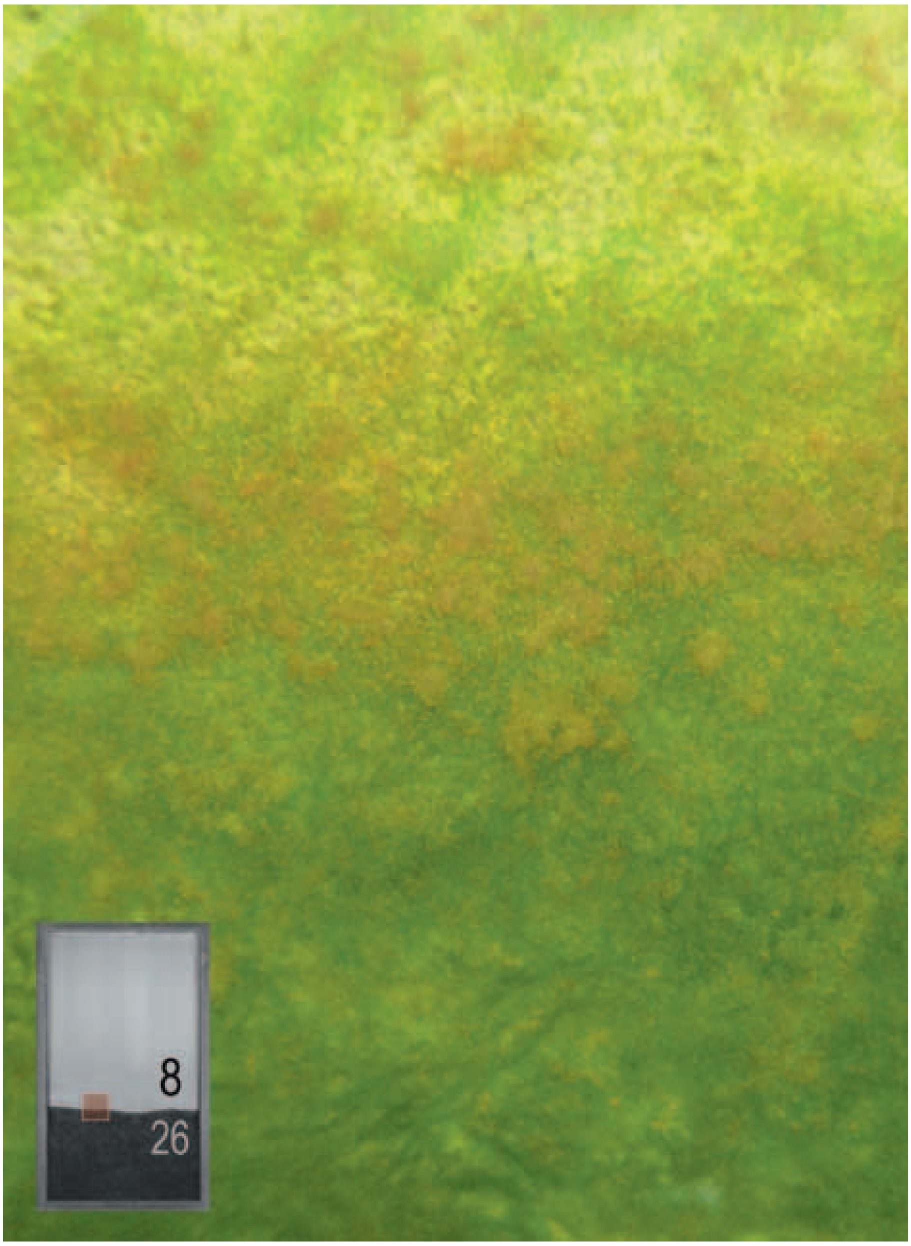

Figure 7

Journal Entry 26 August 2004

Showed a resource economist the piece today. Tantalized him with a metaphor of a finite earth. When he saw it he said, 'lovely colors, but it's just a painting.'

What interests me most about American landscapes is the human figure in the scene.[4] Barbara Novak's (2007[1980]) *Nature and Culture* references Brian O'Doherty's (1973) discussion of landscape painting: 'the single figure, engaged in some sort of meditative dialogue with nature, "whose back makes us conscious of our own"' (p. 163). In a footnote, she continues to quote O'Doherty (pp. 159–60):

> In a study of Rothko, O'Doherty speculates convincingly on the nature of the immobile figure: 'Surely this figure represents mind – mind separated from nature so that, in the epitome of the Romantic idea, it may be reabsorbed and interfused with it.' Later he makes a distinction between 'the transcendental watcher' and 'the tragic spectator,' antagonistic to each other and yet forced to coincide in what he feels is Rothko's idea of the figure. The implication is that *we* become the figure in Rothko's work, without the interposition of a surrogate.

