Bateson's Method: Double Description. What is it? How does it work? What do we learn?

Julie Hui, Tyrone Cashman, Terrence Deacon

University of California, Berkeley
Department of Anthropology
Berkeley, CA 94720-3710

Introduction:

In his book Mind and Nature, Gregory Bateson presents a method of analysis that he believes is critical to sorting out some of the fundamental questions of biology. He argues that this method is largely unrecognized and underutilized, and yet it is essential for investigations within the realm of *creatura*, i.e. the living world in which information processes, not just material-energetic processes, are relevant. He describes his method as "double description". More than mere comparison, double description includes elements of both Charles Sanders Peirce's abduction and Bertrand Russell's logical types, although neither term is used in their original senses. The historical origins of this concept and its relationship to other analytical concepts such as these will not be explored here. The purpose of this paper is to examine what Bateson means by double description, how it works as an analytic tool in Bateson's hands, and what Bateson believes can be achieved by its careful application (where possible to determine). In particular, we hope to critically develop the logic of this analysis to the point where we can reconsider an exemplary challenge that Bateson poses at the beginning of Mind and Nature (which involves multiple levels of double description) in light of more recent developments in evolutionary and developmental biology. He asks:

> What pattern connects the crab to the lobster and the orchid to the primrose and all the four of them to me? And me to you? And all the six of us to the amoeba in one direction and to the back-ward schizophrenic in another? (Bateson, 1979: 8)

Double Description:

Bateson's methodology is introduced in chapter 3 of Mind and Nature, where he "[brings] to the reader's attention a number of cases in which two or more information sources come together to give information of a sort different from what was in either source separately." (Bateson, 1979: 21) One of his primary examples is that of binocular vision. As with all primates, humans can perceive a single object in front of us with both of our eyes due to our overlapping fields of view. We cannot, however, perceive distance ahead of us with only one eye since the image on the retina of each eye is only two-dimensional, on the left-right, up-down axes. It is only when the images of the two eyes are combined that the brain creates the additional sensation of depth in the forward direction. The information from our two retinas is fused to form a single image in our experience, but it is the differences in the original two images, as acknowledged and interpreted by our brains that generate depth perception. According to Bateson, "the twoeyed way of seeing is itself an act of comparison." (Bateson, 1979: 87) Acts of comparison involve taking account of both the similarities and the differences between the compared objects.

The neural logic of this process was just becoming understood by the time of Bateson's writing. Binocular fusion of the slightly disparate information arriving from our eyes is accomplished by processes taking place in the cerebral cortex. In the primary visual cortex of mammals like ourselves, monkeys, and cats inputs arriving from the two eyes are assembled into separate cortical strips called ocular dominance columns. (Hubel and Wiesel, 1965; Hubel, Wiesel, and LeVay, 1977) Although information taken in from each eye is initially segregated, both eyes survey visual scenes that have extensive overlap and receive information from both the left and right sides of the visual field. This information remains segregated, but nerve fibers from each eye segregate so that half go to one side of the brain and the other half to the other. As a result, information from each eye about one side of the visual field is sent to the opposite hemisphere of the brain. In this way, inputs from both eyes conveying information about things on the right side of the field are separated from inputs about things on the left side of the field and analyzed in separate hemispheres. On each side the information from the two half-retinas converges in the visual cortex, forming a series of zebra-stripe like patterns, or ocular dominance columns, that interdigitate the maps from the two eyes so that information from a point in space as seen from my left eye will be adjacent to information from that same point in space as seen from my right eye. (Steward, 2000) Light reflected from objects that are close will enter the two eyes at more divergent angles than objects that are more distant, and require more convergence of the eyes to fuse the images. Images from close objects will thus also be more different from each other as seen by each eye. This means that neurons in adjacent columns receiving information from opposite eyes will differ more in their patterns of activity for close versus distant objects. Through a comparison of the firing disparity of neurons from opposite eyes surveying corresponding points in the visual field information about objects' relative distances is integrated into the unified visual experience.

[Insert Figure 1. Binocular vision]

This is a slight simplification of the explanation of binocular vision, but it is sufficient to show correspondence between Bateson's understanding of depth perception, and other examples in which comparisons between similar phenomena yields information not evident in either phenomenon alone. Bateson's point is that the act of comparison in the case of binocular vision allows for the difference between the incoming information of our two retinas to make a difference in our visual experience. This act of comparison requires both a similarity in the images (due to the overlapping fields of view), and also some systemic difference between them that is extracted by the brain through the process of juxtaposing just slightly variant signals. "From this new sort of information, the seer adds an extra *dimension* of seeing." (Bateson, 1979: 70)

Despite beginning from this very concrete example of depth perception, in which information about a third spatial dimension is generated by comparison of two-dimensional images, he intends to use this logic more generally to describe a somewhat more metaphoric exposure of a previously hidden dimension, or depth, generated by comparisons of a special sort. He proposes that, “[in] principle, extra "depth" in some metaphoric sense is to be expected whenever the information for the two descriptions is differently collected or differently coded.” (Bateson, 1979: 70) Comparing stereoscopic vision to a few other examples of double description will help us grapple with Bateson’s understanding of this sort of “bonus” in information, or depth, that can be generated by double description.

