

"New directions in Marxism: Shakespeare, ecology and production" by Gabriel Egan

In putting production at the centre of historical change, Marx was aware that his historical materialism appeared to ignore what seems the obvious reality that war and conquest are the driving forces of large-scale social change. In fact, Marx argued, war and conquest are ultimately irrelevant:

Nothing is more common than the notion that in history up till now it has only been a question of taking. The barbarians take the Roman Empire, and this fact of taking is made to explain the transition from the old world to the feudal system. In this taking by barbarians, however, the question is, whether the nation which is conquered has evolved industrial productive forces, as is the case with modern peoples, or whether their productive forces are based for the most part merely on their association and on the community. Taking is further determined by the object taken. A banker's fortune, consisting of paper, cannot be taken at all, without the taker's submitting to the conditions of production and intercourse of the country taken. And finally, everywhere there is very soon an end to taking, and when there is nothing more to take, you have to set about producing. From this necessity of producing, which very soon asserts itself, it follows that the form of community adopted by the settling conquerors must correspond to the stage of development of the productive forces they find in existence . . . (Marx & Engels 1974, 90)

Money, Marx observed, is so much valueless paper outside of the system of exchange that guarantees that it can be swapped for life's necessities. Thus in this clearest argument for production lying at the root of everything, Marx in the same breath introduced the complicating factor that ideas and practices, what we might otherwise think of as the superstructural, are at work in the economic structure.

The German Ideology, co-written with Engels, outlined Marx's break with German philosophy and he thereafter began to work on what he planned as his magnum opus of political economy. The plan changed considerably over time and only the first volume of Capital was completed by Marx, although his notebooks contained enough material for posthumous completion by others. In the twentieth century a subsequently abandoned early plan and notebooks of drafts for the magnum opus (from 1857-8) were discovered and printed as Grundrisse der Kritik der politischen Ökonomie (Foundations of the Critique of Political Economy), known commonly as the Grundrisse. This work is important in particular for its introduction's reflections on method. Adam Smith and David Ricardo had started their economic theorizing with the idea of a lone producer, a hunter or a fisherman, and they considered how he worked:

Smith and Ricardo still stand with both feet on the shoulders of the eighteenth-century prophets, in whose imaginations this eighteenth-century individual--the product on one side of the dissolution of the feudal forms of society, on the other side of the new forces of production developed since the sixteenth century--appears as an ideal, whose existence they project into the past. Not as a historic result but as history's point of departure. As the Natural Individual appropriate to their notion of human nature, not arising historically but posited by nature. (Marx 1973, 83)

For Marx, the individualized individual was a product of recent political events: if one goes back in time the individual producer was more dependent on others. Only if a modern-made 'individual producer' were by chance thrown into the wilderness would arise the situation Smith and Ricardo thought the natural state of man. Marx attacked previous political economists for treating the particularities of production in any one epoch, usually their own, as though these were true for all epochs.

Shakespeare and Middleton's thought-experiment

Whereas previous economists had believed their theorizing to have stripped away the historical accretions that made modern man, Marx showed that they had only really achieved the thought experiment of throwing modern man, with all his ideas intact, into a wilderness. The same anachronistic juxtaposition of the modern and the pre-modern forms the basis of a thought-experiment that Shakespeare and Middleton dramatized as scene 14 (or 4.3 in older editions¹) of their play Timon of Athens for the King's men company 400 years ago, in the spring of 1606 (Shakespeare & Middleton 2004, 3-9). As we shall see, Timon the individualist, ripped from his social circuits of exchange, comes to the conclusion that 'taking' is the fundamental principle of the universe. To see how he came to this, we must look at how money in its various guises figures in the scene.

In this scene in which Timon digs for roots and hits gold, Marx found a moment that summed up the peculiar transformatory power of money, and (unaware of the play's dual authorship) wrote that

Shakespeare stresses especially two properties of money:

(1) It is the visible divinity--the transformation of all human and natural properties into their contraries, the universal confounding and distorting of things: impossibilities are soldered together by it.

(2) It is the common whore, the common procurer of people and nations.

[. . .]

