Stability and Dynamics of Individual Personality in a Dominance Hierarchy

by Denis Rancourt / January 2nd, 2019

In this article, I develop a physics model of the bimodal personality of the social animal. The model uses free-energy barrier-crossing theory and provides a new and testable paradigm of individual behaviour and perception in a dominance hierarchy.

A realistic theory of social organization must use a correct model of the individual. The said correct model must not only contain correct elements but it must also be sufficiently complete to be predictive and to produce observed social behaviour.

For example, it is correct to say that the individual is intrinsically driven to seek safety, resources and to reproduce, however actually expressed in society. By "intrinsic" I mean "hard-wired" or "evolutionary" or "physiologically prescribed". But these correct biological characteristics of the individual are not sufficient by themselves to explain that dominance hierarchy is virtually always the organizational type in societies of social-animal species.

Nor do these correct characteristics of the individual explain the long-term stability of a given class-structured dominance hierarchy, or the phenomenon that many individuals in society can choose to forgo reproduction or even forgo striving to obtain optimal levels of safety and access to vital resources.

Having posited the internal drivers for safety, resources and reproduction, the next level of complexity of the model of the individual is to describe the individual's intrinsic response function to external (i.e., societal or environmental) signals. Such signals include both positive and negative social feedback, and include both aggression and rewards from the dominance hierarchy.

Regarding the individual's intrinsic response function, in a 2011 article I postulated that the strong causal relation between poor individual health and subjection to dominance-hierarchy stress was a biological reality that both enabled the formation of dominance hierarchy and provided a mechanism to cull burdensome individuals from the society.[1]

However, this was a linear response function that incorrectly does not admit any beneficial effect from stressor events, in any circumstances. It also did not make the important distinction that the "stress" that determines health is not an objective consequence of the external stressors but, instead, must be understood as the "experienced stress". I described the important additional concepts of "experienced stress" and comparative "self-image" in

2014.[2] These modulators move us towards the needed non-linearity of the response function, and in themselves explain many health outcomes.

Independently, it has been a major theoretical breakthrough, in the area of individual health, to explicitly posit that the individual's intrinsic response function is not linear and has a "U" shape. This is scientist-reviewer Sapolsky's "inverted-U" function.[3] I have reviewed these advances in my critical assessment of cancer science.[4] The inverted-U idea is that there is an optimum degree of stress, not too little (isolation) and not too great (overwhelming oppression), which maximizes individual health.

While the inverted-U curve of stress response is a useful unifying concept, it does not account for the capricious nature of experienced stress, which in turn is the actual determinant of health in a given individual. The same objectively measured external stress can have opposite health effects in different individuals in the same social class, and opposite effects in the same individual at different times while remaining in the same social class, for example.

The above considerations, the overwhelming importance of dominance hierarchy as the main organizational principle in animal societies, and a review of the science of the monoamine neurotransmitter serotonin in relation to social status, aggression and dominance interactions led me to propose the simplification that "social animals have two modes of being", which I explained in the following way:[5]

> I propose that the animal has two modes of being, which are binary end-points on an attitudinal, self-image and behavioural psychological-state-scape.
>
> I'm not saying that each individual is permanently in one or the other mode of being. Rather, I propose that the individual shifts and slides into one or the other mode depending on his immediate social circumstances and on his history (biological and metabolic memory) of being predominantly in one mode or the other.
>
> The modes of being that I propose map onto the social dominance hierarchy, and are consistent with the roles of different individuals within the hierarchy.
>
> Specifically, one mode is the mode (and strategy) adopted by the dominated individual. This mode is one where the individual seeks "fairness" and minimal aggressions in their environment. The individual seeks a "safe space" and has no actual design to displace dominants. The culture of individuals that coalesce into such a stratum of the hierarchy is one where "kindness" and "being a good person" are the highest social values that are encouraged and rewarded. Altruism and "goodiness" are elevated to a status meriting religious indulgences. Viciousness actuated by enforcers within the social stratum is turned towards violators of this code.
>
> The other mode is the mode (and strategy) adopted by the individual who intends to be and to remain dominant. It is an outlook of waging and winning battles for dominance. This is the climber with a "killer's instinct", prepared to joust for relative advantage and eager to dominate.
>
> These modes are distinct mental and physiological states of being. …

In the present article, I want to extend and formalize the proposal of two modes of being by casting it within the physics paradigm of thermally induced transitions between two free-energy minima of different depths. My

intention is to optimally capture the biological, metabolic and social dimensions of the problem with a minimalist model that is sufficiently realistic to explain non-trivial social phenomena.