Landscape painting is representational. In this way, a landscape painting, like a graph, is an abstraction. Bergson (2001[1913]) posits that this sets us apart: 'in order to perceive a line as a line, it is necessary to take up a position outside it' (p. 103). Similarly, to be in a position outside the *Winogradsky Rothko* allows us to see it: the rise and fall of color indicates embodiment of resources and signals the return to resource flow. Our recognition of color shift marks particular ecological transformations; we see 'radical distinctness (the one having ceased to be when the other appears on the scene)' (p. 121). The sealed frame of mud and water creates a set of discernable changes that we perceive because we stand apart. As viewers, we have the opportunity to observe states of transition 'under the form of a discrete multiplicity, which amounts to setting them out in line, in the space in which each of them existed separately' (p. 121). In serializing the images to keep up with the changing form, we take measure of the molecular landscape as it is synthesized into living pigments.

And yet, it is precisely this living movement that keeps *Winogradsky Rothko* from being representational (i.e. a product of abstraction) in the conventional sense. Insofar as the substance, the subject, and the constitutive process are biological, *Winogradsky Rothko* does not reproduce a likeness to a landscape. Rather, the living pigments effect a real – that is, literal – landscape. In their living and dying, the bacterial cultures constitute an ever transforming scene which holds our attention – we are of a kind, i.e. biological organisms. As these moments of color indicate both procurement/growth and loss/decay of material resources, they reveal the mutability of self with respect to an environment so we might conceive 'succession without distinction' (Bergson, 2001[1913]: 101). The *mind* can then 'think of it [succession] as mutual penetration, an interconnexion and organization of elements, each of which represents the whole, and cannot be distinguished or isolated from it' (p. 101). In this regard, the *Winogradsky Rothko* aspired to something analogous to Rothko's abstract expressionism; it draws us into the landscape.

