‘Diversity’ & ‘Heterogeneity’
Ecological measures for MET

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The bottom line

‘Diversity’ and ‘heterogeneity’ are concepts typically used synonymously,

yet a gap – and at some important contexts a conflict – lays between them.

Structure of the talk

- Brief Review of ecological measures of difference.
- Suggest a new measure: 'Heterogeneity'.
- In the context of models representing major evolutionary transition to individuality:

The Arguement : group diversity (D) & heterogeneity (H) differ in important ways, i.e. measure different causal factors relevant for METI. Therefore, conflating H and D or sufficing with D alone, could side-track models that attempt to explain METI.

- Conclusion

Review: Variance

- Measurable properties ("variables") of a group of individual measurements ("population") typically take on a range of values $\boldsymbol{y} = \{y_1, y_2, y_3, \ldots y_n\}$
- the value of the variable measured for the i^{th} individual is denoted y_i. The average value of the distribution of the measured variables (often its mean value $\bar{y}$): $\bar{y} = \sum_{i=1}^{i=n} \frac{y_i}{n}$.
- The variance : $\sigma^2 = \sum_{i=1}^{i=n} (y_i - \bar{y})^2$.

Review: 'Diversity' in ecology

- Simpson Index (1949)

$$D = \frac{\Sigma\, n(n-1)}{N(N-1)}$$

It measures the unweighted number of organisms, weights by the abundance of each species.

- *Alpha, beta and gamma* diversity differ by scale and by whether populations are compared.
- All diversity measures ***ignore*** species' interaction and structure in their ecosystem.

Are such measures enough?

- ‘Variance’, ‘co-variance’ and ‘diversity’ count an entity’s presence in proportion to its relative abundance.
- Being present does ***not*** imply interacting with the “others” and with the “same”,
- yet it is ***these*** interactions, their relative strength and structure that may be ***causally relevant*** – at least partly – to the real-world target we try to model and explain.

Maybe Another Way (to measure difference)?

- We use standard analysing methods of networks of interacting entities (e.g., species in food webs, individuals in social networks) to suggest an index of heterogeneity - from simpler to more complex - to determine to what degree is an entity also part of a heterogeneous collective.

A Few Working Definitions

- A ‘network’ is a set of connected things.
- More formally, a network is consists of a set of interacting *nodes* (e.g. brain cells, organisms, ecosystems, buildings sharing infrastructure) that are connected by *edges* (e.g. paths, links, linages) that define the relationships between each pair of nodes.
- Nodes and edges may be weighted by their abundance and strength and/or by their direction of interaction (e.g., strong positive interactions, weak negative interactions), or they be unweighted.

Measures of Heterogeneity

- 'Heterogeneity' is derived from 2 basic quantities:
- the number of different nodes *N* (e.g. species in an ecosystem, cells in an organism, cars on the road etc.)
- the number of edges (interactions) between the nodes *L*.
- If every node is connected to one other node, there would be $N(N-1)/2$ total edges. But in most networks, not every node is connected to any other.
- We therefore define the 'connectance' *C* of a network as the number of nodes that do connect relative to those that could connect.

Heterogeneity as Connectance

- $C = \frac{L}{[N(N-1)/2]}$
- *C* is the most basic measure of heterogeneity.
- A group of entities, no matter how diverse, will have *C* = 0 if none of them interact with one another.
- As interactions increase, so will *C*.
- A fully connected network will have *C* = 1
- **Heterogeneity as measured by C quantitatively identifies a bassline for group collectivity, above which – species and context dependent – the network is no longer a pure aggregate, and a new type of selective interactions is beginning to emerge.**

Heterogeneity as Ascendency

- Adding a measure of interaction strength and structure to the network's connectivity:
- $A = \sum_{i,j} T_{ij} \ln \left(\frac{T_{ij} T_{..}}{T_{i.} T_{.j}} \right)$
- T_{ij} measures the transfer of materials, information *etc*. from node *i* to node *j*.
- The ascendency of a network is a combination of its overall internal organization and the amount of content flowing through it.
- As a measure of Heterogeneity A quantifies the degree to which a network behaves as a **collective whole,** which, in our evolutionary context, is the degree to which a new level of individuality is emerging

The diversity/heterogeneity gap
a conceptual claim

- The difference between diversity and heterogeneity is not only of mathematical representation.
- Attributing heterogeneity to an entity implies that this entity is a collective whole;
- while attributing diversity to an entity implies no such pre-assumption.
- There is an important distinction here:
  - ‘diversity’ does not describe collectives well
  - While ‘heterogeneity’ is limited to collectives

