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Trajectories

What we do not know: Using information murals to portray scientific ignorance

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1. The problem

Increasingly, complex socio-technical public policy issues involve scientific uncertainty and even complete ignorance of phenomena. The lack of crisp description of uncertainties often leads to lack of trust by the general public, which in turn impedes solving serious public policy issues. One-sided ideas of ‘sound science’ that do not carefully describe uncertainties and degrees of unknowns also confuse public discussion. They all increase the need for ways to understand and display what we do not know as well as what we do know.

Future studies are by definition about the unknown. We try to understand key features about possible futures with a variety of techniques from simulation to scenarios, forecasts to conjectures. Many of these methods attempt to say what might happen, but *not* how we will get to know what is unknown. Rarely are we content to simply say what we do not know. Rarely do we specify the paths to knowing more about unknowns. However, the approach to stating what we do not know is beginning to be explored through the creation of visual information murals.

2. Origin of visual unknowns murals

These issues came to my attention most directly as I was working on a pilot project on genetically modified crops (GMC). A number of the key discussions about GMC were focused on the precautionary principle that is explicit about what should be done in public policy when there is ‘lack of scientific certainty’. It is stated in one version: ‘Where there

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46 are threats of serious or irreversible damage, lack of full scientific certainty should not be
47 used as a reason for postponing measures to prevent environmental degradation'. United
48 Nations Economic Conference for Europe, 1990

49 There have been many debates about the applicability of the principle and there is
50 difficulty of interpreting it in specific cases [3,5]. But overall there has been a continuous
51 movement toward incorporating it into increasing numbers of treaties, laws, and
52 regulations, especially in Europe.

53 If there is lack of scientific certainty, this means that there are identifiable areas of lack
54 of knowledge—there are things that science does not know. I asked myself: If scientific
55 unknowns figure strongly in the application of the precautionary principles, exactly what is
56 it that we do not know in a particular domain? And then, from the design and
57 communication standpoint, I wondered: 'How would we *represent* these unknowns in a
58 attractive, useful, inviting, and organized way?' This has led to the development of a new
59 class of diagrams or knowledge maps called 'Unknowns Maps'.

61 3. Specification of the unknowns: the sources and method

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63 About the same time, I discovered two publications that enabled creation of the first¹
64 knowledge map of what is unknown. They provide the crucial data as well as important
65 insight and context for the debates about the precautionary principle.

66 One of these publications was a National Research Council report that listed a couple of
67 dozen recommendations for future research [4]. A careful reading of these recommen-
68 dations revealed that there were huge gaps in our knowledge of ecology and biology.
69 Indeed, each recommendation stated as 'Further research is needed on (x)' could be
70 restated as 'Not much or nothing is known about (x)'. Later, a survey article in *Science* [6]
71 presented further recommendations for research that were easily translatable into
72 unknowns.

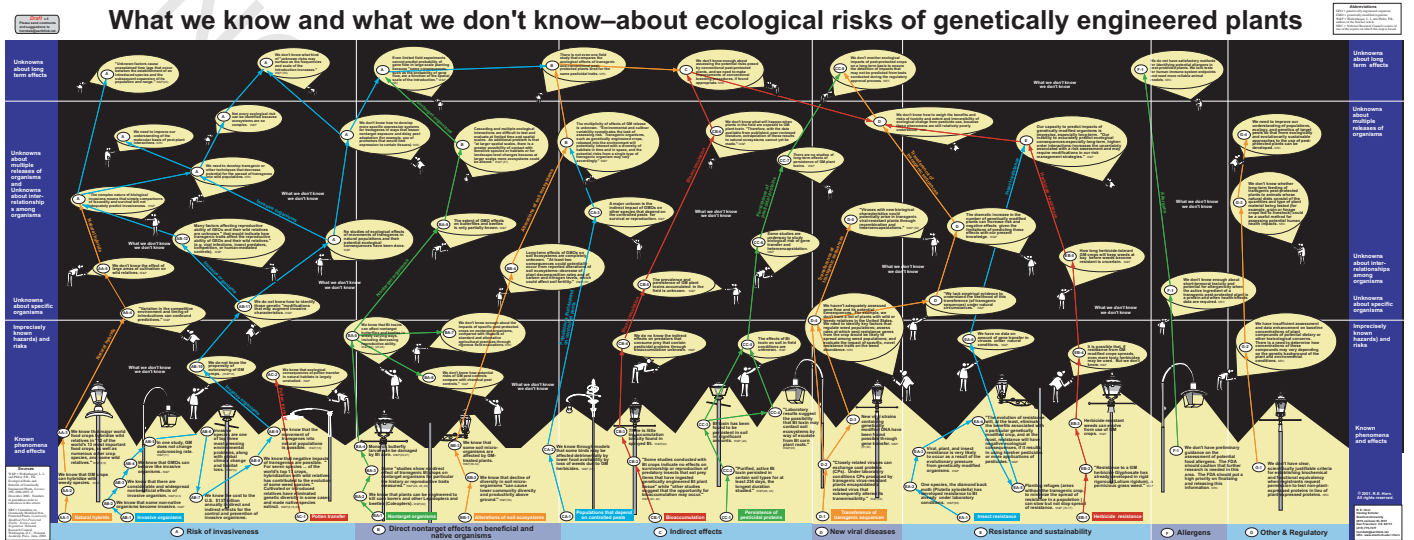
73 The question for me then became 'How can we create a knowledge map that usefully
74 shows the depth and breadth of our ignorance in this area so as to inform the debate about
75 the precautionary principle?'