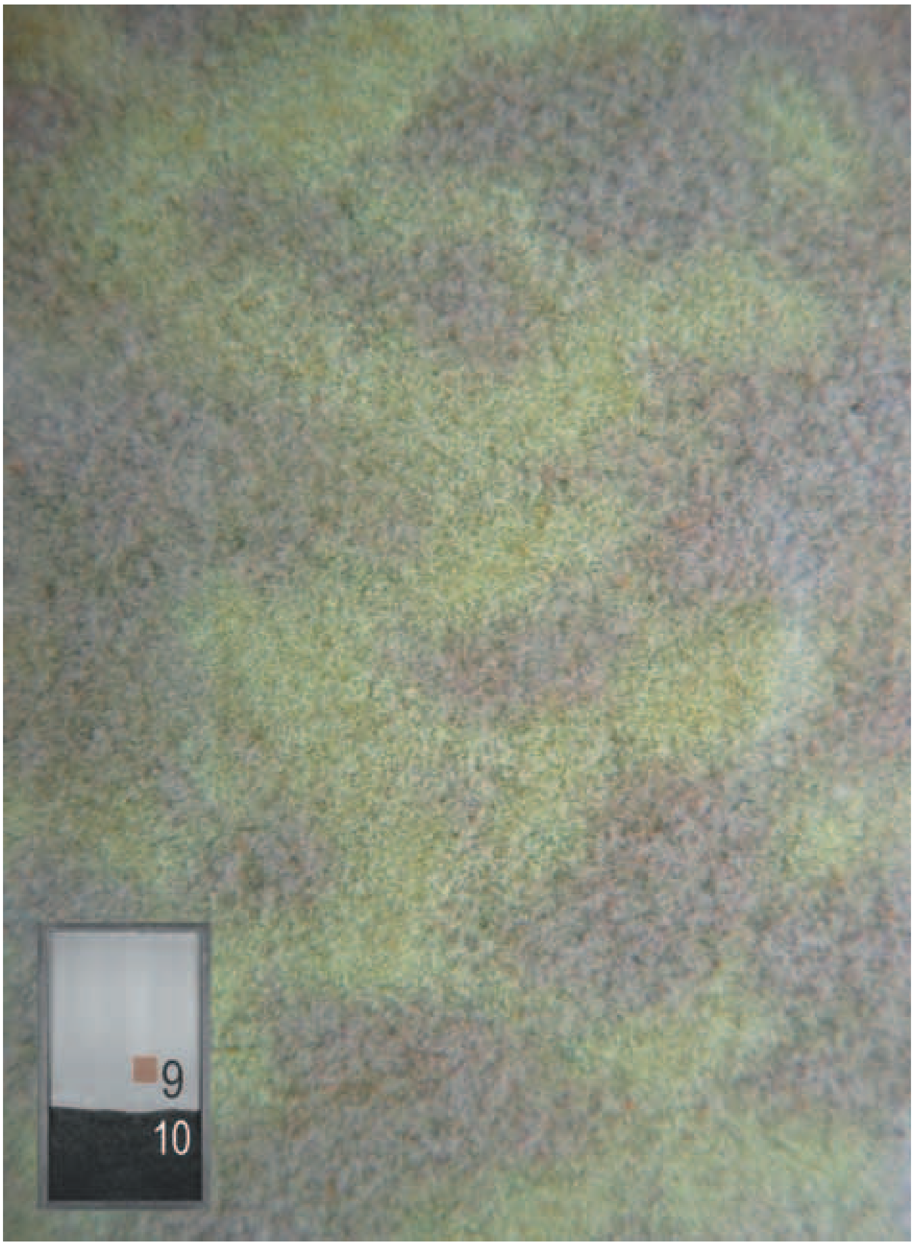

Figure 8 Cyanobacteria: Oxygenic phototrophs.[5]

As a literal landscape, *Winogradsky Rothko* visualized infinite expression of a materially finite world. Made from the same material, it invites us to recognize ourselves as being party to the comprehensive motion of ecology and its cyclical reiterations of de/composition. Standing with *Winogradsky Rothko*, we are no longer bystanders. We *figure* in the landscape.

Acknowledgements

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Notes

1. A simple example of how two variables can set up a gradient of ecological niches for a horizontal banding pattern is diagrammed in Figure 9. Imagine 100% oxygen at the top, and zero oxygen at the bottom; 100% sulfur at the bottom and zero sulfur at the top. With two inverted scales of resources, we have a whole range of horizontal ecosystems.

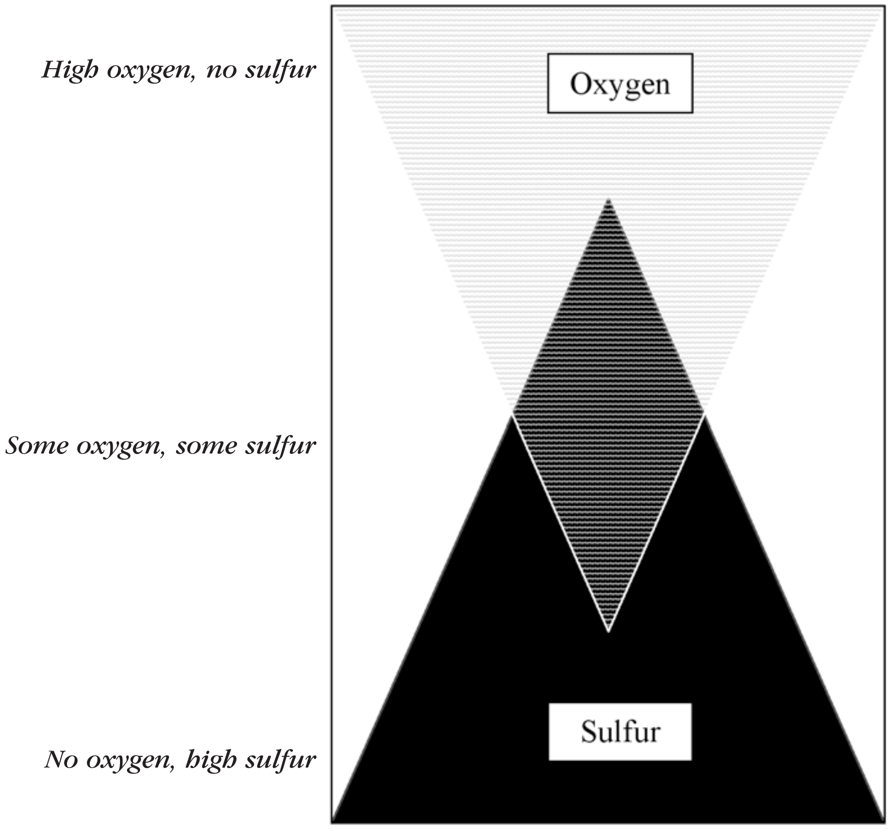

Figure 9 Two variables create diverse ecological niches for a horizontal banding pattern.