That which I am unable to do as a man, and of which therefore all my individual essential powers are incapable, I am able to do by means of money. Money thus turns each of these powers into something which in itself it is not--turns it, that is, into its contrary.

(Marx 1977, 122-23)

Marx was responding to Timon's comments about what gold can do, which begin:

[TIMON] Thus much of this will make
Black white, foul fair, wrong right,
Base noble, old young, coward valiant.
(Timon of Athens 14.28-30)

Timon goes on at length about the power of gold to alter human relations, but we should not be so quick as Marx is here to associate gold with money, for in his splendid isolation

Timon expects to be in no networks of circulation that enable a simple metal to become money.

That gold is not inherently money was Marx's point when in the first volume of Capital he discussed 'Exchange':

The truth of the proposition that, 'although gold and silver are not by Nature money, money is by Nature gold and silver,' is shown by the fitness of the physical properties of these metals for the functions of money. . . . An adequate form of manifestation of value, a fit embodiment of abstract, undifferentiated, and therefore equal human labour, that material alone can be whose every sample exhibits the same uniform qualities. On the other hand, since the difference between the magnitudes of value is purely quantitative, the money-commodity must be susceptible of merely quantitative differences, must therefore be divisible at will, and equally capable of being reunited. Gold and silver possess these properties by Nature. (Marx 1954, 92-93).

Marx here tried to explain how gold and silver, albeit mere commodities possessed (like all their kind) with exchange-value, came to be universally accepted commodities and thus media for exchange in general. His main point was that gold and silver merely have useful characteristics that enable them to widely accepted as generalized money. They are relatively hard to win from the Earth, so the labour congealed in them is densely packed and hence large quantities of congealed labour may be carried easily, and they are uniform and easily divided and rejoined.

To make this point, Marx oversimplified his argument, for the gold one usually finds in the ground is not uniform and nor is it easily divided and reformed but rather it has to be refined before it has these properties. Gold is, in general, hard to win from the Earth, and Timon might seem just absurdly lucky to happen on a large quantity for so little effort of digging. What kind of gold does Timon find, though? John Jowett surveyed the theatrical preference for it being a hidden hoard of someone's refined gold rather than the unrefined ore (Shakespeare & Middleton 2004, 55-56), although the text, as Jowett rightly pointed out, wants to have it both ways. That is, the gold has to be "Yellow, glittering, precious" (14.26) and yet within a minute of stage time the same stuff is "damned earth" (14.42). This ambiguity, Jowett observed, captures the ambiguity of Timon's relation to society: "he finds himself in the very middle of economic culture at the very point when he was most sure that he had escaped it" (Shakespeare & Middleton 2004, 56). Timon goes on to use the gold as though it were money, and since only refined gold is money, he must have dug up refined gold. And yet, as Jowett remarked, although theatre directors have interpolated scenes of the precedent burying of the gold, the play text is silent on the matter.

The opening lines of this scene might throw light on this ambiguity, via alchemy. Renaissance alchemy had a practical end, the transmutation of cheap metals into gold, but it was underpinned by a complex and subtle model of the universe derived from Aristotle and significantly modified by Paracelsus in the early sixteenth century (Debus 1977, 63-126). The philosophical purpose of turning base metal into gold was to prove a theory about the nature of matter, according to which "all metals are made from the same basic matter and grow within the crust of the earth like a giant tree or plant" (Abraham 1998, 'gold and silver'). In this model, gold is merely the most refined kind of metal, one

that cannot be transmuted further, and hence unalterable even by fire. But it is also a fiery principle in itself:

In the microcosmic-macrocosmic law of correspondences, gold is the metallic equivalent of the sun, the image of the sun buried in the earth. The sun in turn is the physical equivalent of the eternal spirit which lodges in the heart (the 'sun' of the human microcosm). (Abraham 1998, 'gold and silver')

The sun's rays, penetrating the Earth, were thought to provide "the generative warmth to ripen such imperfect metals as iron, copper and lead into the perfect metal, gold" (Abraham 1998, 'sun'). The microcosmic-macrocosmic correspondence mentioned here is part of a supposed cosmological and ideological system shared by all educated Elizabethans that was outlined by E. M.W. Tillyard during the second world war (Tillyard 1943). As intellectual stock Tillyard's claimed Elizabethan World Picture has fallen precipitously since the 1980s, but there is much of value in it and elsewhere I have argued in its favour (Egan 2004, 62-68; Egan 2006).

