

Conceptualizing Living Factories

The first obstacle to grasping the meaning of our living factories is that they are generally subsumed as one more example of “biotechnology,” “genetic engineering,” the “life industries,” or some other equally vague term intended to capture what is unique about recent productive applications of molecular biology.¹ Although I have been content to use these terms myself to this point, I run the risk of obscuring what is unique about living factories, by contrast both to other uses of life and to non-living technologies. As we will see, problems of definition figure prominently in discussions of the uses of life in industry and are often at the root of competing views on the novelty of genetic engineering. As we are interested precisely in this question of novelty, we must be sure to distinguish our living factories from the numerous other kinds of things considered biotechnological.

The purpose of this chapter is to conceptualize living factories in a way that will enable us in subsequent chapters to assess their ontological significance for the human–nature interface. I’ll focus on two questions: (1) How is biotechnology conceptually distinct from technology more generally? and (2) How are living factories conceptually distinct from the many other kinds of things that might be considered biotechnological? I argue that living factories are a specific kind of biotechnology whose unique characteristics demand that they be located with reference to the set of practices through which they are created and employed as tools of industry, what I have referred to as the “transgenic labour process.” This conceptual move will prove valuable in subsequent chapters when we come to assess the significance of our living factories by contrast to other forms of the labour process, both industrial and non-industrial.

LIVING FACTORIES AS BIOTECHNOLOGY

Our task is made somewhat easier by the fact that we began our enquiry with a specific object in mind: living factories. We know already that we have before us a kind of instrument – as distinct from simply one more transgenic organism – and that this instrument is used to produce pharmaceuticals and other substances. We also know, from my earlier elucidation of Marx, that understanding the ontological significance of technology for the human–nature interchange requires that we locate it with reference to the labour process.

At first glance, official definitions of biotechnology would appear consistent with our needs. The Canadian Biotechnology Strategy (CBS 1998) defines biotechnology as “an umbrella term covering a broad spectrum of scientific applications used in many sectors. It involves the use of living organisms, or parts of living organisms, to provide new methods of production, make new products and find new ways to improve our quality of life” (2). A similar, but more concise, definition is provided by the Organization for Economic Co-operation and Development: “the application of biological organisms, systems and processes to the production of goods and services” (OECD 1998, 15). That living factories are biotechnological according to these definitions seems clear enough. They are indeed living organisms: microbes, plants, and animals. And they are indeed applied in the production of goods: pharmaceuticals, plastics, fine chemicals, etc.

The difficulty with these definitions, however, is that they do not delineate a specific set of instruments nor a specific kind of labour process. Compare the above definition of biotechnology with, for example, the OECD definition of information technology:

... technologies used in the collection, processing and transmission of information. It includes micro-electronic and opto-electronic based technologies incorporated in many products and processes and increasingly affecting the service sector. It covers, inter alia, computers, electronic office equipment, telecommunications, industrial robots and computer controlled machines, electronic components and software products. (1987, 12)

Now, whatever the subtle adjustments that might be made to this fairly standard definition, its incommensurability with official definitions of biotechnology is clear. Where information technology is

generally taken to refer, at the very least, to a set of tangible objects, biotechnology is much more elusive, referring to the “application of life” rather than to a specific set of things.

The difficulty with this definition from our perspective is that a focus on the application of life does not allow us to distinguish our living factories from any number of other instruments employed in a broad range of labour processes. Agricultural labour processes, for example, clearly “apply” life in the creation of goods, and so agriculture is accordingly considered a biotechnology sector by government and industry organizations.² But of course this would mean that the whole history of humanity – at least since the Neolithic Revolution – has been biotechnological in this sense.³ Moreover, any instrument required for the application of life in agricultural labour processes could then be considered a biotechnology, from the seed itself, to hand tools and plows, to the sophisticated information technologies employed in today’s industrial farming. Indeed, if we include mining, forestry, and health care as biotechnology sectors (as Industry Canada does) it is difficult to imagine an instrument that could *not* be conceived of as a biotechnology.

