How to fund science effectively and efficiently

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The problem

We want science to make our lives better. Therefore, evaluation of scientific merit should relate to the long-term impact of the research on well-being. However, such impact is difficult to evaluate, even for experts.

Introduction

Grant peer review is the dominant form of public support of science. It relies on scientific expertise to evaluate the merit of proposals written by researchers. The ranking of merit is used to allocate funds.

However, grant peer review is also:

- not reliable: panel composition could alter funding decisions [1],
- very costly: totals 14% of funding body's annual budget [2].

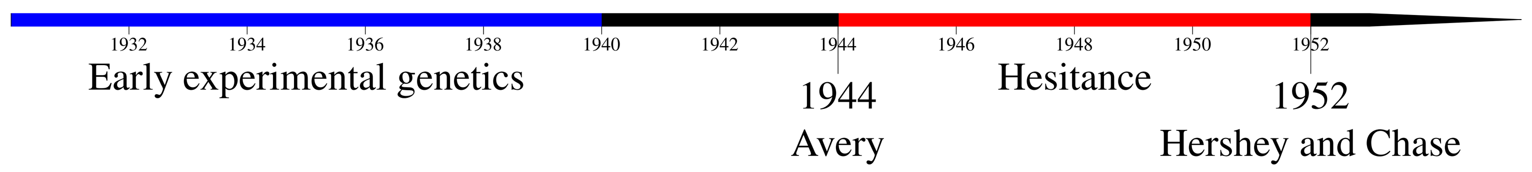
These recent empirical evaluations suggest allocating a certain portion of the research funds to researchers at random, following basic screening, to cut costs in the face of low reliability.

Historical examples of significant unpredictable impact

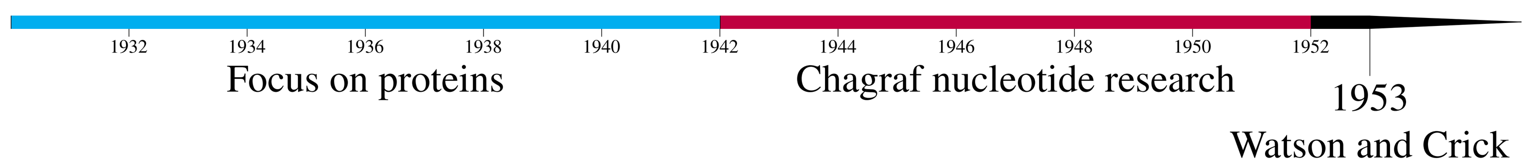
Discovery of DNA structure

Biochemistry focused for many years on the study of proteins, not DNA, to understand heredity. A combination of results from biochemistry and genetics led to renewed interest in DNA and the discovery of its structure [4].

Genetics timeline:

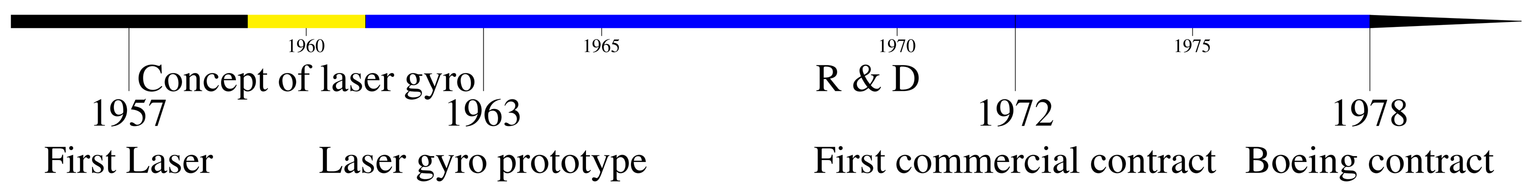


Biochemistry timeline:



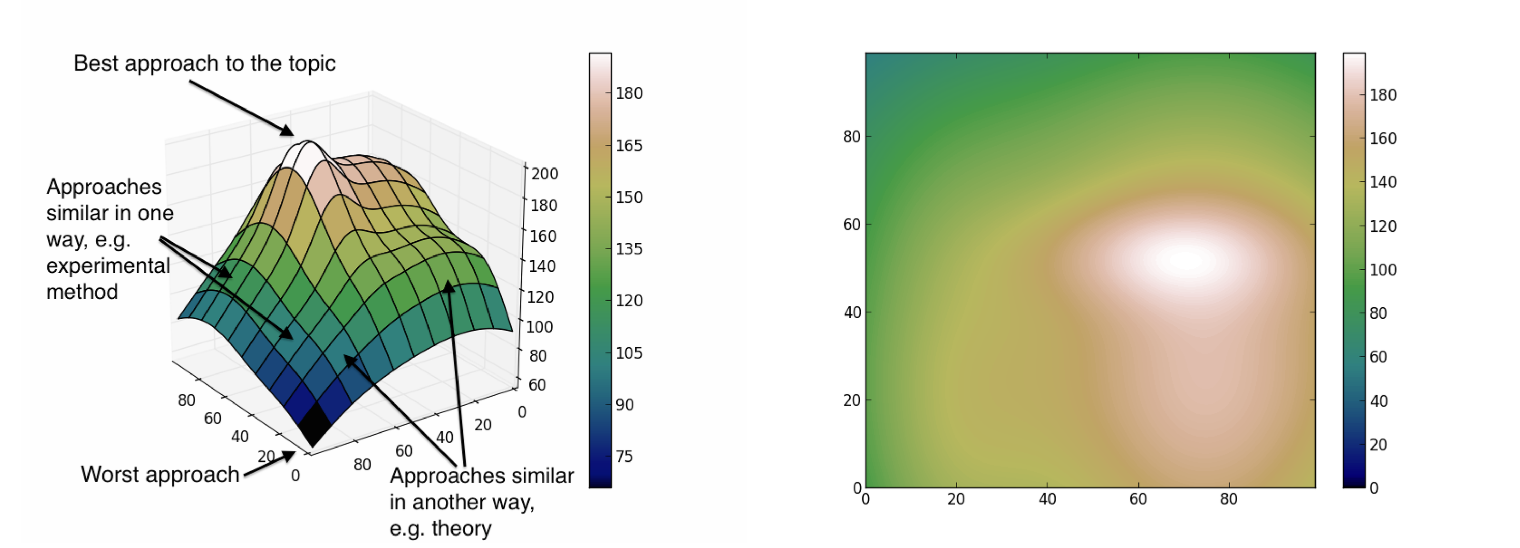
Invention of the laser gyroscope

The laser gyroscope, a key component in modern aircraft and missiles, is based on an effect discovered in 1913. Sagnac was trying to disprove Einstein's theory of relativity and defend the theory of the ether [3].



Simulating science funding

The insight from historical examples has been expanded into a computer model of an *epistemic landscape* (Fig. 1).