In the opening lines of the scene, Timon calls upon the sun to do its work of separating elements:

TIMON

O blessèd breeding sun, draw from the earth
Rotten humidity; below thy sister's orb
Infect the air. Twinned brothers of one womb,
Whose procreation, residence, and birth
Scarce is dividant, touch them with several fortunes,
The greater scorns the lesser.
(Timon of Athens 14.1-6)

Timon hopes for the evaporation of moisture from the ground to make unhealthy air, but what seems achieved is the transformation of ordinary matter into gold. Timon's first sentence here refers to the sun and moon, but the second sentence is tricky and only after the subjunctive sense of "touch them" has been grasped does it resolve itself into a call for dissension to be sown between brothers. An easier sense, and one made almost irresistible by the collocation of a "breeding sun" and its sister (the moon) with "Twinned brothers" and a "womb", is that the celestial family of the first sentence is still being elaborated: as with identical twins, so with the heavenly bodies. With this talk of the procreative nature of sun, moon, and Earth, it is not surprising that Timon in his alienated and socially-inverted state (without the walls of home, outside of social circuits) thinks of the Earth and its products in terms not of healthy but of debased sexuality: "damned earth, | Thou common whore of mankind . . . Thou'rt quick; | But yet I'll bury thee. He buries gold" (14.43-46).

Timon's unmotivated sexual hostility towards Timandra also speaks of his anxiety about production and reproduction, but a clue about how Timon sees the Earth in all this is his peculiar encouragement to Alcibiades: "Follow thy drum. | With man's blood paint the ground gules, gules" (14.58-59). The word "gules" is an heraldic term for red, but it was also an eighteenth-century spelling of 'gold' meaning marigold, the gold-flower (OED gold²), a form confined apparently to the north of Britain. Even without this link, however, it is not hard to trace how blood and gold were related in Shakespeare's mind, as I have

shown (Egan 2003) and as W. A. Murray showed in relation to the celebrated image of the murdered king in Macbeth (Murray 1966). Murray claimed that ideas about alchemical transformation were made topical by the controversy about the new sixteenth-century medicine of Paracelsus, and argued that the context in Macbeth is primarily religious: Duncan's blood is special because he is a saintly king. However, I would observe that in alchemy blood has strong associations with the principle that metals must 'die' in their original forms to be reborn as gold and with the life-giving red elixir (synonymous with the philosopher's stone) achieved after the white (silver) stage, featured in alchemical treatises with the attendant associations of moon and sun, and of virginity giving way to fecundity, that one might expect (Abraham 1998, 'blood', 'rubedo').

Of course, the word 'blood' itself is highly polysemous and when Shakespeare's King John acknowledges that "There is no sure foundation set on blood" he immediately glosses his meaning as "No certain life achieved by others' death" (King John 4.2.104-5) but the opposite meaning is equally active: there is no certainty based on "lineage, descent" (blood n. 9a). After the inconclusive offstage battle of the English and French between the first two acts of King John, the English herald sickeningly describes the once "silver-bright" armour now "all gilt with Frenchmen's blood" (2.1.315-6), and we might ask why Shakespeare likens gold-plating to painting in blood. An alchemical explanation is not necessary since there is an equally viable alternative in the inescapable 'guilt' of being caught red-handed, that is being caught in the act of murder with the damning evidence, the red blood of one's victim, still on one's hands. Of course, Macbeth should have merely bloodied hands to literalize the Scottish legal expression meaning "having the evidences of guilt still upon the person" (OED red-handed a., red-hand a. and n.), which kind of 'guilt' suggested to Shakespeare's associative mind its homophone 'gilt' and hence he put together images of blood-painting and gold-plating. Thus we can explain Lady Macbeth's "I'll gild the faces of the grooms withal, | For it must seem their guilt" (2.2.54-55), although Macbeth's "His silver skin laced with his golden blood" (2.3.112) additionally suggest an alchemical influence in its linking of death, the transformation of silver to gold, and the red elixir.