To be useful for our purposes, the concept of biotechnology must, at the very least, delineate a specific set of instruments as distinct from those we would consider non-biotechnological. We are assisted in this endeavour by the fact that the prefix “bio-” indicates that the technology is distinct by virtue of the involvement of living organisms or parts of living organisms. Now, a technology can *involve* living organisms in two kinds of ways: it can be employed in the transformation of living things, or it can itself be a living thing. Industry Canada employs the first criterion in its consideration of biotechnology as distinct in its “manipulation of living things to produce goods and services.”⁴ We must of course reject this definition because, again, it fails to distinguish biotechnology as a set of instruments from the hand tools, machines, and information technologies that have been, and continue to be, employed in the transformation of living nature since the beginning of human history. And so, by default, we arrive at our working definition of biotechnology: the set of living things employed by human beings as instruments in the transformation of nature (living or not) to meet their needs.

Such a definition is valuable insofar as it allows us to distinguish biotechnologies both from the mere application of life in a variety of industries and from instruments that are not themselves living.

Agriculture is thus not a biotechnological process *per se*. While its instruments of production are employed to transform living materials, the instruments of agricultural production are not necessarily alive themselves. In fact, the more recent history of agriculture suggests a shift away from biotechnology as draft animals have been replaced through mechanized farming; certainly, this shift would seem to be the essence of debates regarding the industrialization of agriculture. Perhaps more importantly, however, we can now clearly distinguish between biotechnology and those non-living instruments that may or may not be used in the make over of living materials: hand tools, machinery, computers, etc.

This conception of biotechnology as living instruments has much in common with that employed by historian of technology Robert Bud (1993), who identifies three stages of biotechnological development. The first is marked by the employment of yeast in ancient practices of brewing; the second, by the characterization and employment of microbial life in fermentation processes yielding pharmaceuticals and industrial chemicals from the late nineteenth century; and the third, by the revolution in molecular biology over the past few decades that has allowed for the employment of organisms as bioreactors, or “living factories,” for the manufacture of proteins that these organisms would not have otherwise produced in their “found” form. Even though Bud’s history of biotechnology tends to focus on the use of microbes at the expense of appreciating the ways in which animals, especially, have been employed as technologies, his approach is nevertheless valuable in conceptualizing biotechnology as technology and in highlighting the historical continuity of developments in biotechnology. And, to be sure, we can go further than Bud in charting this history and locate the origin of biotechnology in the Neolithic Revolution and the early efforts of humanity to domesticate and make use of animals as the tools of agriculture.

Still, while there may be nothing new about the use of life as an instrument of production *per se*, even a cursory glance at some of our living factories is enough to raise some doubt as to their continuity with past biotechnologies. Is the type of bacteria engineered to produce human insulin even moderately continuous with those used in traditional fermentation processes? What about goats that produce spider silk in their milk or chickens that make human growth hormone in their egg whites? Are these merely more advanced forms of animal husbandry? Such examples seem to provide at least enough

prima facie evidence to suggest that there is more going on with the current use of transgenic organisms than Bud's history of biotechnology would suggest; and no doubt, they point to a weakness of the concept of biotechnology in grasping whatever is unique about the contemporary use of life as an instrument of production. For what the concept of biotechnology neglects is the process through which these living instruments are themselves produced. What these transgenic organisms suggest is a possibly discontinuous development in the ability of human beings to create living technologies. Our interest in understanding the significance of these technologies for our exchange with nature thus requires that we enquire into the process of their creation.

ENGINEERING LIVING FACTORIES

Among those wanting to emphasize the unique threat posed by recent developments in biotechnology, the term *genetic engineering* has become popular. Even those in government and industry who wish to stress the continuity of biotechnological development are willing to acknowledge a distinction between the more traditional techniques of brewing from more modern techniques concerned with altering the genetic structure of living things at the molecular level.⁵ The roots of the latter are generally traced to the advent of rDNA (recombinant DNA) in the early 1970s, and while other important techniques have emerged, most agree that the splicing together of the genetic material of dissimilar species was the crucial breakthrough marking a new phase in the albeit long and reasonably continuous history of biotechnology. Also, rDNA is widely considered the cornerstone of a new kind of productive process, without which the industrial application of molecular biology would have been much more limited.