Figure 10 Purple Phototrophic Bacteria: Anoxygenic photosynthesis.[6]

In this example, if a bacterium's major source of energy is generated by pulling an electron off sulfur, it can gather enough surplus energy to expend in reproduction. If it is also exposed to sunlight, these exponentially growing bacteria will also photosynthesize pigments and we, like Sergei Winogradsky, will see their activity. The reproduction turns an individual into a colony, and a pigmented collective begins to appear in a horizontal band defined by its requisite sulfur and oxygen levels.

2. This winter, I came to realize that color was abject, color was that which was reflected from a form, and not of the form or synthesized into the form. That the color an object appeared to be was, in fact, what the object was not. The other colors were absorbed into the object, and what I see is a mixture of what it does not use. Color is surplus, color is fraud. The molecule β-carotene is one source of rejected orange wavelengths:

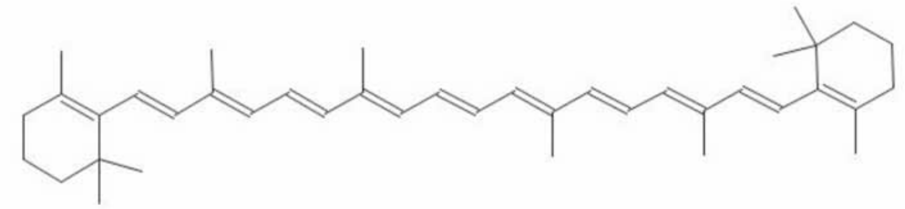

Figure 11 Diagram of β-carotene.

Molecules belonging to the carotenoid family make bacteria range in color from red to yellow. In the diagram of β-carotene in Figure 11, a single line represents a single bond, a double line represents a double bond. What is so exciting about this molecule and others in the carotenoid family is the alternating double (C=C) and single (C–C) bond sequence. This sequence repeatedly behaves like a sequence of dominos when touched. As light touches one end, it activates the molecule, the double and single bonds flip flop electrons down the line, and delivers an electron to the other end, where it dumps the electron into a reaction center. My point: light harvesting pigments transform light into electrons so they may be used to make ATP – the basic units of energy in a cell. β-carotene absorbs the energy of the blue wavelengths to fuel a cell, and reflects unused orange wavelengths. This explains why carotenoids make such pretty colors. The *Winogradsky Rothko* is seen through this surplus of light.

3. I quote Darwin at length, from 'Geometrical Ratios of Increase' in *Origin of Species* (1872[1859]: 53–5):

> A struggle for existence inevitably follows from the high rate at which all organic beings tend to increase. Every being, which during its natural lifetime produces several eggs or seeds, must suffer destruction during some period of its life, and during some season or occasional year, otherwise, on the principle of geometrical increase, its numbers would quickly become so inordinately great that no country could support the product. Hence, as more individuals are produced than can possibly survive, there must in every case be a struggle for existence, either one individual with another of the same species, or with the individuals of distinct species, or with the physical conditions of life. It is the doctrine of Malthus applied with manifold force to the whole animal and vegetable kingdoms; for in this case there can be no artificial increase of food, and no prudential restraint from marriage. Although some species may be now increasing, more or less rapidly, in numbers, all cannot do so, for the world would not hold them.