For example, he compares the fusion of slightly disparate images to the fusion of two slightly different sound frequencies that produces an audible “beat” superimposed on the tone. “In the case of rhythmic patterns, the combination of two such patterns will generate a third. Therefore, it becomes possible to investigate an unfamiliar pattern by combining it with a known second pattern and inspecting the third pattern which they together generate.” (Bateson, 1979: 79) This third pattern, in the case of two close sound frequencies, is a rhythmic beat that results from the way that the peaks and troughs of superimposed waveforms alternately reinforce and cancel as the slightly different frequencies shift in and out of phase alignment with respect to one another. The rise and fall in amplitude of the composite wave produces the “beat,” and its occurrence is completely dependent upon the relationships between the two frequencies, but not either alone. So knowing the difference in frequencies, one can calculate the resulting beat. Such beats are most noticeable when the two interfering frequencies are quite close, because the resulting beat will be quite slow in comparison (since it takes much longer for the waveforms to shift 180 degrees out of phase), but a beat is also a frequency and it may be more in the range of the other two if they are not highly similar and in this case heard as a sort of third, often dissonant, tone. More importantly, if you are given the rhythmic beat of amplitude and only one of the input sound frequencies you can calculate the missing input sound frequency. The relationship of these three frequencies allows you to predict any one of the three from the relationship between the other two. To put this in Bateson’s terms: the double description provided by the juxtaposition of any two can provide information about the third.

Moiré phenomena offer a related spatial beat-like phenomenon, in which two line patterns can generate a third. If two sets of regularly spaced lines are superimposed such that one is slightly rotated with respect to the other, a third linear pattern is produced. Similar to the sound beat pattern, from this set of three patterns, any two, when superimposed, will produce the absent pattern. Again, the superimposed patterns must be highly similar for the difference pattern to be robustly noticed. More generally, both of these examples demonstrate that the relationship between two similar regularities or habits is also a regularity or habit.

[Insert Figure 2. moiré phenomenon]

The generation of this new regularity is seen by Bateson to be an analogue to the generation of added dimensionality in stereoscopic vision. The regularities in the differences provide an extra dimension or an extra frequency beyond what was provided as input; a bonus. This, then, becomes a metaphor for what should result from useful double descriptions, and serves as a template for distinguishing double description from mere comparison. But whereas in these cases prior similarity in the regularities of the inputs are nearly inevitable or else assumed as given, for Bateson's method of double description to be a useful analytic tool for uncovering hidden patterns or pointing to unnoticed dimensions of relationships, the selection of inputs with respect to their similarities is a critical first step. This then begs the question of the logic or strategy for selecting potentially informative input phenomena leading to promising double descriptions. Though on this point Bateson is less than clear, he considers a largely overlooked form of inference as the key: abduction.

Abduction:

Abduction is a mode of logical inference that was first systematically described and explored by the late 19th century American philosopher Charles Sanders Peirce. Though still mostly ignored and misunderstood today, Peirce showed that abduction (his term) was a third inferential mode of reasoning in addition to the more traditionally recognized modes: deduction and induction. Continued historical neglect of this form of inference can probably be attributed to the fact that it appears to be merely an error of deductive inference; a logical fallacy. While Peirce would not have disagreed with its ultimate fallibility of inferential reliability, he nevertheless claimed that this form of inference is the foundation on which all other forms ultimately rest. This is because it is the inferential logic of categorization; of identifying similars.

As described above, similarity is an essential component of Bateson's double description. He appeals to abduction as a critical step in generating this further analytic operation based on an initial assessment of similarity. To investigate the relationship between abduction and double description, then, we need to spend some time distinguishing abduction from the other forms of inference. We can begin by exemplifying the familiar forms of deduction and induction and contrasting these with abduction using the classic forms of syllogistic (or sentential) logic (though these three can be generalized to more abstract and general logical forms).