A conceptual claim

- ‘Heterogeneity’ applies to a **collective,** holding – to a lesser or higher degree – complex and coordinated interactions between different types of entities;
- ‘Diversity’ applies to a **collection** of different entities, ignoring their connected interactions and structure, whether or not they exist in whatever degree.
- in that sense ‘diversity’ pre-assumes ***divergence,***
  - It is <u>not</u> a neutral measure of difference.
  - measuring diversity may, in some contexts, not only differ but also <u>contrast</u> with measuring heterogeneity

Fit of our suggested H/D difference to common parlance (thanks to Anat Kolumbus)

- We searched the corpuses of COCA and the *Wikipedia* for frequencies of “diverse” and “heterogeneous”.
- Statically, “collective”, “whole”, “integration” and “interaction” co-occurred significantly more frequently with “heterogeneous” than with “diverse” and improved prediction by 8% to 24%.
- The results ssupported the meaning of ‘heterogeneity’ as interactions among different kinds of entities within a collective whole, and the implicit lack of collectivity for ‘diversity’.

Relevance of the H/D difference to evolutionary models

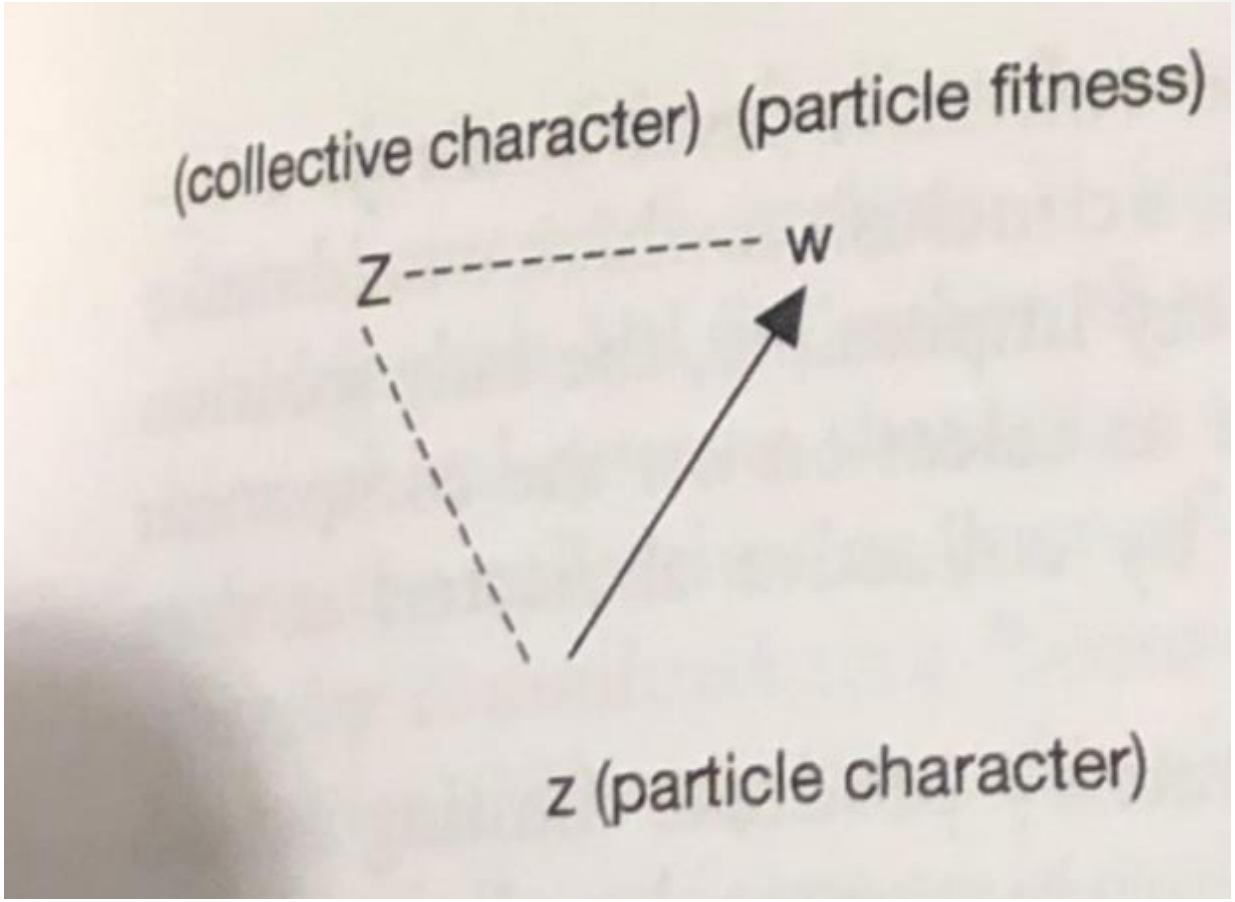
- A model is an incomplete representation, specified by descriptions – including casual descriptions – and interpretations (Weisberg, 2013)