76 Fig. 1 presents my initial attempt to answer these two questions of what we do not know
77 and how we might display this ignorance for the field of genetically modified crops. It is an
78 'information mural'.

80 4. The metaphor of light and darkness

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82 I have used the idea of an 'information mural', a now widely used method of
83 communicating complex scientific technical and organizational information [2]. The
84 mural uses the metaphor of darkness to convey the idea of our ignorance and the figures of
85 scientists with flashlights (torches) shining on small fragments of text that describe what
86 we do not know. The streetlights at the bottom illuminate what science does know.

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89 ¹ Prof. Michael Twyman, historian of information design, says that he knows of no earlier diagram showing
90 what is not known.



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Fig. 1. What we know—and what we do not know—about ecological risks of genetically engineered plants. To download a readable file of this mural, <http://www.stanford.edu/~rhorn/a/policy/ucUnknwnsInGMFoodv7.pdf>.

5. Structure of the information mural: vertical axis

The overall structure of the mural is tabular. Along the vertical axis is a continuum running from well-established knowledge to the most difficult aspects of what remains to be understood. That continuum (top to bottom) reads as follows:

- Unknowns about long term effects
- Unknowns about multiple releases of organisms
- Unknowns about inter-relationships among organisms
- Unknowns about specific organisms
- Imprecisely known hazards) and risks
- Known phenomena and effects

6. Structure of the information mural: horizontal axis

The horizontal axis is comprised of a small taxonomy of kinds of effects, diseases, risks, etc., that various branches of environmental and biological sciences investigate. It provides a comfortable framework for most lay and professional readers to cluster the unknowns and anchors the paths through the mural. The horizontal axis (left to right) is:

- Risk of invasiveness
 - Natural hybrids
 - Invasive organisms
 - Pollen transfer
- Direct non-target effects on beneficial and native organisms
- Non-target organisms
 - Alterations of soil ecosystems
- Indirect effects
 - Populations that depend on controlled pests
 - Bioaccumulation
 - Persistence of pesticidal proteins
- New viral diseases
 - Transference of transgenic sequences
- Resistance and sustainability
 - Insect resistance
 - Herbicide resistance
- Allergens
- Other and Regulatory

7. Structure of the information mural: the paths

Colored paths connect the various illuminated area of what we know we do not know arising from these various pieces describing what is not known. They suggest paths for possible research programs. For example, one path, linearized and not showing all of the connections (running from known to unknown) is:

- We know that the movement of transgenes into natural populations is possible [6] (18).
- We do not know the propensity of outcrossing of GM crops [6] (10).
- We do not know how to identify those genetic ‘modifications that may augment invasive characteristics’ [6].
- ‘The complex nature of biological invasions means that simple comparisons of fecundity and survival will not adequately predict invasiveness’ [6].
- We need to develop transgenic or other techniques that decrease potential for the spread of transgenes into wild populations [4].
- We need to improve our understanding of the molecular basis of pest-plant interactions [4].
- Not every ecological risk can be identified because ecosystems are so complex [6]. ‘Unknown factors cause unexplained time lags that occur between the establishment of an introduced species and the subsequent expansion of its population and range’ [6] (23).
- We do not know what kind of ‘unknown risks may surface as the frequencies and scale of the introduction increases’ [6] (55).

The remainder of the blackness represents what we do not know we do not know.

8. Uses of the mural

Some have suggested that the murals should be placed in the lobby to biology and ecology buildings around the world. One biologist told me the mural could be used to inspire students to choose more daring dissertation topics than are frequently chosen [1].

This first mural GM Crops has inspired the creation of other murals as well including one for what is unknown in ocean biology and one that characterizes the challenges to the growing field of visual analytics of which the unknowns map is only one example.²

9. Conclusions

The creation of detailed visual representations of what we do not know can illuminate the debates that revolve around crucial issues. They can provide a context and a depth of understanding when the precautionary principle is being invoked. And they can suggest what is missing in typical use of the idea of ‘sound science’, which in its common usage only focuses on what is known.

² Examples of other information maps and murals may be found on my website: www.stanford.edu/~rhorn.

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