Within this new picture, the individual's intrinsic response function (response to external signals), realistically depends on the state (or mode of being) that the individual temporarily occupies and on the landscape of possibilities for given expenditures of metabolic energy.

The single-variable "free-energy" function that I will draw has a y-axis labelled "E", which is excess metabolic energy expenditure that the individual needs to use in changing their circumstances on the road to transitioning between modes of being. "E" is analogous to the so-called free energy in physics and chemistry. However, it is excess energy expenditure (or effort) and is therefore on a per-unit-of-time basis for the individual. It is a rate of energy expenditure. It is an "excess" rate because there is always a basal metabolic rate of energy expenditure simply to sustain the life of the inactive individual (beating heart, etc.).

In chemistry, one could be looking at transitions between two bonding configurations of a molecule. In physics, one could be modelling transitions between two orientations of a supermoment on a magnetic iron-oxide nanoparticle. In all cases, the x-axis (or variable) in the "free-energy" picture is a quantity that represents the "state" of the system (molecule, nanoparticle, individual animal) at a given instant.

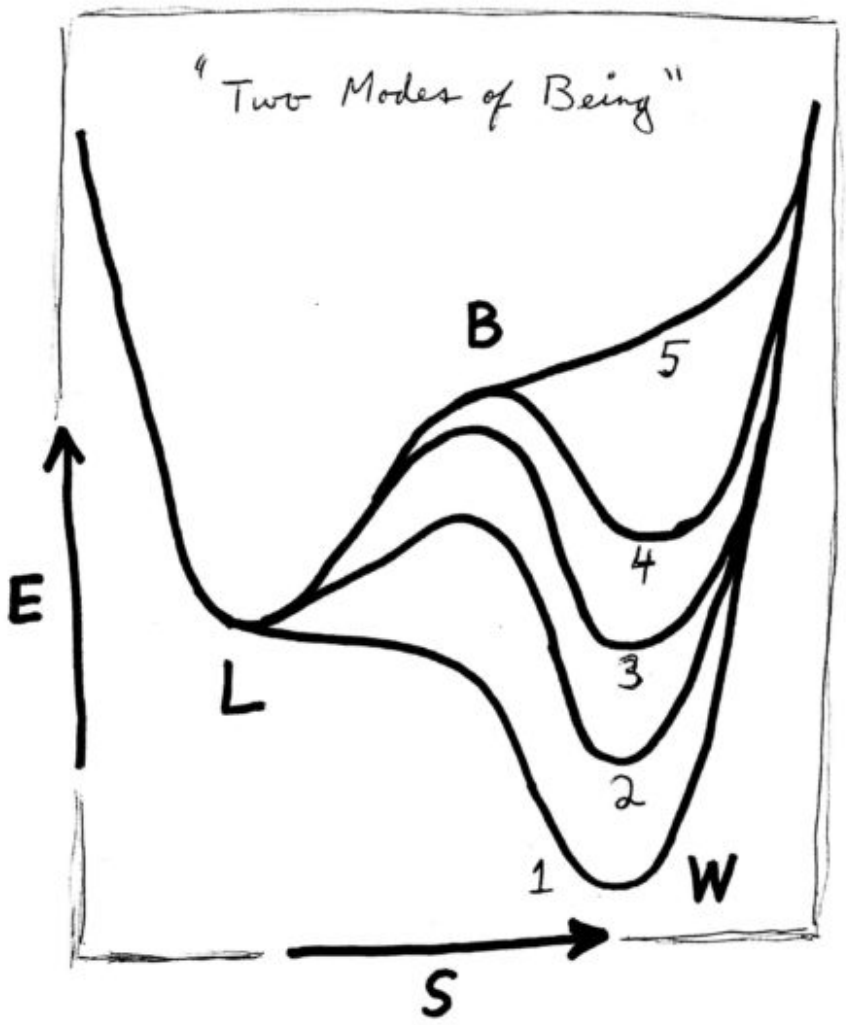
I label the x-axis "S", for "state". In the chemistry example, "S" is a parameter that captures the molecular configuration (a bond angle or an inter-atomic separation). In the physics example, "S" is a parameter that captures the magnetic state of the nanoparticle, such as the angular orientation of the supermoment relative to the ambient magnetic field.