- A model's casual description "amounts to identifying a factor that "makes a difference' for an idealized model in the sense that its removal prevents the model from entailing the occurrence of the phenomenon". (Ibid, 107)

Relevance to models of METI

- Such models aim to represent a target not well defined but with the common feature of: "entities that were capable of independent replication before the transition can replicate only as part of a larger whole after it" (Maynard-Smith and Szathmáry 1995, 6)
- We will focus on the transition to sociality, which Lloyd (2017) describe as three diachronic stages following MLS1 and MLS2.

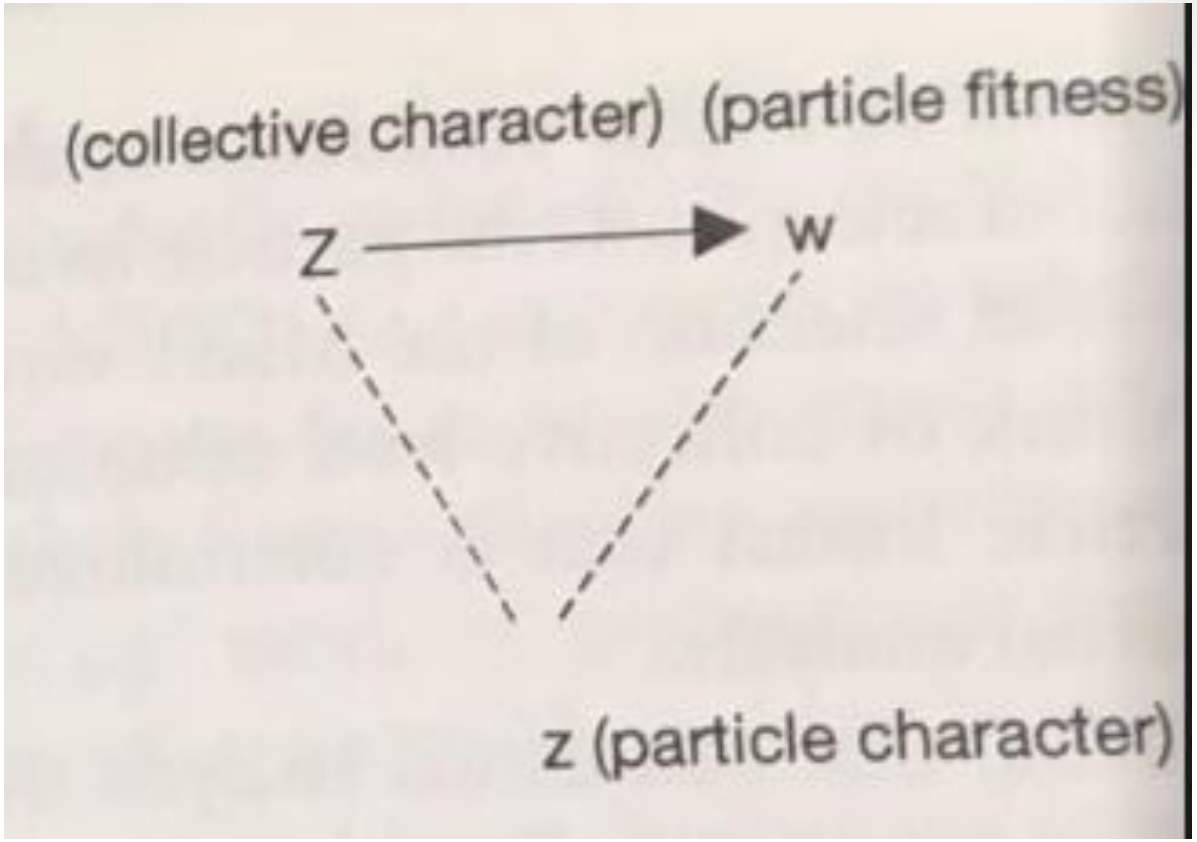
Okasha (2006)
MLS1
Casual Graph, p. 91



In this initial stage, an individual's fitness is caused by the value of its individual character, so a strong correlation (high co-variance) between collective character and individual fitness is a mere statistical by-product.

