THE PRACTICAL MECHANICS OF INTERDISCIPLINARY SCIENCE. Rich Gazan[1] and Lisa Miller[1], [1]University of Hawaii Department of Information and Computer Sciences, 1680 East-West Road, Honolulu, HI 96822, gazan@hawaii.edu, ljmiller@hawaii.edu.

Introduction: In astrobiology and all interdisciplinary science, we want to do more than just hope for synergistic interactions of diverse types of knowledge. Knowledge created by researchers in distinct scientific communities must undergo active processes of translation in order to inform one another. This paper provides an overview and discussion of successful elements of translation and integration from past studies of interdisciplinary science practice.

Discussion: Interdisciplinarity can be plausibly reworded as a quest for a diversity of inputs to the process of knowledge production [1]. It is both a democratic idea, to include many voices, and a pragmatic one, to have many hands and minds working together. However, interdisciplinarity implies some sort of emergent offspring, with properties beyond those of the disciplines from which it inherits. Astrobiology brings together diverse researchers, data and objects of study toward the question of life in the universe, and in so doing, makes a contribution as a field in its own right. However, assembling a diverse or multidisciplinary team certainly does not guarantee meaningful interaction, integration or innovation. Any collaborative environment that claims to facilitate the cross-fertilization of diverse kinds of knowledge must recognize and reconcile its diverse membership, find a common language, and create a persistent shared space in which present and future researchers can build on one another's ideas.

Diverse membership. Researchers are trained to view problems through the lens of their home discipline, naming the components of interest and framing the context in which investigation takes place [2]. Some researchers focus on common objects of study and use terms like 'specialisms' [3] or 'hybridization of fragments of sciences' [4] to classify researchers who share similar interests and practices but work in distinct fields. Others take a more social view and talk of invisible colleges [5], communities of practice [6] or epistemic communities [7], which can include those not formally trained in a discipline but who nonetheless contribute to its knowledge base, such as amateur astronomers. Epistemic culture is defined as the "different practices of creating and warranting knowledge in different domains" [8]. Critically, the reward structures within one's home discipline must be acknowledged and balanced with the costs of participation in interdisciplinary work.

Within disciplines and communities of practice, warrant is formalized: only certain types of information, from certain sources, are considered valid knowledge. And this sort of warrant is rarely portable from one domain to another. Trust, status and prestige are interwoven factors which are important components of any social network [9]. However, as more and more research and design collaborations take place between people from diverse disciplines and communities of practice, in order to communicate effectively, significant barriers must be overcome [10].

Common language. A core ontology—defined as an underlying formal model for tools that integrate source data—is one of the key building blocks necessary to enable the scalable assimilation of information from diverse sources [11]. When primary source data collected by and intended for a microcommunity is dispersed via a merged repository to larger macrocommunities, tacit knowledge can be lost, and the interpretation and application of data outside the source domain is often compromised. Scientists working in the National Computational Science Alliance regularly transformed knowledge embedded within highly specific domains into "mobile knowledge" useful across multiple domains, resulting in a complex series of trade-offs between communication efficiency and preserving context [12]. In particular, a 'pidgin' language or boundary object [13] often must be constructed that is not scientifically precise, but which gets the job of cross-disciplinary and cross-contextual communication done. Concepts similar to boundary objects have been identified by researchers working in a variety of disciplinary traditions, such as a "zone of interpenetration" [14], where more than one theoretical scheme may apply to the same concrete set of phenomena, or an "interactive stabilization of heterogeneous elements" [15].

Constructing a core ontology is equivalent to creating a course syllabus or textbook outline for a given field of study. The fundamental concepts and applications are identified and arranged within a logical taxonomic framework, such that interrelationships are preserved and expressed. Any individual work within the field can then be located within the core ontology and linked with others at a higher conceptual level. Just as a new student is taught broad concepts first to scaffold understanding, newcomers to a constituent field of astrobiology who might benefit from the new field's

research can access it through the shared language of the core ontology.

Persistent, shared space. Physical or intellectual spaces such as laboratories, research centers or scholarly societies have been imagined as "trading zones," which make communication possible by providing a common area in which people and ideas from different backgrounds can merge and interact [16]. Biodiversity data, like that of environmental science more generally, relies on data sets from a large number of disciplines in order to build up a coherent picture of the extent and trajectory of life on earth [17]. The emerging field of biodiversity informatics is confronting the challenges of attempting to merge longitudinal data sets collected at different times, by different people and for different purposes. As sets of heterogeneous databases are made to converge, contextual metadata about the conditions of data collection and use are critical to the design of a robust and flexible system, and further underscores the need to understand the diverse communities that create and use data. In this way, while a botanist and a climatologist may have very different objects of study, the conditions under which each collects and processes data are relevant to mutual understanding. Persistent spaces such as collaboratories [18] and shared data repositories provide researchers the ability to communicate across time as well as across discipline.

Shared databases can catalyze interdisciplinary science and new knowledge. In a classic work, Swanson [19], an information scientist, conducted searches across two separate medical literature databases, and found a link between the blood disorders associated with Raynaud's disease and fish oil, which was known to relieve the conditions. Two years after the publication of his hypothesis, it was corroborated by a clinical test. If data is persistent and shared, and accessible through a common language, researchers from any field might use it to create new knowledge for all.

Conclusion: What counts as knowledge within diverse disciplines, and why individuals participate in interdisciplinary research, are two important yet rarely-considered questions which are critical to the practical mechanics of integrative science. Researchers studying diverse aspects of astrobiological questions typically have their own data sets which, if shared, could help bootstrap understanding about the broad spectrum of astrobiology's constituent fields. While any common language trades precision for accessibility, the application of a core ontology need not add to researchers' labor or dilute specificity. It can be expressed in a pidgin metadata understandable to all, focused on shared research questions, missions, methods, instrumentation or objects of study. Integrationists from any field might collaborate to assemble the pieces and build the metadata bridges from one data domain to another. Software visualization of interdisciplinary relationships and the Web's reach and persistence could create a vibrant idea trading zone, while at the same time allowing a robust evaluation component to track how often data in one field is viewed, cited or incorporated into the work of another. While the barriers to interdisciplinary science are considerable, so too are the potential rewards.

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