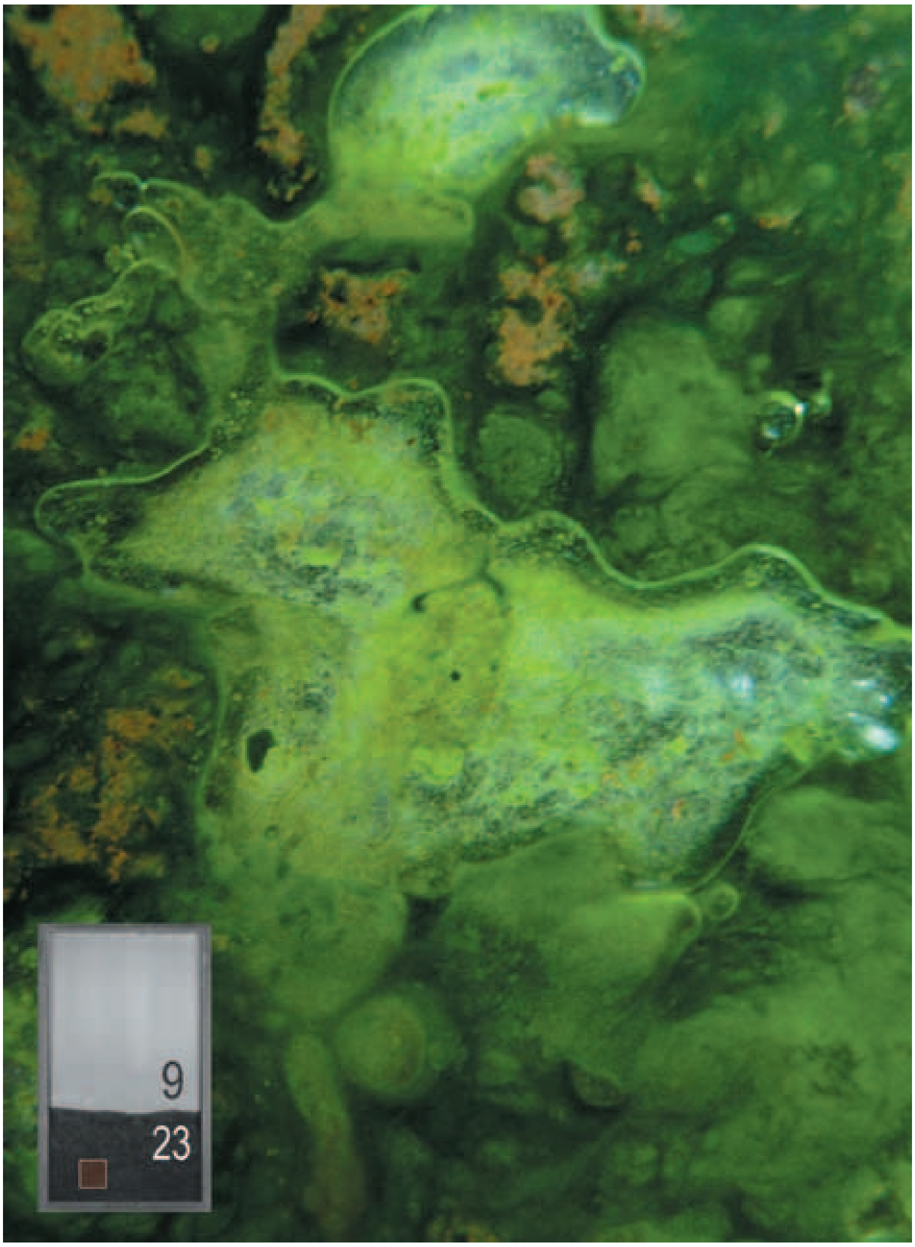

Figure 12 Green Sulfur Bacteria: Anoxygenic photosynthesis.[7]

> There is no exception to the rule that every organic being naturally increases at so high a rate, that, if not destroyed, the earth would soon be covered by the progeny of a single pair. Even slow-breeding man has doubled in twenty-five years, and at this rate, in less than a thousand years, there would literally not be standing-room for his progeny. Linnaeus has calculated that if an annual plant produced only two seeds – and there is no plant so unproductive as this – and their seedlings next year produced two, and so on, then in twenty years there should be a million plants. The elephant is reckoned the slowest breeder of all known animals, and I have taken some pains to estimate its probable minimum rate of natural increase; it will be safest to assume that it begins breeding when thirty years old, and goes on breeding till ninety years old, bringing forth six young in the interval, and surviving till one hundred years old; if this be so, after a period of from 740 to 750 years there would be nearly nineteen million elephants alive, descended from the first pair.
>
> But we have better evidence on this subject than mere theoretical calculations, namely, the numerous recorded cases of the astonishingly rapid increase of various animals in a state of nature, when circumstances have been favourable to them during two or three following seasons . . . Several of the plants, such as the cardoon and a tall thistle, which are now the commonest over the whole plains of La Plata, clothing square leagues of surface almost to the exclusion of every other plant, have been introduced from Europe . . . In such cases, and endless others could be given, no one supposes that the fertility of the animals or plants has been suddenly and temporarily increased in any sensible degree. The obvious explanation is that the conditions of life have been highly favourable, and that there has consequently been less destruction of the old and young, and that nearly all the young have been enabled to breed. Their geometrical ratio of increase, the result of which never fails to be surprising, simply explains their extraordinarily rapid increase and wide diffusion in their new homes.
>
> . . .
>
> In looking at Nature, it is most necessary to keep the foregoing considerations always in mind – never to forget that every single organic being may be said to be striving to the utmost to increase in numbers; that each lives by a struggle at some period in its life; that heavy destruction inevitably falls either on the young or old, during each generation or at recurrent intervals. Lighten any check, mitigate the destruction ever so little, and the number of the species will almost instantaneously increase to any amount.