[Insert Chart 1. Three forms of inference]

To begin with, abductions and inductions both make predictions. In abductions, we use the similarity of predicates to attempt categorization of the subjects. In the case of induction, we use cases to generate a general rule. Neither abductions nor inductions generate conclusions with the logical necessity as formulated in deduction. However, abductions and inductions can be strengthened. In abductions, the iteration of the number of predicates strengthens the hypothesis that the subjects belong to the same category. Inductions are strengthened by iterating the numbers of cases. For instance, if a case about Aristotle is added to the inductive case above one is more confident about the general rule. On the other hand, deductions are only extended with further subject-predicate rules because the rules follow necessarily from one another. A point where Bateson appears to overlap with Peirce is in the use of abductions for making classifications, and the certainty about whether or not the classification holds true is through a strengthening of the abduction with further predicates. In essence, by showing that the similarities between two subjects is strong, we feel more confident that they are exemplars of a common type and probably share other properties in common as well. This can be seen in Bateson's example of the similarity between natural relations and social organization:

> "If I examine the social organization of an Australian tribe and the sketch of natural relations upon which the totemism is based, I can see these two bodies of knowledge as related abductively, as both falling under the same rules. In each case, it is assumed that certain formal characteristics of one component will be mirrored in the other." (Bateson, 1979: 143)

In this case, the abduction involves the categorization of the natural relations and the social organization based on similar rules. Bateson hints at the implication of further parallels in the final sentence of this quote. This implies that abductions need not require experiencing both inputs simultaneously, as might be suggested by the example of vision. It is only simultaneous in the sense that one can call the other to mind. In essence, abductions occur whenever there is a co-categorization based on similarity, and this can include situations as separated as the case of an anthropologist spending one field season studying the natural relations of a totemic system, and then in a subsequent field season noticing a correspondence with the kinship organization of the same group. If the kinship organization then brings to mind similar relationships found in the natural relations, or vice versa, then an abduction has occurred.

However, while Peirce uses abductive categorizations as the basis for inductions or deductions, Bateson seems to understand the term somewhat differently. "Every abduction may be seen as a double or multiple description of some object or event or sequence." (Bateson, 1979: 143) He proposes that abductions are not the basis for double description, as a Peircian might propose, but instead that double description is the basis for the abduction. This apparent circularity can be a bit confusing, but it follows from his notion of the primacy of relationship. He proposes that "[*relationships are*] *always a product of double description*." (Bateson, 1979: 132 – emphasis in the original). In this passage, he is arguing that the act of abduction requires putting two inputs or descriptions into relationship with one another in order to discover their similarities. This will become somewhat confusing, however, when we consider what else Bateson hopes to achieve by double descriptions: some guidance in formulating useful explanations.

Bateson appears interested only in a subset of all Peircian abductions: abductions that lead to something else: a larger systemic relationship. He includes this larger relationship as part of the abduction. In doing so, he inserts a hierarchical logic into the abduction. Confusion arises from this mixing of abductions with this ascent in the logical hierarchy of abstractions. We suggest that clearly separating these two features of double descriptions can clarify exactly what is involved, but at some cost to Bateson's more extended use of these concepts.

We will argue that the first step of a double description involves identifying potentially informative similar patterns through abduction, and then by virtue of their comparison discovering higher-order rules about their similarities and differences. While this can be seen as Peirce applied to Bateson, we believe that this clarification is necessary if double description is to be used as a scientific methodology. Although abductions may establish the ground for double description, they do not seem adequate for guaranteeing its usefulness. Bateson sees this usefulness in the capacity to provide metaphoric depth, but this is an aspect that requires a clear distinction between abduction and the hierarchical inference that the abduction can elicit. For Bateson, the key to the metaphoric depth comes from an idea he borrows from mathematics: logical types.

Logical Types:

The theory of logical types was developed at the turn of the 20th century by the British philosopher Bertrand Russell as a way of avoiding logical paradoxes in mathematics. These paradoxes, related to vicious circle reasoning, are derivatives of the Liar's Paradox. The most familiar form of the Liar's Paradox is, "I am a liar." If I am liar, then I am lying about being a liar and therefore am telling the truth; but if I am telling the truth, then I must be a liar. The paradox produces a never-ending alternation between truth and lie that is ultimately irresolvable. The undermining of hierarchic structure in the logic of this paradox can be better recognized if we slightly modify the sentence to read: "This sentence is false." In this case the subject of the sentence ("This sentence") refers to the whole sentence, but the negation in the sentence changes the reference implicit in the subject, and so on. The negation continually negates itself. Russell's remedy for avoiding such vicious circles requires distinguishing members of a class from the class as a whole and disallowing members of a class to refer to or presuppose the existence of the class. This exclusion was necessary to avoid the possibility of equivocation that could undermine his effort to derive mathematics from logic, which he undertook with Alfred North Whitehead, in Principia Mathematica (Russell and Whitehead, 1910), though this remedy was later shown to be inadequate. Nevertheless, the terminology identifies an important logical distinction. A hierarchical distinction is implicit because classes are always about conglomerates of members, making classes a higher order abstraction with respect to the members exemplifying it.