In the case of the individual in a dominance hierarchy, "S" is defined to capture the bio-metabolic state of the individual. For example, we could posit that "S" is the concentration in the blood of a neurohormonal substance that determinatively modulates animal behaviour and perception, which in turn can be interpreted to map onto a "mode of being" or some intermediate transitional mode. Several researchers and scientist reviewers have suggested that serotonin is a candidate to be this substance, but the details of the candidate substance(s) or metabolic quantities do not alter my model.

The possibility of transitions controlled by a modulating substance and occuring in a bimodal state-scape was envisioned for animal behaviour in the landmark 1988 article of Kravitz:[6]

> Such compounds, therefore, can influence large areas of the nervous system in a way that parallels the manner in which transmitters, acting through second messengers, alter the properties of individual nerve or muscle cells: they bring the system (a cell for a transmitter or a circuit for a hormone) from one stable state to a second new stable state that now shows a changed response to selective stimulation. This is done by the alteration or sensitization of a logical set of component pieces that together modify the output of the system.

To continue, here is my picture of the excess metabolic rate versus the state variable value (E-vs-S) function. In fact, five different E-vs-S functions are represented for five different individuals in a dominance hierarchy, subjected to five corresponding different degrees of perceived dominance signaling from their social environment:



The curves "1" to "5" for the five different individuals are labelled in order of increasing dominance oppression perceived by the individual. In most circumstances (2, 3 and 4), there are two troughs (labelled "L" for "loser" and "W" for "winner") in the E-vs-S functions, separated by a barrier maximum labeled "B".

Here, L and W correspond to the "two modes of being" described above. L is the dominated mode, whereas W is the dominant mode.

At small values of S, such as small blood concentrations of serotonin, say, the individual naturally settles into the L-mode simply by minimizing its rate of excess metabolic energy expenditure. Moderate expenditures of excess metabolic energy do not allow the individual to escape the L-mode, as it simply relaxes back down to minimal expenditure after the temporary exertion.

Similarly, at large values of S the individual naturally settles into the W-mode by minimizing its rate of excess metabolic energy expenditure. Moderate expenditures of excess metabolic energy do not bring the individual into the L-mode.

A winning fight, requiring expenditure of metabolic energy up to the barrier value (L to B) can allow an individual to cross over from the L-mode into the W-mode. Likewise, a losing fight that requires metabolic energy expenditure from W to B can push an individual out of the W-mode and into the L-mode.

Some individuals (curve-1 in the figure) cannot escape the W-mode that, for them, is the only stable mode. This shape of E-vs-S curve occurs for individuals that get constant re-enforcement of their high "dominant" societal status, and that are not subjected to threatening hierarchical oppression. An example would be a high-status government or industry leader that is always accompanied by a small army of ego-boosting sycophants.

Similarly, some individuals (curve-5 in the figure) cannot escape the L-mode that, for them, is the only stable mode. This shape of E-vs-S curve occurs for individuals that are constantly reminded of their low "dominanted" societal status, and that are subjected to threatening hierarchical oppression. An example would be a forced coal-mine worker or a prisoner of war in a forced-labour camp.

Importantly, however, the degree "dominance oppression" that determines the shape of the E-vs-S curve for a given individual is subjective rather than objective. It is the "perceived dominance signaling" from the individual's environment. As noted above, the said signaling includes both positive and negative social feedback, and includes both aggression and rewards from the dominance hierarchy.

Therefore, a low-social-class individual can be in a stable W-mode although this will be rare, on a population basis at a given time, and so on. Put another way, on a time basis for a given individual, such a given low-social-class individual will, through the metabolic expenditures of interacting, spend most of their time in the L-mode but some of their time in the W-mode. And these outcomes are similar but inversed for high-social-class individuals.

The said "perceived dominance signaling" that determines the shape of the E-vs-S curve for a given individual plays a central role. Let's simply call it "H", for the sake of convenience. H is analogous to the ambient constant magnetic field experienced by the nanoparticle in our physics example, and it is analogous to a uniaxial stress (pressure) experienced by the molecule in our chemistry example.