So, returning to Timon of Athens, we may say that Timon imagines that the blood let by Alcibiades's soldiers will paint the ground gules because this blood is the source material for a transformative process triggered by the sun and culminating in the production of subterranean gold. The idea of spilt blood productively enhancing the ground might seem strained, but Shakespeare uses it elsewhere, as in Bishop of Carlisle's prophecy that in the coming Wars of the Roses "The blood of English shall manure the ground" (Richard 2 4.1. 128). Such an image of change in the ground suits the play's pivotal scene of change in Timon himself, who links his alteration to the cosmological cycles:

ALCIBIADES

How came the noble Timon to this change?

TIMON

As the moon does, by wanting light to give.

But then renew I could not like the moon;

There were no suns to borrow of.

(Timon of Athens 14.66-9)

As Scott Cutler Shershow pointed out, a useful way to understand what is going on in the circuits of exchange in Shakespeare was opened up by George Bataille's The Accursed Share and Jacques Derrida's Writing and Difference:

He [Bataille] suggests that the central problem of all material existence is how to expend the surplus energy that flows unceasingly to the Earth from a Sun that 'gives without ever receiving' (Bataille 1991: vol. 1, 28). This literal surplus of energy in the terrestrial biosphere cannot, in principle, be fully expended, and so 'can only be lost without the slightest aim, consequently without any meaning' (cited in Derrida 1978: 270). (Shershow 2001, 247).

Shershow developed this line of thinking to show that intellectual economies have, since ancient times, produced meaning as though we were confined to a finite and 'restricted' intellectual economy (founded on scarcity), whereas we should, according Bataille, celebrate the reality of surplus meaning via a poststructuralist 'general' economy. From this view, Shakespeare came to be thought of radically generous and non-economistic as part of the process of sealing off the areas of artistic creation from other discourses, especially business. Derrida read the restricted/general economy distinction not as a simple choice but an axis always available in any economy, and Shershow pointed out that in the Bible and in medieval theology there is always an injunction to thrift and an exhortation to give things away (Shershow 2001, 248-49).

Shershow's brilliant essay is a landmark of Marxist Shakespeare criticism, but one of Bataille's premises, which it invokes, is faulty: the sunlight bathing the Earth is not quite the free plenitude it seems to be. Noticeably, Timon speaks of the moon's renewal coming not from a free gift of sunlight, but specifically from a borrowing. Although we should resist the temptation to credit Shakespeare and Middleton with direct appreciation of the Second Law of Thermodynamics, Timon is right that while the Earth and moon seem to be recipients of the sun's free gift of light, there is in fact (as we now know) a cost to this giving. The local decline in entropy that we enjoy on Earth is at the expense of an increasing entropy at the core of the sun as hydrogen atoms fuse to make helium. Although we like to speak of energy from sunlight as a renewable resource, taking the widest frame of reference it is a cosmic analogue of our local hydrogen economy and distinctly irreversible.

Although we habitually reject as pre-Enlightenment folly the alchemical thinking that I have invoked to explain part of this scene, it is worth noting that the atomic model of the universe is entirely compatible with the transmutation of elements. When Dmitri Mendeleev ordered the known elements by their atomic weight in 1869 he left gaps for elements predicted by his model but which had not been discovered, and when in due course they were found (and with just the characteristics he predicted) Mendeleev's Periodic Table gained wide acceptance. Mendeleev was, however, unshakeably convinced that the elements were, as their name implies, immutable so that a material occupying one position in his table could never be altered to occupy another. Work on the natural radioactive decay of elements by Mendeleevs' French contemporaries Henri Becquerel, and Marie and Pierre Curie led Ernest Rutherford to demonstrate the first artificial disintegration in 1919: collision with an alpha particle turned an atom of nitrogen into an atom of oxygen and an atom of hydrogen. One of the many peculiarities of twentieth-century science--one of the many ways in which it challenges Enlightenment thinking--is that it shows that the alchemists' dream was always, in principle, achievable.