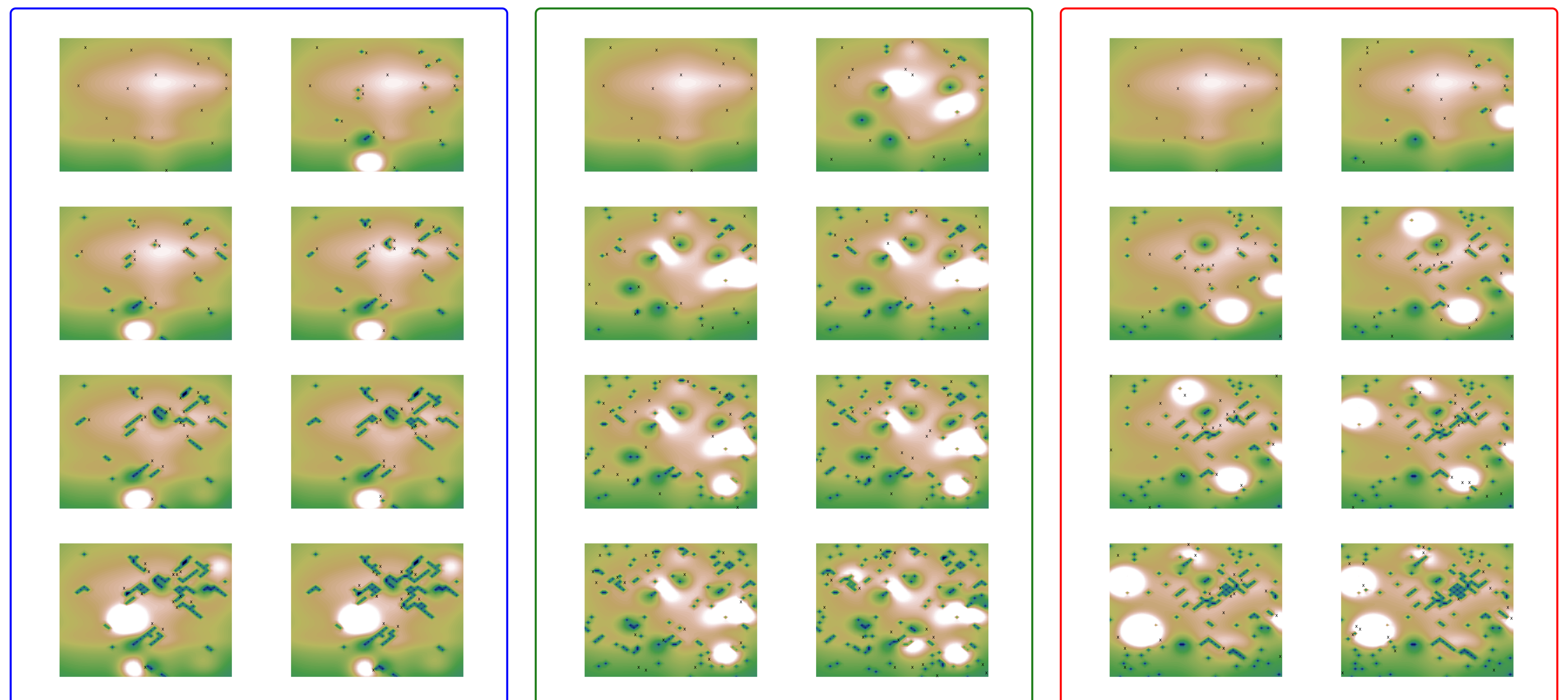


(a) Three-dimensional surface plot. (b) Two-dimensional filled contour plot.

Figure 1: Different representations of the epistemic landscape model. Each (x, y) coordinate represents a single approach to investigating the topic. The associated z coordinate represents the merit of pursuing that particular approach. Distance between approaches represent their similarity: the closer they are, the more similar.

The model simulates three funding mechanisms:

- Best visible: Only approaches similar to historical approaches are considered, and the best are selected (Fig. 2a).
- Lottery: Projects are chosen at random, regardless of their merit or whether they are similar to historical projects (Fig. 2b).
- Triage: A 50%/50% combination of best visible and lottery (Fig. 2c).