In our case of an individual in a dominance hierarchy, H can be defined as $H = fp.Mp - fn.Mn$, where the first term is the product of the occurrence frequency (fp) of positive signals and the average magnitude (Mp) of a positive signal. The second term is the product of the occurrence frequency (fn) of negative signals and the average magnitude (Mn) of a negative signal. A signal is a social feedback, such as a facial expression or a look, or an interaction in the dominance hierarchy, including aggressions and rewards.

H has a value that is measured on a certain sensitivity or measurement time (ts) of the individual. The value of H is not sensitive to environmental changes that occur within times smaller than ts, and H may vary in time on timescales larger than ts. The sensitivity time, ts, is the integration time for establishing a long-term memory that modulates perception. For adult humans, it can be as short as days and as long as years. In other words, the frequencies (fp and fn) of signals in the above formula are determined on the time window ts, where fp and fn are necessarily (much) larger than 1/ts.

All this to say that social environmental changes occurring on a timescale larger than ts can change an individual's E-vs-S curve that in turn determines both (a) the relative amount of time the individual spends in either the L-mode or the W-mode, and (b) the kinetics of the individual's transitions between the L-mode and S-mode. See below.

The picture I have described so far gives a statistical-mechanics view, based on animal metabolism of a social animal in a dominance hierarchy, to explain an individual's inertia regarding personality, perception and behavioural changes, and provides a model for an individual's transitions between the dominated and dominant modes of being, as follows.

If we define a correct “temperature” of the system, then the model will give quantitative predictions for time spent in each mode and kinetics of transitions between modes.

By analogy with the systems in physics and chemistry to which free-energy barrier-crossing theory applies, we can define “temperature” as follows. Let the temperature, T, of an individual in a dominance hierarchy be the mean magnitude of the rate of spontaneous excess metabolic energy expenditure, which is self-generated by the individual (same units as E). This is the rate at which the individual expends metabolic energy to act in the world, beyond just being alive.

Key predictions follow. Let E(L) be the E-value at the bottom of the L-trough, E(W) be the E-value at the bottom of the W-trough, and E(B) be the E-value at the barrier maximum (see figure). And write the natural exponential function (of x) as “exp[x]”.

Then the average time, t(L), spent by the individual in the L-mode before transitioning to the W-mode is given by this simple formula:

$$t(L) = t(TLW) \exp[(E(B) - E(L)) / T]$$

where t(TLW) is the average time between temperature events (of average magnitude T) that constitute attempts to crossover into the W-mode.

The corresponding formula for the average residence time in the W-mode of being is:

$$t(W) = t(TWL) \exp[(E(B) - E(W)) / T]$$

where t(TWL) is the average time between temperature events (of average magnitude T) that constitute attempts to cause cross-over into the L-mode. Here, 1/t(TLW) and 1/t(TWL) are the so-called attempt frequencies of free-energy barrier-crossing theory.

The ratio of residence times is independent of E(B):

$$t(L)/t(W) = (t(TLW)/t(TWL)) \exp[(E(W) - E(L)) / T]$$

The latter equation can be tested experimentally, since all the quantities are times and rates of energy expenditure that can be measured.

The above equations may be the first physics equations that predict average residence times of individuals in given L and W metabolic states (modes of being), and that describe the underlying statistical mechanics of animal transitions between the two modes of being.

My model predicts how an individual embedded in a class (characterized by “H”) within a dominance hierarchy is confined to react to their environment to adopt a mode of being. Is your E(L) larger or smaller than your E(W)…? Dominants have E(W) < E(L), whereas dominated individuals have E(L) < E(W), assuming t(TLW) = t(TWL). Arguably, the single number that best characterizes the main coarse features of the individual’s true personality is the dimensionless ratio E(L)/E(W), which largely results from the individual’s environment (H).

The model shows how the dominance hierarchy creates two kinds of individuals that predominantly reside either in the L or W (dominated or dominant) modes of being. In this way, the animal’s intrinsic bio-chemical response to environmental signals provides a foundational mechanism for creating a stable dominance hierarchy, irrespective of the individual health consequences of an individual’s mode of being.

Dominance hierarchies are highly successful from an evolutionary perspective, such that social organization and individual metabolic reaction mechanisms would have co-evolved to be inseparable.

For humans, therefore, while complex institutions, technology and resource extraction efficiency theoretically permit individual emancipation, nonetheless the human animal cannot escape its intrinsic socio-bio-metabolic nature. Dominance hierarchy rules.[7],[8]

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