While genetics as a science can be traced to the rediscovery at the turn of the century of Gregor Mendel's work on heredity, the unveiling of the structure of DNA in the early 1950s marked the beginning of a revolution in the field (J. Marx 1989). Mendel, in experiments involving pea plants, had discovered in 1864 that certain characteristics are passed along from generation to generation in a systematic way. His work was largely ignored, however, and was revived only in light of the discovery of chromosomes as the locus of the hereditary units, or "genes." In the late 1940s the chemical composition of

the genes was identified as DNA (deoxyribonucleic acid) and their role in guiding protein synthesis was elucidated. Still, genetics to this point remained a largely descriptive science. While great advances were being made in understanding the role that DNA plays in protein synthesis, and cellular reproduction more generally, very little was known about the mechanism whereby the information contained in genes (genotype) becomes expressed in the observable features of an organism (phenotype). With Watson and Crick's identification of the precise structure of DNA in the early 1950s, however, geneticists were in a position to explain in ever-increasing detail the reproductive capacities of organisms at the molecular level.⁶

The revolutionary potential of Watson and Crick's model lay in both its simplicity and universality. Although the chemical components of DNA had been identified some years before, it was unclear how something with so simple a structure could direct the synthesis of the many proteins that make up complex higher organisms. DNA is composed of nucleotides, each of which consists of the sugar deoxyribose, a phosphate, and one of four bases – cytosine (C), thymine (T), guanine (G), or adenine (A). The structure of DNA deduced by Watson and Crick is that of a “double helix” – two intertwined strands of nucleotides whose protruding bases face one another, pair up in a systematic way (A–T, C–G), and hold together with weak hydrogen bonds. Each grouping of three nucleotides, a codon, contains a portion of the information needed to synthesize one of twenty amino acids, which combine to form the polypeptide chains that make up proteins. A gene, then, is a section of DNA that “codes” for the synthesis of a specific protein. During cellular reproduction, the two strands of the double helix separate and each matches up with a new strand according to the sequence of bases, so that two identical copies are formed. The simplicity of the model is striking; the genetic codes for all life on the planet can be represented with only four letters corresponding to the four bases (A, T, C, G). And it was the reducibility of life to this common genetic code that facilitated the rapid advances in molecular biology during the following decades.

The most significant of these advances was the development of rDNA in the early 1970s.⁷ It did not take long for molecular biologists to realize that if protein synthesis in all organisms was determined by some variation of a common four-letter code, efforts to manipulate this code could induce cells to produce “foreign”

proteins, that is, proteins not normally coded for in the cell's DNA. Herbert Boyer and Stanley Cohen first achieved this feat through rDNA, what Jeremy Rifkin describes as "a kind of biological sewing machine that can be used to stitch together the genetic fabric of unrelated organisms" (1998, 12). The technique involves splicing together pieces of DNA from two dissimilar organisms and "persuading" a host cell to "express" the trait coded for by the new recombinant DNA. First, the desired gene or set of genes is isolated using a restriction enzyme – a pair of molecular "scissors" that cuts DNA at a specific location. This leaves "sticky ends" on the desired fragment that can then be joined to the sticky ends of a piece of DNA from a host cell. The host DNA is then used as a "vector" to insert the foreign DNA back into the host cell, which proceeds to reproduce itself with the cloned DNA in each copy. While identifying the structure of DNA enabled biologists to explain the reproductive capacities of living things at the molecular level, rDNA first enabled them to manipulate these capacities to meet human requirements.

Though the new technology would have certain similarities with past techniques employed by plant breeders and industrial microbiologists, and hinge on advances in molecular biology throughout the twentieth century, the term *genetic engineering* captures something of the novelty of rDNA and related techniques. Species boundaries have by no means been historically inviolable; plant biotechnologists have been developing hybrid varieties since the early twentieth century and, as evolutionary biologists point out, such boundary-crossing also occurs "naturally," without human intervention. Nor did the technique of rDNA itself emerge from the lab *ex nihilo*; molecular biologists and industrial microbiologists have understood and employed the reproductive capacities of microbes in production for years, albeit in their found form. However, the technique of rDNA constitutes a qualitative shift in both instances. Genetic information is now itself manipulated at the molecular level, allowing for a potentially unrestricted crossing of all species of plants, animals, and microbes with each other. The speed and relative accuracy with which this can be done allows for the design of life at a most basic level through rearranging its molecular genetic building blocks.