In addition to the main thread of macrocosmic transformation in Shakespeare and Middleton's scene, and providing a local analogue for it, is an ironic microcosmic transformation. For all his desire to remain outside circuits of exchange and to remain unchangingly froward, Timon gets hungry. The recurrent human transformation from satiety to hunger infuriates Timon because it requires him to be dependent on the bounty of the Earth:

TIMON (digging)

That nature, being sick of man's unkindness,
Should yet be hungry! Common mother--thou
Whose womb unmeasurable and infinite breast
Teems and feeds all, whose selfsame mettle
Whereof thy proud child, arrogant man, is puffed
Engenders the black toad and adder blue,
The gilded newt and eyeless venom'd worm,
With all th'abhorred births below crisp heaven
Whereon Hyperion's quick'ning fire doth shine--
Yield him who all the human sons do hate
From forth thy plenteous bosom, one poor root.

(Timon of Athens 14.177-87)

All nature, human and animal, is united in this reliance upon the "mettle" (we should also hear 'metal') of the Earth, and to that extent digging up a root is no less an act of dependency than is the digging of gold. One cannot eat gold, as Midas famously learnt, but not many people can eat nature's bounty in its raw state either. As the thieves point out in response to Timon's claim that "The bounteous housewife nature on each bush | Lays her full mess before you", they as humans "cannot live on grass, on berries, water, | As beasts and birds and fishes" (14.420-23).

The thieves insist upon the necessity of what we would call the food chain: the lower creatures consume the raw bounty of nature, and the higher creatures consume the lower. Timon objects that as thieves they position themselves so highly in the chain that they effectively "eat men" (14.425). But their insistence upon the chain gives Timon the idea that the food chain is just one part of a larger, cosmological, chain of being that manifests their principle of taking:

[TIMON]

The sun's a thief, and with his great attraction
Robs the vast sea. The moon's an arrant thief,
And her pale fire she snatches from the sun.
The sea's a thief, whose liquid surge resolves
The moon into salt tears. The earth's a thief,
That feeds and breeds by a composture stol'n
From gen'ral excrement. Each thing's a thief.
The laws, your curb and whip, in their rough power
Has unchecked theft. Love not yourselves. Away,
Rob one another. There's more gold. Cut throats;
All that you meet are thieves. To Athens go,
Break open shops; nothing can you steal
But thieves do lose it. Steal no less for this I give you,

And gold confound you howsoe'er. Amen.
THIRD THIEF
He's almost charmed me from my profession
(Timon of Athens 14.436-50)

The scene's principle of contrarious effects is epitomized in the final line above: if thieving is a universal principle of all human society and of the cosmos, the true thief turns into an honest man.

Effectively the same dark irony underlies Timon's next social encounter, when his former steward tries to recover his old position even if he has to reverse the circuit of payment:

STEWARD
I beg of you to know me, good my lord,
T'accept my grief,
 He offers his money
 and whilst this poor wealth lasts
To entertain me as your steward still.
(Timon of Athens 14.487-9)

For a moment the flow seems reversed, but still money is, as Marx remarked, a power for transmutation of anything into its contrary: here, the servant seeks to be his own paymaster. We might read this as a distinctly social phenomenon but what the scene suggest is that social relations must needs manifest the wider cosmological situation regarding exchange. Timon does not take his former servant's money, for if he did he would truly be within a circuit of borrowing, which differs from ordinary taking in that there is an implied obligation to later give what is borrowed back to the lender. Timon starts this scene thinking of the moon's light as a borrowing of the sun's--which itself is closer to the mark than Bataille's notion of the sun gifting its energy--but by the end he has revised this to a principle of taking because, of course, the moon does not return the energy. Nature, Timon says, is not founded on exchange, upon loans later repaid, but rather energy flow is uni-directional and irreversible. Thinking ecocritically about our world we may want to model human relations on natural ones, and if we do we ought not to wish away Timon's realistic and materialist characterization of nature.