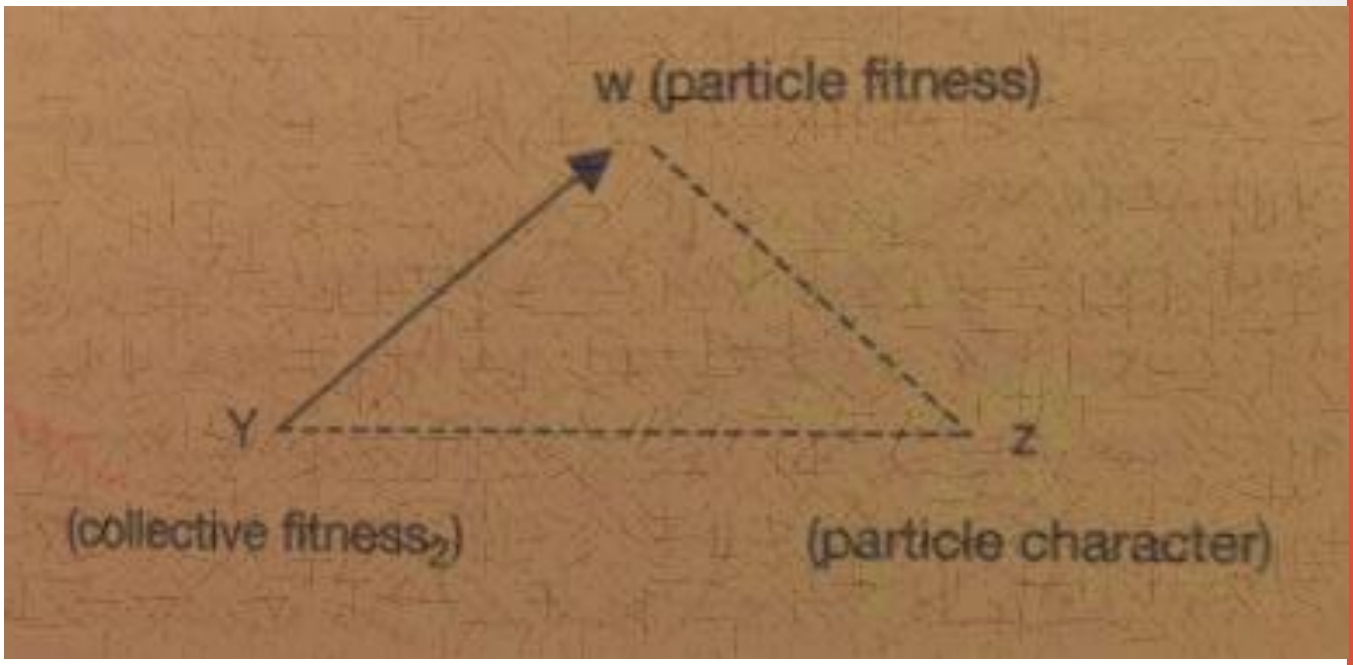
Expected low H, while D could be low or high.

Okasha (2006)
MLS1
Casual Graph p. 91



In this second stage, a proportion (yet no longer a direct correlation) exists between individual character and collective fitness, as the collective character that causes individual fitness is an average of individual fitness.
H & D expected to increase, yet not necessarily similarly

Okasha MLS2 (2006)



At last stage of transition, direct proportion are not expected between an individual character and fitness, since an individual's fitness is caused by a collective fitness, resulting from a collective character.

A Heterogeneity-Diversity trade-off is expected:

In a non-egalitarian inheritance system,

a new level of individuality will hold high H and low D;

high H will maintain the new level of individuality (for example, by division of labor)

while high D (for example, genetic diversity) at this stage will increase inner-divergence and the chance of brake the emerging individual from within,

Conclusion

- Diversity is not heterogeneity, nor will increasing the former eventually increase the latter, since in some non-trivial contexts these measure describe conflicting casual forces.

Thanks!

To recapitulate…

- A surprising gap – and sometimes a conflict – exists in the informal and formal meanings of ‘diversity’ and ‘heterogeneity’.
- ***So what?*** non-trivial costs – ignoring relevant casual descriptions – may exist for evolutionary models that conflate these different measures of difference.
- ***Possible relevance?*** measure the heterogeneity of an entity as an indicator of its degree of individuality (alongside other measures)?