We can see clearly now the conceptual relation between genetic engineering and biotechnology and where to situate "living factories." As we have seen, biotechnology refers to any living instrument employed by human beings in the transformation of nature to meet

their needs and has a long history in agriculture and fermentation. Until recently, however, living things have been employed as instruments by virtue of their found characteristics. Living factories, by contrast, are transgenic organisms created through techniques of genetic engineering and are thus a specific kind of biotechnology.

The concept of genetic engineering also allows us to locate living factories in a specific labour process in a way that the concept of biotechnology fails to do. While the notion of living instruments of production is certainly more precise than the “application of life,” the history of biotechnology can nevertheless be traced to the domestication of animals during the Neolithic Revolution and runs through the development of varied and otherwise divergent labour processes. Animals, for example, are used for their tracking skills in hunting, their herding skills in animal husbandry, as well as for their “horse power” in agriculture and industry, although in this latter case with decreasing frequency with the coming of the machine. The concept of genetic engineering, alternatively, allows us to appreciate the long history of biotechnology and its relevance across a wide range of productive sectors, but at the same time to identify a unique labour process concerned with the specific task of creating transgenic organisms.

Yet, despite the value of this conceptual shift, it would at the same time lead us somewhat astray from our purpose, which is, after all, to assess the significance of living factories for the human–nature relation by looking at their role in the labour process. Though the concept of genetic engineering succeeds in directing our attention to the practices through which organisms come to have their unique transgenic nature, it fails to capture what is distinctive about our living factories, compared with all of the other transgenic organisms created through genetic engineering – that is, that they are employed as instruments, that they are themselves biotechnologies. However, we do not want to merely dissolve the creation and employment of transgenic organisms into a vague concept of “biotechnology,” which as we have seen does more to obscure than illuminate. Maintaining an analytical distinction between the creation and employment of living factories is particularly important in light of the very different roles that the organism plays in the two processes; in genetic engineering the organism is the primary raw material transformed into a transgenic product, whereas in the case of living factories the organism itself is the instrument of production, what we might call a transgenic biotechnology.

Of course there is nothing terribly new here, for all technologies are characterized by the same product/instrument duality. In the case of information technology, for example, the distinction is clear: information technologies are both the product of IBM's labour process and instruments in General Motor's labour process. It might be enough, then, to merely distinguish between labour processes for which living organisms are the raw material transformed through genetic engineering into transgenic organisms, and those for which transgenic organisms serve as productive instruments. And since our concern is with the significance of living factories, rather than the genetic engineering of transgenic organisms per se, we could simply disregard the former.

However, a further complication of living factories makes such a distinction, and the parallel with information technology on which it is based, problematic. Despite the fact that the creation of transgenic organisms and their employment as living factories may be analytically distinct processes, they would also seem to involve one another in a unique way. Unlike the computer, whose significance derives from its use in multifarious industries, transgenic organisms are designed for the production of specific proteins. In this sense, those firms engaged in genetic engineering are more akin to Microsoft than IBM insofar as they "program" an organism for a specific purpose, rather than build one whose use is largely determined by those who employ it as a technology. Then again, genetic "information" is not distinct from an organism in the same way that software is distinct from hardware and so this analogy is also inadequate. Genetic information is not so much "processed" by the organism as it is the molecular building blocks of the organism without which it ceases to be. Transgenic organisms are thus "dedicated machines" in a way that differs from computers.

This is no mere academic distinction. This unique aspect of living factories is reflected in the structure of the firms engaged in their creation and employment. Where firms that produce information technologies can be distinguished in a reasonably straightforward way from those that merely employ these technologies to produce other products, the manufacture and use of transgenic biotechnologies takes place in the same firm, or at least within the same partnership of firms. SemBioSys Genetics Inc. of Calgary, for example, both genetically engineers safflower seeds and employs these seeds to produce biopharmaceuticals and feed additives, or at least enters

into partnerships with firms that possess the required manufacturing and other necessary capabilities.⁸ The firm thus produces and claims proprietary rights to both the biotechnology, the Stratosome Biologics System, and the products it is used to produce – for example, Immunosphere, a feed additive that protects against viral disease in shrimp. Similarly, Nexia of Montreal claims proprietary rights to both the Bele goats and the BioSteel.⁹ This is a unique characteristic of these biotechnology firms and is reflective of the dedicated nature of living factories. What we need, then, is a concept that locates our living factories within the set of practices through which they are both created through genetic engineering and made use of as instruments in the manufacture of such desirable commodities.