Over the course of his career, Bateson developed a wider use of the term 'logical type' from this mathematical-logical notion, and came to use it to great effectiveness throughout his writings to elucidate hierarchic relationships in many domains. In his conception of double description, Bateson argues that the metaphoric bonus obtained is inevitably of a higher logical type than the phenomena being compared. This application of a logical type to double description makes it more than simple abduction, in the Peircean sense. This logical type distinction is a second aspect of a double description. It requires using the abductively linked cases that were identified in the first step of this method to point to something in addition, which is at a higher logical type. The abduction allows the differences to make a difference (to use one of Bateson's favorite aphorisms). The differences between the two information sources form the basis for the treatment of the sources as two distinct cases of the same phenomenon exemplifying a general rule. In the Peircian categorization of inferential forms, described in the above section, inferring a rule from a comparison of cases is an induction. By definition, the rule is of a higher logical type than the cases which exemplify it. It is the shift of emphasis from similarities to differences that marks the transition from abduction to induction. Bateson does not, however, call this step an induction, but collapses both inferential steps into his notion of abduction. But maintaining this distinction both clarifies the relationship between Peircean abduction and double description and explains why this latter process generates a higher logical type result. It involves using an abduction to bring attention to a potentially instructive induction.

Invoking this framework of working from abductions to inductions can help to clarify some of Bateson's more confusing examples. Consider again his argument that the perception of binocular vision is an example of a shift in logical types, in which "the *difference* between the information provided by the one retina and that provided by the other is itself information of a *different logical type*." (Bateson, 1979: 70; emphasis in the original) Perceiving depth depends on registering a systematic difference in signals from the two eyes, but this cannot be recognized until the signals are juxtaposed and aligned with respect to their similarities.

What does it mean for this systematic difference to provide information of a different logical type? To be brought into relationship is to be categorized as cases belonging to the same class by abduction, and once the similarity is established the information sources can be systematically compared, exposing their differences. But without systematic comparison these patterns of differences will remain unnoticed, as will any higher-order rule accounting for the process that generated this pattern. It seems that for any double description to count as useful it must result in something of a higher logical type by making an induction possible. Presumably, if a double description does not render some further regularity of differences apparent, there may be something wrong with our categorization (the abductive step).

Bateson's example of binocular vision is a minimalistic variant of this logic. The overlapping fields of vision represent an innately evolved (and therefore reliable) abduction, that effectively "categorizes" the inputs from the two eyes as cases of the same class. The difference in patterns of neuronal firing are thus systematically compared when they converge in the cerebral cortex. From this comparison the distribution of differences across the visual field can be discovered to exemplify a general rule, which itself can be encoded in systematic neural firing patterns elsewhere in the brain. Although depth is not itself a rule, it is only experienced because a rule or regularity was discovered in the comparison. This new pattern of difference signals contributes to the experience of depth, and is itself potentially susceptible of further double descriptions. For example, it can potentially produce ever more abstract double descriptions with respect to other coupled processes (e.g. it can provide information about the amount of force that needs to go into a leap in order to reach the other side of some ditch in the path of running). Bateson's emphasis on depth as a product of the double description is merely a short-cut for talking about the regularity generated in the double description upon which it depends. Depth as a metaphor, does however provide a sense of what this hierarchic inference feels like, as an experience.

We can now return to the question that began this paper and Bateson's Mind and Nature. Understanding how an abductive juxtaposition creates the possibility of hierarchic ascent (or induction) in Bateson's logic of double description, helps to give meaning to his special use of the word 'connection' as exemplified in his homology comparisons.

> 1. The parts of any member of *Creatura* are to be compared with other parts of the same individual to give first-order connections. 2. Crabs are to be compared with lobsters or men with horses to find similar relations between parts (i.e., to give second-order connections). 3. The *comparison* between crabs and lobsters is to be compared with the comparison between man and horse to provide third-order connections. (MN, 11)

Here Bateson proposes that first-order connections are relationships of structures within one organism, in which parts share some structural resemblance to one another. The 'similar but different' aspect of sequentially modified body parts defines a series of double descriptions in which the relationships between parts and their systematic differences point to a theme and variations, that is modified in linear series. In the crab and lobster there is a gradient of similarity, e.g. between legs, where parts that are more similar tend to be located closer to one another than parts that are vastly different. We perform an abduction by noting the similarities between parts of an organism. For instance, leg segments in a crab are topologically similar to one another; that is they all share a rule about how a leg is structured from the same number of jointed segments. Each comparison between legs suggests a general rule about leg architecture with respect to which each is a slight variation. But how each leg differs is also dependent on where in the series the leg is located. The comparison of the bilateral and serial patterns of the leg-theme variations arranged along the crab's body suggests that a higher logical type of pattern characterizes the crab as a whole. So even within Bateson's "first-order connections" two nested levels of double descriptions are brought to bear. While Bateson categorizes these nested levels as one, in order to distinguish the first-order connections as internal, our distinction shows that both levels nevertheless follow a logic of theme and variations.