4.

> We know that the idea of Creation – of a primal and untouched nature – had an immense resonance for the American psyche. The uninhabited landscape amplifies this thought. The spectator, with no surrogate to license his entry into the picture, is all eyes, and the virgin space suggests that looking is a spiritual act composed of wonder and purification. (Novak, 2007[1980]: 162)

In one landscape, Novak writes of the figure: 'Somehow undaunted by the sublime terribilità, they inch along the paths of still-primeval nature, indeed walk all over it. As they explore within the picture, they encounter nature as "spectacle"' (p. 162). In another example:

> the foreground is occupied by a hayfield, in which farmers perform their appropriate tasks. One has a sense of the specific roles available within the larger natural dramas these figures witness or are indifferent to . . . these figures (set apart formally and symbolically by planar distinctions) maintain a

Figure 13

Journal Entry 19 October 2004

Today I saw a red worm take a shit! Something unbeautiful – say death, rotting, maggot thriving, implies loss of something that presumably was once considered beautiful.

> distance from nature: this allows for a more purposeful activity within nature, diminishing transcendental unities in favor of what we might call a middle phase of reconciliation between man and nature. The Garden is already acculturated to the point where it presents fewer problems to its human inhabitants, who stroll casually through the landscape or work with unconscious absorption at daily tasks. (p. 163)

5. Cyanobacteria made a leap in evolution when they developed a photosystem that could use H_2O as an electron donor for photosynthetic CO_2 reduction in the creation of sugars. Cyanobacteria have only one form of chlorophyll – chlorophyll *a* – and all of them also have characteristic biliprotein pigments called phycobilins, which function as accessory pigments in photosynthesis. One class of phycobilins, phycocyanins, are blue, and together with the green chlorophyll *a* are responsible for the blue-green color of the bacteria. However, some cyanobacteria produce phycoerythrin, a red phycobilin, and species possessing this pigment are red or brown in color (Stanier et al., 1986[1957]: 344–82).
6. Unlike cyanobacteria, purple bacteria photosynthesize without oxygen. Purple sulfur bacteria use hydrogen sulfide (H_2S) as an electron donor for CO_2 reduction in photosynthesis. Purple sulfur bacteria are generally found in illuminated anoxic zones of lakes where H_2S accumulates. If sufficient sulfate is present to support sulfate reduction, the sulfide produced in the sediment diffuses upward into the anoxic bottom waters, and here purple sulfur bacteria can form massive blooms, usually in association with green sulfur phototrophic bacteria. Purple nonsulfur bacteria can use H_2S for energy, but cannot grow in such high levels of sulfur as the purple sulfur bacteria. They are known for their ability to practice photoheterotrophy (where light is the energy source and organic compounds are the carbon source). This combination is probably what makes the purple nonsulfur bacteria successful in nature. Purple bacteria contain chlorophyll pigments called bacteriochlorophylls and additionally contain any of a variety of carotenoid pigments. Together, these pigments give purple bacteria their spectacular colors, usually purple, red, or brown (Stanier et al., 1986[1957]: 344–82).
7. Like purple sulfur bacteria, green sulfur bacteria use H_2S as an electron donor. But unlike purple sulfur bacteria, the sulfur produced by green sulfur bacteria resides outside the cell. The bacteriochlorophylls found in green sulfur bacteria include bacteriochlorophyll *a*, and either bacteriochlorophylls *c*, *d*, or *e*. The latter pigments function only in light harvesting reactions and are located in unique structures called chlorosomes. Because the chlorosome is such an efficient light harvesting structure, little light is required to support the photosynthetic activities of green sulfur bacteria and thus they are typically found at the greatest depths in lakes of any phototrophic organisms. Color is determined by combinations of bacteriochlorphylls and carotenoids. Most are green unless they have a carotenoid that renders them brown (Stanier et al., 1986[1957]: 344–82). (Note: this image is of algae rather than green sulfur bacteria.)