THE TRANSGENIC LABOUR PROCESS

To get beyond the confines of existing conceptions of biotechnology and genetic engineering, this section sets out the concept of a “transgenic labour process” in response to the unique empirical challenges posed by living factories. While the term *transgenic production* is appearing with increased frequency in industry literature, it can be expanded in two ways. First, though the term is most commonly used to refer to the industrial use of transgenic animals in particular, there appears little reason to distinguish between the use of animals and the use of other forms of life in industry. Second, despite the fact that the term is often used to refer to only the employment of transgenic organisms in industry, we will include not only the industrial use of transgenic life but also the creation of transgenic life through techniques of genetic engineering. Thus, we arrive at a preliminary definition of the transgenic labour process as incorporating our definitions of both biotechnology and genetic engineering: a labour process centred on the genetic engineering of organisms and their employment as biotechnologies in the production of goods.

The concept of a transgenic labour process focuses our immediate attention on the unity of the process through which organisms are being designed at the molecular level and harnessed as biotechnologies. The process begins with life in its found form and ends with a useful substance. Harnessing living things to the labour process in this way is achieved through altering their genetic structure at the molecular level so that they might be persuaded to produce

substances that they would not otherwise. Considered as a whole, then, a transgenic labour process transforms living nature at the molecular genetic level so that it might serve as an instrument to create substances to satisfy our needs.

The concept of a transgenic labour process, conversely, also allows us to clearly differentiate between the two analytically distinct phases of the process: (1) the *creation* of transgenic organisms; and (2) their *employment* as transgenic biotechnologies. In the creation phase of the process living organisms and their parts are the objects of labour that are worked up with the technologies and techniques of genetic engineering. A new, transgenic organism emerges from the creation phase whose genetic design reflects a need for a specific substance. In the employment phase of the process transgenic life is “scaled up” in order that it might produce commercially viable quantities of the substance. Whereas in the creation phase the living organism is the object of labour, in the employment phase it serves as the instrument itself insofar as it is of service as a bioreactor to generate its valued results. The concept of a transgenic labour process thus enables us to begin to capture the changing role of life in the production process that has emerged with the advent of the novel tools and techniques of genetic engineering: life is at once raw material, technology, and product of the transgenic labour process.

Locating living factories within the transgenic labour process avoids the difficulties we encountered with the concepts of biotechnology and genetic engineering. Our focus on transgenic organisms and the practices to create them avoids the tendency of the concept of biotechnology to obscure what is clearly unique about these biotechnologies. Our subsumption of genetic engineering as a phase of the transgenic labour process further enables us to avoid a tendency among those interested in transgenic organisms to neglect the ways these organisms are actually employed as biotechnologies. And as we have seen, the need to grasp both the design and use of transgenic organisms is necessitated by the dedicated nature of living factories themselves.

However, despite all of its conceptual advantages, we find ourselves confronted with a rather indeterminate object of investigation, the analysis of which requires that we generate more concrete descriptions of exactly how transgenic life is being created and employed as an instrument of production. To generate such descriptions we need to establish criteria for distinguishing types, or modalities, of the transgenic labour process.

There are two kinds of criteria commonly used to distinguish forms of biotechnology. First, industry associations and governments tend to divide the biotechnology industry into various sectors according to their product lines and generate descriptions through case studies of specific firms.¹⁰ Though the design and use of transgenic life as an instrument of production does indeed take place in different industrial sectors (e.g. pharmaceuticals, fine chemicals, food additives, new materials), the differences between such sectors would seem irrelevant to our purpose. As we are interested in what is distinctive about the design and use of *living technologies*, we need to differentiate our labour process so as to foreground the differences in the way these processes take place, differences obscured by a focus on product lines.