In second-order connections, we now look between classes of individuals (e.g. two distantly related crustacean species). Here, the results of first-order double descriptions become the basis for a second-order abduction. One can ask: what can we gain from noting similar serial patterns of part-to-part relations in two different species where we also find a systematic pattern of differences between their serial patterns? Bateson notes that these forms of shared characteristics are due to a shared common ancestry. Crabs and lobsters have similar appendages, laid out in a similar topological fashion, partially because of their linked phylogenetic history. They diverged from a common form, but the pattern of this divergence also carries information about what else influenced their divergence, i.e. what they differently adapted to.

Unfortunately, Bateson can be read in several ways on this point. Crabs and lobsters have similar appendages laid out in a similar topological fashion. In one sense, he might be suggesting the existence of a sort of *ur*-form that is neither crab nor lobster, but that both are partially expressing in their adult forms. Such a conception of biological forms was characteristic of much pre-Darwinian evolutionary thought, such as the morphological theories of Wolfgang von Goethe, Geoffroy Saint Hillaire, and Richard Owen. But Bateson's recognition of the role of common ancestry suggests that he is not interested in some type of idealized form, but rather in the logic of the generative process itself. He is interested in how the system of shared traits between crabs and lobsters, and their differences, informs us about the shared and divergent phylogenetic histories of these lineages, provides hypotheses about the traits of their common ancestor, hints at their adaptive differences, and possibly provides insight into the logic of their segmental morphology. However, Bateson indicates that these important biological insights are only part of what he thinks his analysis can lead to. This is because he notes that a third-order double description is also possible by using our double description of a crab and lobster, with a similarly derived double description of a horse and man (or an orchid and primrose) potentially telling us something about the theme and variations logic itself.

[Insert Figure 3 (crab and lobster) and Figure 4 (orchid and primrose)]

At this level of third-order connections we can ask: what can we learn about the overarching process producing theme and linear variation, of which genetic change and adaptation are exemplars? With each level of connection, we are forced to ask ourselves how the patterns and relationships that we see are more universally applicable and further generalized. Bateson is pointing us towards a general logic of form production that can generate highly complex and organized systems such as organisms.

The Pattern Which Connects:

If we now re-examine the challenge that opens <u>Mind and Nature</u>, which was cited at the beginning of this paper, we find that each of the questions are posed as double or multiple descriptions. Although it perhaps betrays Bateson's acknowledged attraction to neoPlatonic conceptions of biological form, when placed in the context of his interest in identifying a "necessary unity" between mental processes and evolutionary processes it suggests that he is ultimately interested in understanding the commonalities of the formative processes behind these examples. Although the biological mechanisms underlying these regular and symmetrical segmental body patterns was unknown in Bateson's time, subsequent advances in molecular and developmental biology have uncovered many of the details of these processes. In hindsight, we can fill in much of the detail that Bateson believed held the key to forging this unity. In this way, we can take a final step that Bateson could only gesture toward: identifying the ur-logic of the pattern which connects.

We can begin with the first-order double description as exemplified by the cases of serial homology Bateson describes. Molecular-developmental biologists during the 1980s and 90s discovered that such repetitions of body segments were under the control of a special subclass of genes that control genes (often described as regulatory genes). The products of these genes are transcription factors: proteins that control the expression of other genes by binding to sequences of the DNA chain just before an exon (a region that contains a sequence coding for a protein's structure) and thereby initiates, inhibits, or otherwise modulates its transcription into mRNA necessary for protein synthesis. The homologies Bateson points to in the crab-lobster comparison are consequences of the evolution of a subset of transcription factors produced by the set of homeotic genes Hox 1 to 9. These are responsible for segmentation and differentiation patterns of the body from the posterior head through the abdomen in arthropods and vertebrates. (Gerhart and Kirschner, 1997) It is thought that the complex of Hox genes evolved over time through a series of duplications of a single ancestral Hox gene. Oftentimes in this process the duplicated gene is inserted into the genome next to the original. But because Hox genes control the expression of large suites of genes that produce the integrated structure of a single body segment, Hox gene duplication results in the serial duplication of a whole body segment. While the immediate result is two nearly identical segments, the two genes eventually accumulate differences over time due to mutations that slightly change the structures of each, and thus their products' binding to the control regions of target genes. This slightly alters the expression patterns of the different target genes, in turn slightly altering corresponding aspects of segment structure. For example, the anterior legs of crabs have diverged to exhibit pincers, as opposed to simple pointed tips. This difference evolved as an adaptation for feeding and fighting instead of walking, and in this way reflects two different ways that the logic of leg design can be modified with respect to extrinsic constraints of crab ecology. In this way, leg duplication with slight serially varying differences was produced by an evolutionary duplication and differentiation of homeotic genes.