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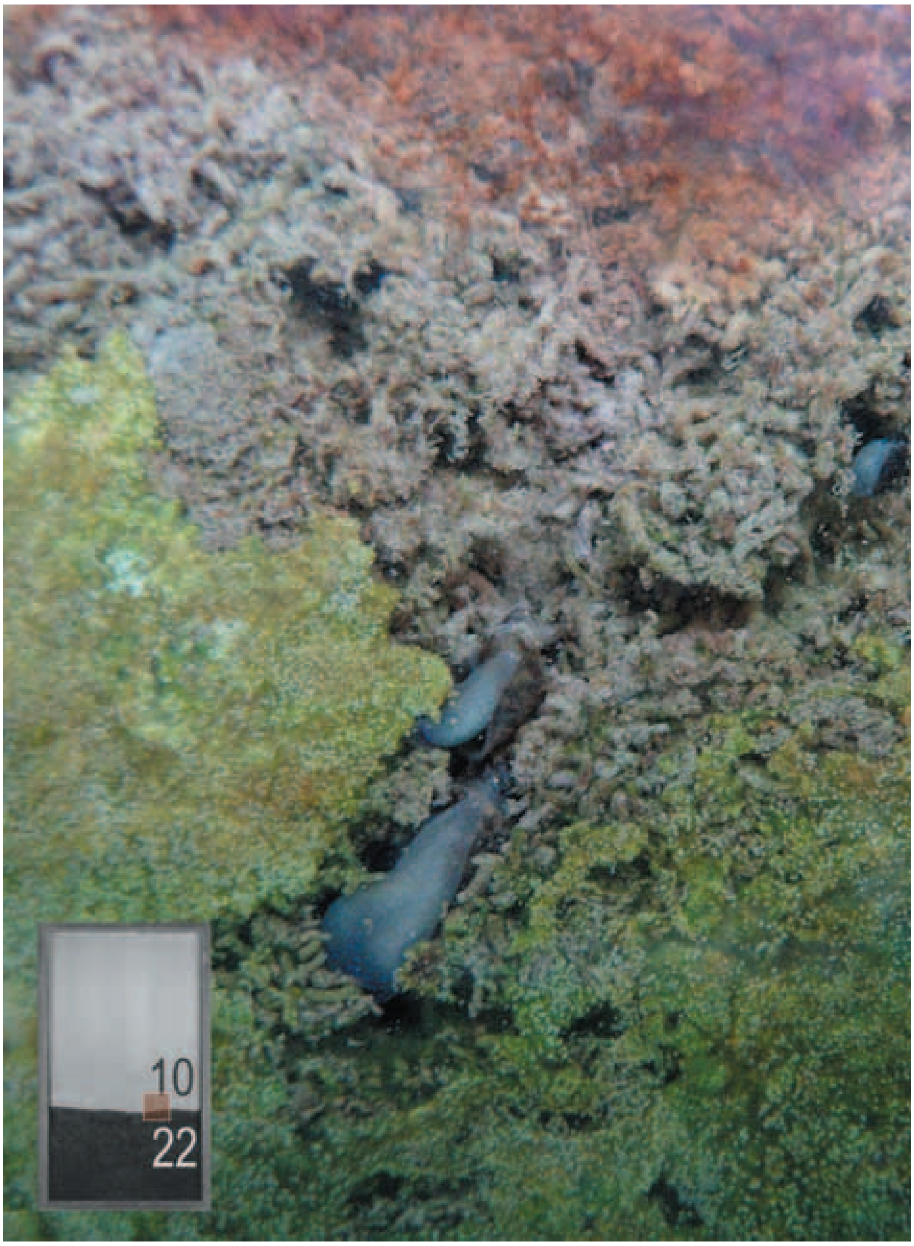

Figure 14

Journal Entry 27 October 2004

Feel glum and dispossessed. WR comes down this weekend. But I saw the most lovely thing today. A snail glommed onto one of the almost dime-sized seeds floating at the top and changed its weight so the two of them sunk. It was a seed elevator!

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