More promising is the practice, common in both the more technical literature as well as in more popularized accounts, of differentiating genetic engineering/biotechnology according to the specific organism created and/or employed. Many edited collections written for a scientific audience are divided into sections devoted to microbial, plant, and animal genetic engineering/biotechnology, and individual contributions often focus on specific organisms (e.g. *Escherichia coli*, corn, goats).¹¹ The advantage of this method of differentiation is that it attends to the characteristics of the organisms themselves, rather than the product they are used to produce, thus highlighting what is specific to the creation and employment of *living technology*. The limitation of this approach, however, is a general tendency to regard microbial, plant, and animal genetic engineering/biotechnology as *sui generis*, which obscures the underlying logic of the process through which life itself is being harnessed as a productive force.

Given these limitations of a focus on either particular industries or specific life forms, our transgenic labour process will in many ways remain abstracted from both. Though our descriptions of the process rely on industry and firm literature, this will be used to construct the “transgenic labour process” in abstraction from its existence in any particular industry or firm. This will prove necessary to get at the essential characteristics of the process, which is particularly important if we are to get at the degree to which it is qualitatively distinct from other forms of the labour process. And, again, even if the technical literature will be an important source for our descriptions, we want to abstract first from the differences in forms of life in order to get at the essence of the process as a whole; this

will enable us to see the extent to which, rather than dealing with merely one kind of organism, the transgenic labour process harnesses life itself to human needs. The transgenic labour process is thus best understood from this point of view as a conceptual construction intended to trouble certain ontological assumptions concerning nature, rather than as an empirical site of investigation.

Constructing this labour process requires recognition of its uneven development and a willingness to include in this construction much that is still emerging.¹² While the employment of transgenic microbes in the commercial manufacture of pharmaceuticals is well established, their use to produce plastics, for example, is still in its nascent stages. However, the use of transgenic plants as delivery systems for human pharmaceuticals has been stalled by regulatory concerns over contamination of the food supply, whereas their development for use in the production of non-human therapeutics and plastics is somewhat more developed. Interestingly, the prevalence of the “Frankenstein syndrome”¹³ notwithstanding, the employment of transgenic animals has been much more successful than that of plants, with the recent regulatory approval of GTC’s ATryn – a biopharmaceutical produced in transgenic goats – likely marking a turning point for the industry (Pollack 2007).

Thus, the industry must be regarded as largely emergent, with most transgenic production platforms still in the research and development stage and in various stages of clinical trials. Nevertheless, transgenic microbes, plants, and animals are all in use as biotechnologies and there is little to suggest that their slow movement to commercial application is anything more than a reflection of the complexity of biological processes, the high cost of research and development, and the fairly strict regulatory guidelines covering the engineering and employment of living things, particularly in the manufacture of biopharmaceuticals. Indeed, part of the attraction of this application of transgenic life is that it seems to be immune from the kind of public concern that generally attends the genetic engineering of food. Despite their emergent nature and uneven development, enough bits and pieces of living factories are far enough along in their development for us to confidently construct our transgenic labour process, albeit at a rather high level of abstraction.

Still, our interest in what is unique about living technology would seem to suggest the importance of attending more concretely to differences between transgenic labour processes centred on microbes,

plants, and animals. As we shall see, although there is a common logic underlying the transgenic labour process as a whole, the issue of whether the organism created and employed is a microbe, plant, or animal has important implications for the more concrete form this process takes. Accordingly, we will distinguish between microbial, plant, and animal modalities of the transgenic labour process. While the details of these modalities will be discussed in chapters 3–5, a broad outline of them here should prove useful in providing some concrete footing for an analysis that will tend to be conducted at a fairly abstract level.