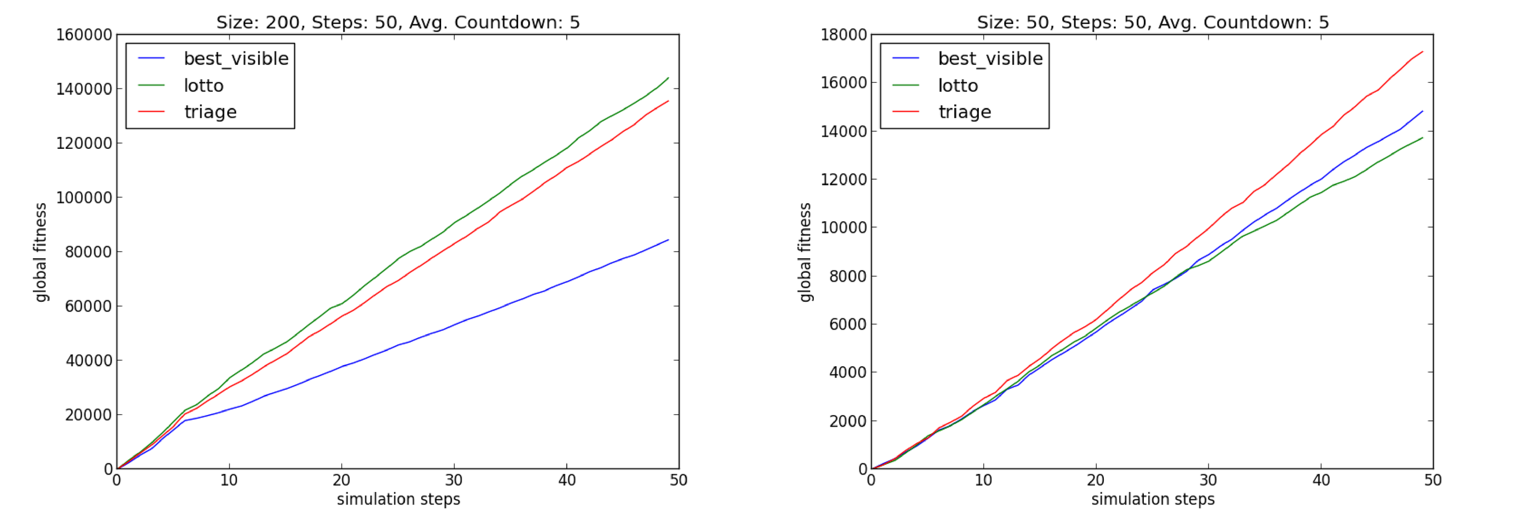
(a) Funding by grant peer review (b) Funding by lottery (c) Funding by triage

Figure 2: Simulations of different funding methods on a dynamic epistemic landscape. Time-series (left to right, top to bottom) show snapshots of the landscape at intervals of 5 simulation steps. Each contour plot shows an epistemic landscape, with colours representing the merit of all available approaches at the time of the snapshot, using the colour bar shown in Fig. 1b. Note how the landscape itself changes as a response to the investigations, reflecting the features of the historical examples.

Results

Changes in merit indeed make merit-based evaluations less effective, relative to random allocation. However, the effect is not identical in all cases:

- Lotteries have a greater advantage in very complex or largely unexplored areas, or where many different fields interact via interdisciplinary links (Fig. 3a),
- Expertise proves more useful in small, highly specialised, or well-explored fields (Fig. 3b).



(a) Large landscape. (b) Small landscape.

Figure 3: Comparison of performance for different funding mechanisms over time on a dynamic epistemic landscape. The funding mechanisms, best visible, lottery, and triage, are described in the text. Plot shows accumulated fitness, or merit (y-axis), as a function of time (x-axis). Merit is the same as the z-axis in Figs. 1 and 2. Time is measured in simulation steps, corresponding to the snapshots in Fig. 2.

Policy implications

The relative advantage of the *triage* mechanism on both small and large landscapes suggests a happy medium. This mechanism combines elements from both peer review and random selection. Implementations of funding by triage will:

- include a formal randomisation element, to select amongst proposals whose merit evaluation is difficult or inconclusive,
- require less information and debate for each proposal, because exact merit scores no longer matter.

The solution

A funding mechanism that combines merit assessment and random allocation would reduce the overall cost of the funding exercise, while maintaining overall high effectiveness for scientific research.

References

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Acknowledgements

I would like to thank my supervisor, Prof. Tim Lewens, and my advisor, Dr. Stephen John, for sustained encouragement and guidance, and Trinity College, Cambridge, for financial support and a superb academic environment.