Relevance of the H/D distinction to MET models: a broad-brush view

- Heterogeneity, but not diversity, is expected to be described in the model as a relevant factor since it can casually:
- ignite an new collective from an aggregate,
- Spatially and/or temporally separate an emergent heterogeneous collective from a diverse assemblage,
- Sustain the emergent collective from braking into an aggregate of competing individuals

- According to Griesemer and Wade (1998) these models ignore the casual role of collectivity during the transition to sociality, thus neglect to describe and take into account a possibly major factor in the transition process: coordinated group development (which may affect the timing and location of group reproduction)
- To address this lacuna we suggest to measure also heterogeneity, not just average frequency, within and between groups.

‘Diversity’ in social sciences (Page 2011)

- *Variation*: diversity within a type, referring to quantitative differences in a specific variable.
- *Diversity of types*: referring to qualitative differences between types.
- *Diversity of composition:* the way types are arranged.

Example II: measuring racial integration via alpha diversity

"Bussing" did not improve academic aspirations or achievements of Afro-American kids (St. John, 1975) and often worsened interracial relations: "integration… enhances ideologies that promote racial segregation, and reduces opportunities for actual contact between the races." (Armor 1972, p. 13).

Is this distinction important III?

A problem for ecological models

- Standard biodiversity models measure species diversity in correlation to climate variables, and ignore species' interaction within their common collective habitat and their causal role in their larger ecosystem.
- In other words, standard biodiversity models neglect a possibly major "difference-maker"/ causal factor in species survival.
- To address this lacuna we suggest to measure also species heterogeneity, not just species diversity.

The wider problem for ecology

- ‘Difference’ in biodiversity conservation is inherently ambiguous, since the same word adheres to two different concepts – diversity and heterogeneity– committed to very different practices of modeling and deducing policy recommendations.
- And while both concepts are needed, one cannot practically employ both at the same spatial scale. In certain contexts a trade-off exits, with non-trivial ecological and social results, and in these cases we suggest focusing on the latter rather than the former

Combining ecology and society
(Page, 2011,2014 and personal communication)

- 'variation' is directly analogous to 'alpha diversity', and 'diversity of types' and 'diversity of composition' are analogous to different dimensions of 'beta diversity'.

- Yet 'diversity' is used as a ***catch-all phrase***, in common parlance and in the social sciences, interchangeably used with 'heterogeneity'.

The benefits of diversity

- An obligation to increase social diversity in science (Haraway 1979; Shrader-Frechette 2002; Fricker 2007; Solomon 2010,2015; Douglas 2009, 2015).
- Academic results improve with social diversity (Gurin et al. 2004; Freeman & Huang 2015; Page 2014).
- Scientific explanations improve with diversity of values, opinions, perspectives and specialities (Longino 1990,2004; Solomon 2006ab, 2010; Gerson 2013; Griesemer 2014).

‘Heterogeneity’ in living systems
Matthewson (2011)

- a heterogeneous system holds different kinds of parts, not just different parts.
- Biological systems are inherently heterogenous.
- Yet there is no index of heterogeneity, because Ecologists and social sciences use these terms interchangeably and suffice with measuring diversity,

Epistemic injustice

- "A wrong done to someone specifically in their capacity as a knower" (Fricker 2006, p. 1)

- "Testimonial Injustice: The Injustice that a speaker suffers in receiving deflated credibility from the hearer owing to identity prejudice on the hearer's part" (Fricker 2007, p. 4)

Reducing epistemic injustice as a major aspect of TSA

- TSA aims at mutual listening and learning, **not** to "educate" the "ignorant" and "irrational" public.
- In practice, many TSA courses document and study local tacit knowledge that is relevant to the community and the researchers alike.
- As a result: localized, community based, research-groups emerge, and new information – including academic publications – is obtained.

An argument for heterogeneous academia as in TSA

- TSA collectively examines information, while recognizing the heterogeneous knowledge and identity of peripheral groups.
- Given the basic role of robust analysis,
- and the basic need to resist epistemic injustice,
- If TSA sometimes – even rarely – succeeds, it is a basic & important success and hence TSA should always be attempted when possible alongside standard academia (Griesemer and Wade, 1988).

The costs of divergence between science and society

- Scientist are un-justifiably exempts from the responsibility of not considering the risks of generalizing their conclusions (Douglas 2009)
- Feelings of alienation from science reduces academic achievements of minorities (Armor 1972; Holoien 2013)
- Given science-society divergence, it is often non-experts who engage with the public, which leads to miscommunication and to degrading local knowledge (Shavit et al. in print).