[Insert Figure 5 transcription factor logic]

Bateson next compares the overall serial pattern of segments in the crab to the homologous patterns in the lobster to generate a second-order double description. This pattern is likewise correlated with a higher-order expression of the duplication-differentiation logic. A corresponding set of Hox genes is found in both groups. However, in the two lineages each component gene-segment relationship is slightly different, while features of the linear logic of the whole complex is also subtly different. The Hox complex has differentiated over time in the separate lineages. This new pattern which connects the crab and the lobster, based on the conserved similarities of their Hox complexes, allows us to use the differences in the complexes to make inferences about the factors that created the differences: i.e. their different adaptational contexts. The adaptation of crabs to environments where they are primarily walking, for example, resulted in wider bodies with tails that are curved under their bodies. The adaptation of lobsters to an environment that included the need to swim probably resulted, in an elongated body and tail. So the pattern of similarities and differences that evolved in the Hox complexes of these two crustacean lineages, corresponds to a higher-order pattern of similarity and difference; the synergies and specialization of segments that correspond to similarities and differences in the environments to which each have become adapted. This reflects a phylogenetic history in which previously very similar body forms derived from a common ancestor become progressively different.

But if we now consider the even higher-order relationship that connects the crab - lobster comparison with the orchid - primrose comparison we can no longer appeal to common ancestry and conserved Hox genes to explain why both comparisons involve the logic of theme and variations of body structures. This is because Hox genes are not involved in plant segmentation. Nevertheless, this common logic exposed by double description suggests that here too there may be a similar solution to the production of form, even though it must have evolved independently within two unrelated kingdoms. Although vascular plants, like orchids and primroses, do not share Hox genes with complex animals, they do have a series of transcription factor genes that work analogously to the Hox complex. So there is a pattern which connects the genetic trick shared by the crab and the lobster to the genetic trick shared by the orchid and primrose, even though they involve unrelated genes, different kinds of segmental strategies, and adaptations to vastly different modes of life. It is a duplication and differentiation logic of form production and adaptation whereby the interrelationships between similar but different forms results in the emergence of higher-order functional relationships. This third-order pattern is of a higher logical type than any particular relationships between genes, between body structures, between organisms, or even between homologous complexes in unrelated lineages. This general logic of duplication and differentiation is effectively a unifying pattern underlying the generation of biological form in organisms with respect to environmental constraints, irrespective of how it is implemented.

Conclusions:

Double description, as a method, is about a process of classifying the world and using that act of classification to learn something about both the justification for the classification and its generation. In some sense, double description looks past superficial similarities and differences to consider the underlying processes evidenced by the system. Bateson presents this method, which we experience metaphorically every moment we experience depth perception, and offers a deeper usage. He claims that this is something that he has learned from 50 years of science. (MN, 87) It is the foundation stone of knowledge generation and he pursues this methodology with a larger goal in mind, implicit in the title of his book Mind and Nature: A Necessary Unity.

This larger goal is seen in the double description between the method and the biological pattern which connects. The method of double description is based on a post hoc examination of a system to determine underlying rules. But the logic of double description, through the mixture of abduction and induction, is also for him the fundamental tool for the generation of knowledge (mind). We have now also followed Bateson's intuition that the logic of the evolutionary generation of biological form is connected to this as well. Exploring the genetic evolution behind the levels of homology and analogy of form between organisms as phylogenetically distant as crabs and orchids, we have uncovered a formative logic that itself exhibits an abstract similarity to the logic of double description. Because it is this logic itself that is being compared, it offers the basis for a yet higher-order double description that may indeed complete Bateson's enterprise.

The similarity between the generation of knowledge and biological form lies in the differentiation and duplication logic. The reliance of abduction upon duplicated similarities is abstractly analogous to the generated duplication found in the evolutionary logic. Similarly, the reliance of induction upon patterns of differences in similar cases is abstractly analogous to differentiation in evolution. Juxtaposing the similarities of these logics allows us to treat them as exemplars of a further process by way of their similarities and differences. In the case of knowledge generation, the similarities and differences explored in the phenomena we encounter become the basis for the discovery of the deeper formative processes that lie behind them. In the case of evolution, duplication of similar units of genetics, appendages, lineages, etc., provides the basis for adaptive differentiation to evolve with respect to an environment. This suggests that in both processes there is a higher order duplication-differentiation pattern at work. It is this abstract formative logic which forms the foundation from which correspondences, in the form of meanings or adaptations, can be built. And this process is common to both mind and nature.

So when Bateson enlarges his comparison to take into account amoebas and schizophrenics, he is pointing to this higher-order process linking mind and nature which all evolvable systems and mind exemplify. The amoeba perhaps represents one end of the spectrum of biological evolution and the schizophrenic represents another; the logic of knowledge creation and the systems of communication in which this process is of differentiation with respect to something not there—an environment adapted to or a phenomenon in the world represented in mind—is embedded. This higher-order process, while connecting all of *creatura*, also marks a distinction between *creatura* and mere material-energetic processes where cause-and-effect is direct and unmediated by information. It is only within the realm of information systems that differences (differentiation) can produce other differences with respect to something beyond either—an environment for an organism or the outside world to which subjective experience points—and yet which can thereby become a necessary constituent, exemplifying a necessary unity.