DaisyWorld: Positive and negative feedback

Timon's understanding of the entire cosmos as circuit of appropriation--of everything taking from everything else--is the outcome of Shakespeare and Middleton's thought experiment in which a modern human is cast into the wilderness with his bourgeois ideas about human autonomy and self-interest intact. His finding in nature the human proclivity for theft is at once the height of anthropocentrism (because he sees the inanimate world in human terms) and a rejection of it, since this universe is indifferent to human concerns rather than being centered upon them. The latest ecological thinking, however, gives us a new way to conceptualize the relationship between human affairs and wider nature. This new way of thinking would have surprised, and been rejected by, Marx because although able to see beyond Enlightenment constructs in economic theory he was limited by an anthropocentric view of nature as an inexhaustible resource for human production. However, it would not have surprised Shakespeare. The new thinking to which I am

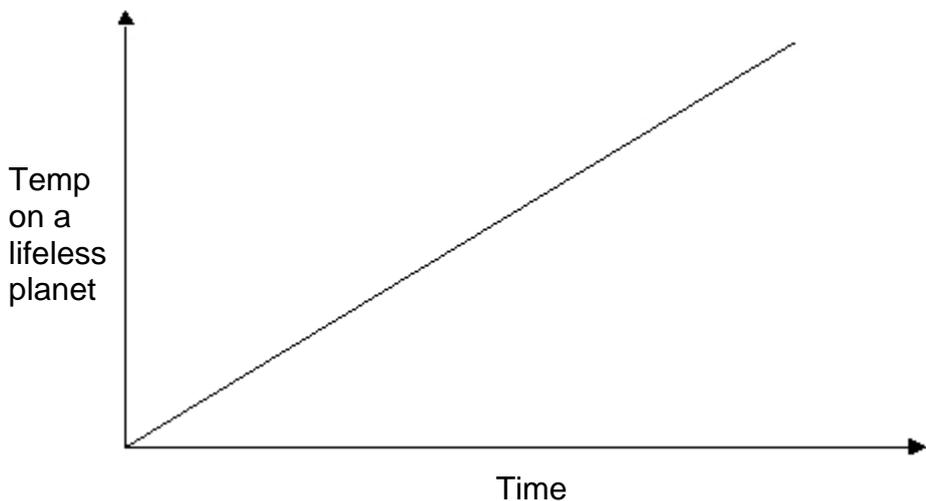
referring is the idea that the Earth itself is alive and that rather than considering the world's biota as existing on an inactive surface, the atmosphere, oceans, and even the rocks of the Earth are part of a wider cycle of exchange that underpins life. When the distinction between the organic and the inorganic is dissolved by this kind of ecocritical thinking, the macrocosmic/microcosmic correspondencies with which (pace New Historicist and Cultural Materialist critical denial) Renaissance drama abounds emerge not as mere analogies but as true homologies.

The Earth is bathed in a stream of energy emanating from the sun, but this stream is not constant. Since life started on Earth about 3.6 billion years ago, the sun's output of energy has increased by about 30% yet the Earth's surface has remained roughly between 10 and 20 degrees Celsius. One way to explain this is the Gaia hypothesis first formerly presented by James E. Lovelock (1972) and subsequently expanded upon by Lovelock and Lynn Margulis (1974a; 1974b). According to the Gaia hypothesis, the Earth (considered singly) actively regulates its own temperature and its chemical exchanges and hence qualifies as a lifeform. To show sceptics that this is a reasonable scientific and materialist way to think about the Earth, Lovelock invented a simple model of a core Gaia process, temperature regulation, and called it DaisyWorld (Lovelock 1983).