The design and use of transgenic microbes as living factories for the production of useful substances has the longest history of any of our modalities and remains by far the most common in terms of commercial production. The process of genetic engineering, as we have seen, transforms individual cells, with the result that the use of quite simple single-celled organisms, and bacteria particularly, has proven an efficient method of working up life so that it issues in a useful substance it would not otherwise produce.¹⁴ The use of microbes as instruments of production centres around the fermentation tank, which is used to monitor and regulate the life process of the microbial population as it grows, and to produce the substance in greater quantities.¹⁵

Whereas the creation and employment of plants as living factories remains the least developed of our modalities, an increasing number of firms and governments are exploring and developing techniques for the design and use of transgenic plants as biotechnologies for the production of a wide range of commodities (Veeman 2008). The creation of rDNA molecules is consistent across the modalities; however, plant genetic engineering requires that transformed plant cells be grown into mature plants and crossbred with one another to produce a “pure” transgenic species, a process that relies on practices with a long history in plant breeding. The seeds of the transgenic plant are then planted and employed as instruments to produce valued substances, which of course relies on agricultural practices with an even longer history than those of plant breeding.¹⁶

And finally, if there is a cutting edge to all this, it must be the creation and employment of transgenic animals as bioreactors for the production of desirable substances. The creation of a transgenic animal, in addition to requiring techniques of rDNA, requires that embryos be made transgenic and brought to term in a mother’s

womb or egg. Once born, these transgenic animals can be bred to produce a founder “herd” whose offspring will serve as transgenic bioreactors. The use of animals in this way centres on the barnyard and requires practices of animal husbandry, which, along with agricultural practices, have their origins in the Neolithic Revolution.¹⁷

Now, the unevenness and emergent nature of the industry, and, indeed, the failure of many of the firms (Thiel 2004), demands that we address how these specific examples of microbial, plants, and animal technology will figure in the analysis that follows. Since the argument here does not concern the proliferation of living factories, nor the relative success of the firms in question, or of the industry as a whole, the rather shaky status of the firms is of less concern than it might otherwise be. The purpose of this discussion is to construct a “transgenic labour process” in order that we may use it to disturb conceptual categories and ontological assumptions concerning the human–nature relation. The question concerns, not whether the firms themselves are successful, or in fact whether their specific products have or will reach the market at all, but how they assist us in constructing a labour process centred around living factories. These firms will prove useful places to pick up the bits and pieces with which we will construct our labour process. We are thus not interested in the firms for their own sake and will make little reference to their specific activities.

The main exception to this policy will be my use of the promotional literature provided on the websites of these firms, a use that requires some justification in light of our interest in the transgenic labour process at a rather abstract level. Not only are these websites valuable as sources of information conveyed in a reasonably user-friendly and non-technical way, but they provide a valuable illustration of the repositioning of life as an industrial force of production. My choice of websites reflects an interest in their illustrative power, with special attention to those that provide the best evidence of the unique characteristics of a transgenic labour process, rather than those produced by the most successful companies. Thus, the promotional literature of Nexia and TranXenoGen will figure prominently in the analysis despite their lack of commercial success. After all, who could resist Nexia’s spider-goats and a proud creator who once suggested that “we’re changing the world from a tiny low-rent sugar farm, and our only machinery is a goat” (quoted in Osborne 2002, 1). The fact that Nexia has encountered difficulties finding

commercial application for these goats is less interesting in this context than what this statement reveals about the repositioning of life as technology.

CONCLUSION

Though our living factories are certainly biotechnologies, they are specific kinds of biotechnologies that require a unique approach to the labour process if we are to assess their ontological significance for the human–nature interface. While refining our definition of biotechnology allows us to see the continuity of living factories with past uses of organisms as instruments of production, the transgenic nature of our instruments suggests the need to take into account the practices of genetic engineering used to create them. While a look at these practices doubtless suggests the novelty of transgenic organisms, it tends to obscure the important difference between the creation of transgenic organisms and their service as living factories. And these limitations of concepts of biotechnology and genetic engineering for conceptualizing our living factories suggest the need to locate them inside the set of practices adopted to create and to use them as instruments of production – what I’ve called the transgenic labour process.

Of course our conceptualization of the transgenic labour process is as it stands too abstract to be useful. Though I have, in keeping with my reading of Marx, located our living factories within a specific labour process, we know little about the kind of labour process we’re talking about. After all, the ontological disjuncture in the human–nature relation Marx identifies with capitalism is not an effect of just any labour process, but of a specifically industrial form of the labour process. We must turn now, then, to assess whether and in what sense our transgenic labour process can be considered an industrial one.