Acknowledgements:
The authors would like to thank Ana Casareto, James Haag, Robert Hui, Jay Ogilvy, Janine Pliska, and Jeremy Sherman for their supportive efforts.

Works Cited:

Bateson G (1979) Mind and Nature: A Necessary Unity. New York: E. P. Dutton.
Gerhart J, and Kirschner M (1997) Cells, Embryos, and Evolution: Toward a Cellular and Developmental Understanding of Phenotypic Variation and Evolutionary Adaptability. Malden: Blackwell Science.

Hubel DH, and Wiesel TN (1965) Binocular interaction in striate cortex of kittens reared with artificial squint. J. Neurophysiol. *28:*1041-1059.
Hubel DH, Wiesel TN, and LeVay S (1977) Plasticity of ocular dominance columns in monkey striate cortex. Philos. Trans. R. Soc. London Ser. B *278:*377-409.
Steward O (2000) Functional Neuroscience. New York: Springer.

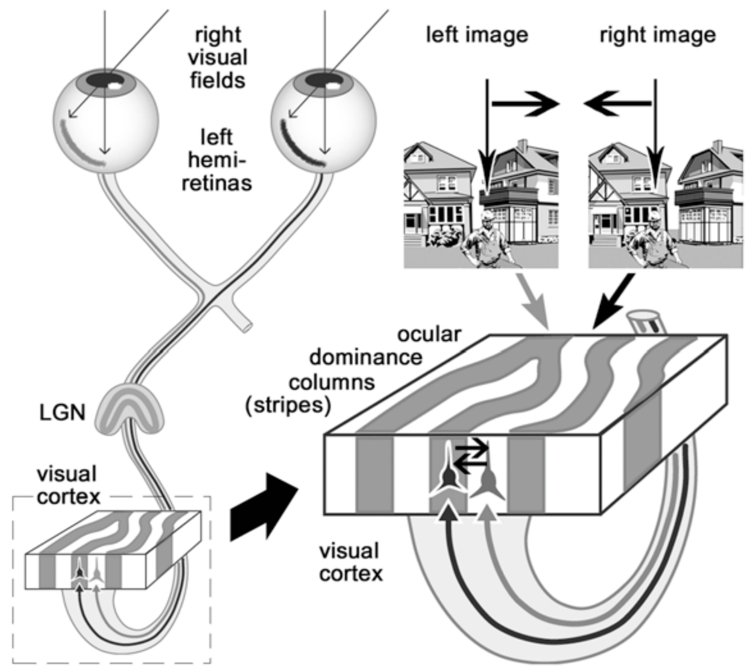

Figure 1. The logic of depth perception depends on light striking the two hemi-retinas opposite to the visual field they survey, and the signals being relayed through the lateral geniculate nucleus (of the thalamus) and ultimately to the contralateral visual cortex where signals from each common locus in the two visual images are systematically compared (as described in the text) in adjacent columns (stripes). The scenes presented to each eye are also depicted in order to exemplify foreground/background object position parallax (see arrows pointing to the man in the foreground) and indicate that this is encoded as an interaction dissonance between neurons in adjacent columns.

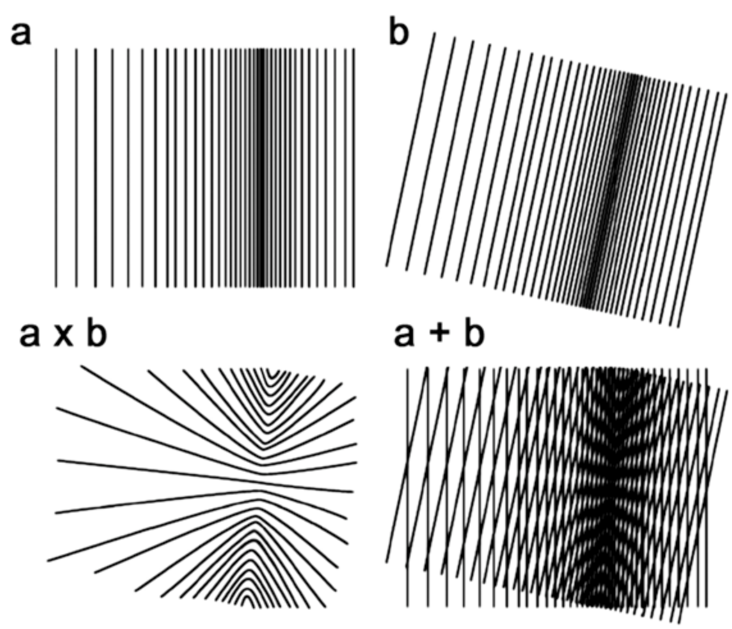

Figure 2. Moiré patterns (named for the effects of light passing through two delicate fabrics when superimposed) result from the analogue of an interference pattern produced when slightly misaligned linear patterns cause the positions of their overlap to stand out. The superimposition of patterns ***a*** and ***b*** shown as ***a*** **+** ***b*** produces a third pattern of curves shown as an interaction pattern ***a*** x ***b***.