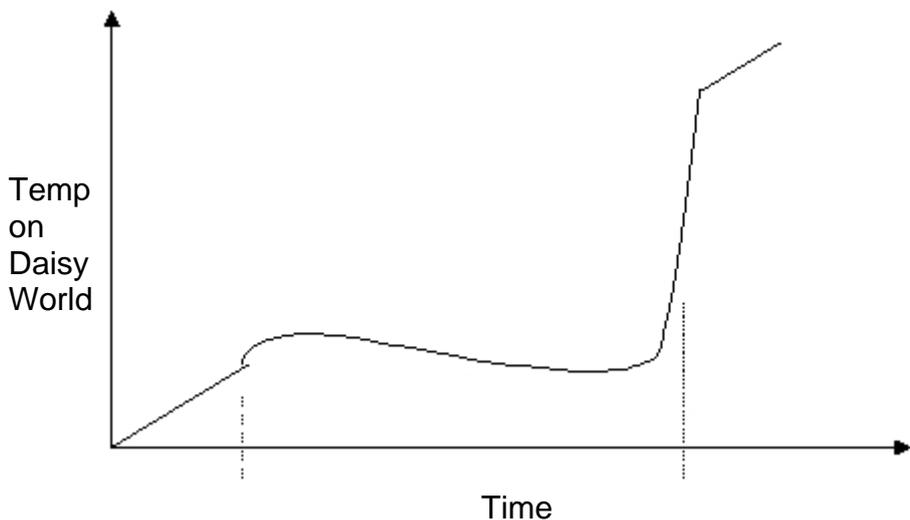
DaisyWorld is a spherical planet uniformly lit by a sun, and upon it there happen to be seeds for two kinds of plant: white daisies and black daisies. White daisies reflect most of the light that falls on them and hence keep themselves and their surroundings cool, but they do not photosynthesize as efficiently as black daisies, which absorb most of the light that falls on them and so quickly warm themselves and their surroundings. Both kinds of daisy thrive at the same ideal temperature, but initially their sun produces too little energy for either to germinate. As suns across the universe do, theirs heats up and as the surface temperature rises both kinds of plant begin to grow and to populate DaisyWorld. In this initially cold climate, the black daisies do rather better than the white ones because they are better at photosynthesis, and by neoDarwinian natural selection DaisyWorld is covered with black daisies. A mostly-black DaisyWorld reflects little light and the entire planet warms up rather more quickly than it would have were it barren. As the sun's output continues to rise, the relative advantage of the black daisies diminishes: there is so much light that even white daisies have enough to photosynthesize efficiently and they begin to thrive. This is just as well because the ever-rising output of the sun is making DaisyWorld rather too hot for daisies, but of course the white, reflective daisies are less affected by this than the black, absorptive daisies are. As the temperature rises still further the black daisy population declines (it is too hot for them) and the white daisies come to dominate the planet's surface, and a mostly-white DaisyWorld reflects much of the sun's energy, keeping things cool enough for life to go on. Eventually, of course, the sun's energy is so great that not even a white daisy-cooled planet can sustain life and eventually all the daisies die.

In this model, as the sun got increasingly hot the temperature on DaisyWorld remained roughly constant (around the ideal temperature for daisies) while it supported life, because the ratio of black to white daisies shifted precisely as needed to counteract the effect of overheating. The daisies did this without any planning or design, it was merely that the ecosystem in general (comprised of the organic matter, the daisies, and the inorganic matter, the surface of DaisyWorld that they grow on) formed a so-called negative-feedback loop, regulating the planet's surface temperature. At the extremes this regulation did not work: when it was too cold at the beginning and too hot at the end, no

daisies grew. But for a significant time between these extremes, the energy from their sun rose steadily yet the surface temperature of DaisyWorld remained stable. To visualize what happened, we can plot the planet's surface temperature assuming that there were no daisies on DaisyWorld as its sun's output of energy began to rise (Figure 1) and compare this with what happens when there are daisies to regulate the temperature (Figure 2).



(Figure 1. Planet's surface temperature unregulated by daisies)



(Figure 2. Planet's surface temperature regulated by daisies.)

There is a roughly level area between the time (marked by the first dashed vertical line) when DaisyWorld became warm enough to support daisies, and the time (marked by the second dashed line) when the sun's output became just so great that even when entirely covered in white, reflective daisies DaisyWorld became just too hot and no daisies could

survive. Within the plateau area of Figure 2, DaisyWorld is regulating its own temperature by adjusting the ratio of black to white daisies to keep things just right for life to be supported.

DaisyWorld is a classic self-regulatory system based on negative feedback. Contrary to everyday use of the term, positive feedback is often a bad thing and negative feedback often a good one. In positive feedback, the outcome of a process reinforces the originating conditions so that the system accelerates, as a debt accumulates compound interest, or the subatomic particles ejected in a chain reaction excite yet more particles. Exponential growth is the characteristic outcome of positive feedback. In negative feedback, however, the outcome diminishes the originating conditions so that the system achieves a dynamic equilibrium, and if perturbed by an external force (so long as it is not too great) the system is able to restore its equilibrium. The brilliance of Lovelock's DaisyWorld model (offered as a fully worked-out mathematical proof using scientifically-valid cybernetic conventions) was that it showed how an organic system (the plants) and an inorganic world (the planet's surface and the sunlight) would, by nothing more complex than plain neoDarwinian evolution, develop into a self-regulatory body.