Abduction:	Induction:	Deduction:
All men are mortal. Socrates is mortal.	Socrates is a man. Socrates is mortal.	All men are mortal. Socrates is a man.
Socrates is a man.	All men are mortal.	Socrates is mortal.

Chart 1.

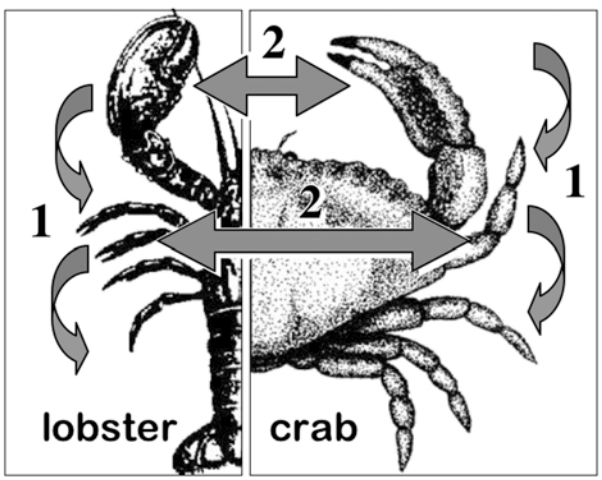

Figure 3. Comparison of the limb morphology of a crab and a lobster indicating first-order and second-order comparisons — serial- and phylogenetic-homologies — with curving arrows (1) and horizontal arrows (2), respectively.

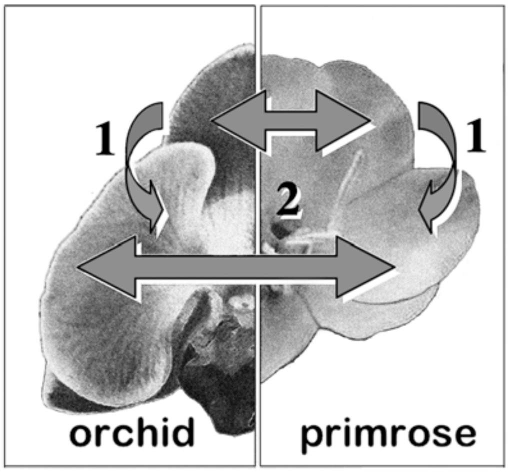

Figure 4. Comparison of the petal morphology of an orchid and a primrose indicating first- and second-order comparisons (homologies) as in Figure 3, comparing crab and lobster.

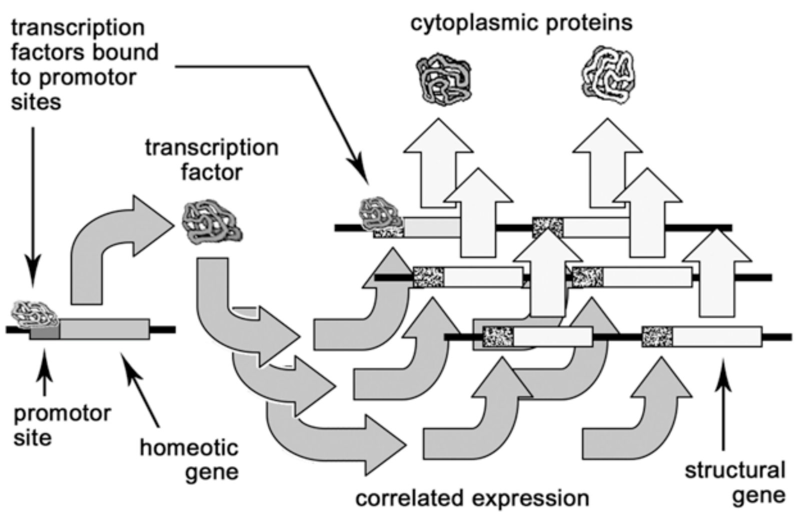

Figure 5. The logic of homeotic gene control. Structural genes and control sites (e.g. promotor sites) are schematically depicted as boxes strung along a chromosome (a line). Two kinds of protein products (transcription factors and cytoplasmic proteins) are also depicted as products derived from these genes. The binding of transcription factors (such as those produced by homeobox Hox genes) to a promotor site activates the transcription of a structural gene. The power of homeotic genes to organize complex segmentally repeated body structures is due to the fact that each can serve to promote the transcription of perhaps hundreds of genes in specific combinations at specific points in development.