Production and self-regulation

Unregulated capitalism as analyzed by Marx in Capital is a classic positive-feedback loop because the exchange between buyer of labour and seller of labour was bound to be self-reinforcing. The extraction of surplus value by the capitalist necessarily results "in reproducing the working man as a working man, and the capitalist as a capitalist" (Marx 1899, 61). Because only capital put out on labour creates surplus value, rates of profits in labour-intensive industries are higher than in machine-intensive industries, and yet competition forces capitalists to use machines. Capital restlessly circles the world chasing the highest rate of profit but it always operates to lower rates of profit (Weeks 1981, 50-62), and concentrating capital in larger and larger accumulations that can exploit ever smaller pockets of vulnerable workers it can find hidden away from consumers' sight.

Marx likened revolutions to locomotives, driving the history of the world forward, but Walter Benjamin demurred in observing that capitalism itself is like a runaway train gaining momentum and that a revolution is the corrective act of the passengers reaching for the emergency brake (Benjamin 1974, 1232). In the topsy-turvy world of self-accelerating international capitalism, conserving what we have before capitalism destroys it is the radical intervention. Hence the apparent paradox that today's radical politics is conservationism. Benjamin's attractive image rightly casts capitalism as the unregulated, destructively-explosive force and its replacement with something more sane as an act of conservation, of regulation and orderliness. Positive- and negative-feedback loops are at the core of our political and economic systems, as Marx identified, but they are also (surprisingly) essential components of the natural systems upon which our production is predicated, which Marx could not know.

For example, the ozone layer problem identified in the 1980s has been solved by banning use of chlorofluorocarbons (CFCs, tradename Freon). The ozone hole (a zone of partial depletion) over the Antarctic remains, but will disappear in about 50 years because of what atmospheric chemists--a group not usually given to anthropomorphism--call the self-healing effect, a classic negative-feedback loop. The ozone layer is created in the upper atmosphere by the bombardment of solar ultraviolet radiation that turns O₂

(oxygen) molecules in O₃ (ozone) that block the radiation from reaching the Earth's surface. Where the ozone-depletion hole exists, the radiation penetrates further down but in doing so it creates fresh ozone at this new lower level, effectively closing the hole, which will be healed from the bottom up just like a puncture on the surface of human skin. Scientists working on such processes learn to expect the existence of negative-feedback loops and can become so used to them that they cease to be amazed that this is what the Earth does.

Marxists should take note too. As a scientific approach to historical change Marxism needs to be revised in the light of ecological thinking. Production is indeed the source of all human value, but it occurs within a system of exchange that taking the widest frame is (as Timon observed) a process of depletion: the sun's hydrogen is finite. Yet, the sun appears to have enough hydrogen for several billion more years of nuclear fusion, so this resource is effectively infinite for all human purposes (but not Gaia's, presumably). Scaling our frame of reference down, however, something alarming emerges: on Earth our productive processes occur within what is effectively a sealed system, bombarded by energy from the sun but closed in the sense that (barring a few trivial exceptions) we and our products cannot leave. Whatever we make here stays here, and the only replenishment of spent energy is in the form of sunlight. This insight is largely absent from mainstream Marxist analysis, which treats the Earth as an infinitely rich supplier of raw materials and an infinitely capacious sink for wastes. This is a surprising oversight, since one of the central principles of Marx's analysis of capitalism was that the extraction of surplus value from producing workers leaves them too poor to buy back what they have made, so capitalism is forced to scour the world for new markets and new workforces (Marx 1954, 713-15; Marx & Engels 1974, 58) and must eventually come up hard against the Earth's finitude: at some point it will exhaust the last market and the last free worker. Since this is a central principle, acknowledging the finite ought really to be habitual for Marxists. Ecological thinking brings home our circumstance of finitude most forcefully.

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¹All quotations of Timon of Athens are from Shakespeare & Middleton 2004. The other Shakespeare plays are quoted from Shakespeare 1989.

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