

Strengthening the 3 Weaker Legs of Science by Supporting Free Choice of Scientific Roles

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Science could be more efficient at

avoiding negative results (recorded by Producers and Explorers), using reproduced experiments in meta-analyses (by Integrators), without re-inventing wheels (free advice from Guardian mentors), drawing connections between fields (by Integrators, Guardians), reducing curriculum load (websites and advice from Guardians), keeping the knowledge of the past (as Guardians maintain it), reducing grant application efforts (ask Guardians for opinion), improving grant review quality (include Guardian reviewer), improving reproducibility (Integrators, Debuggers, Tools), helping to debug analysis pipelines in labs (Debuggers), making it *easy* to know what is known or unknown in detail (asking Guardians, Debuggers, Integrators), inspiring diversity of talents in future scientists, winning back the trust of a confused public by making it *much easier* to check what's right (Engagers, Guardians, Debuggers,...), and making science more transparent for everybody: the public & scientists.

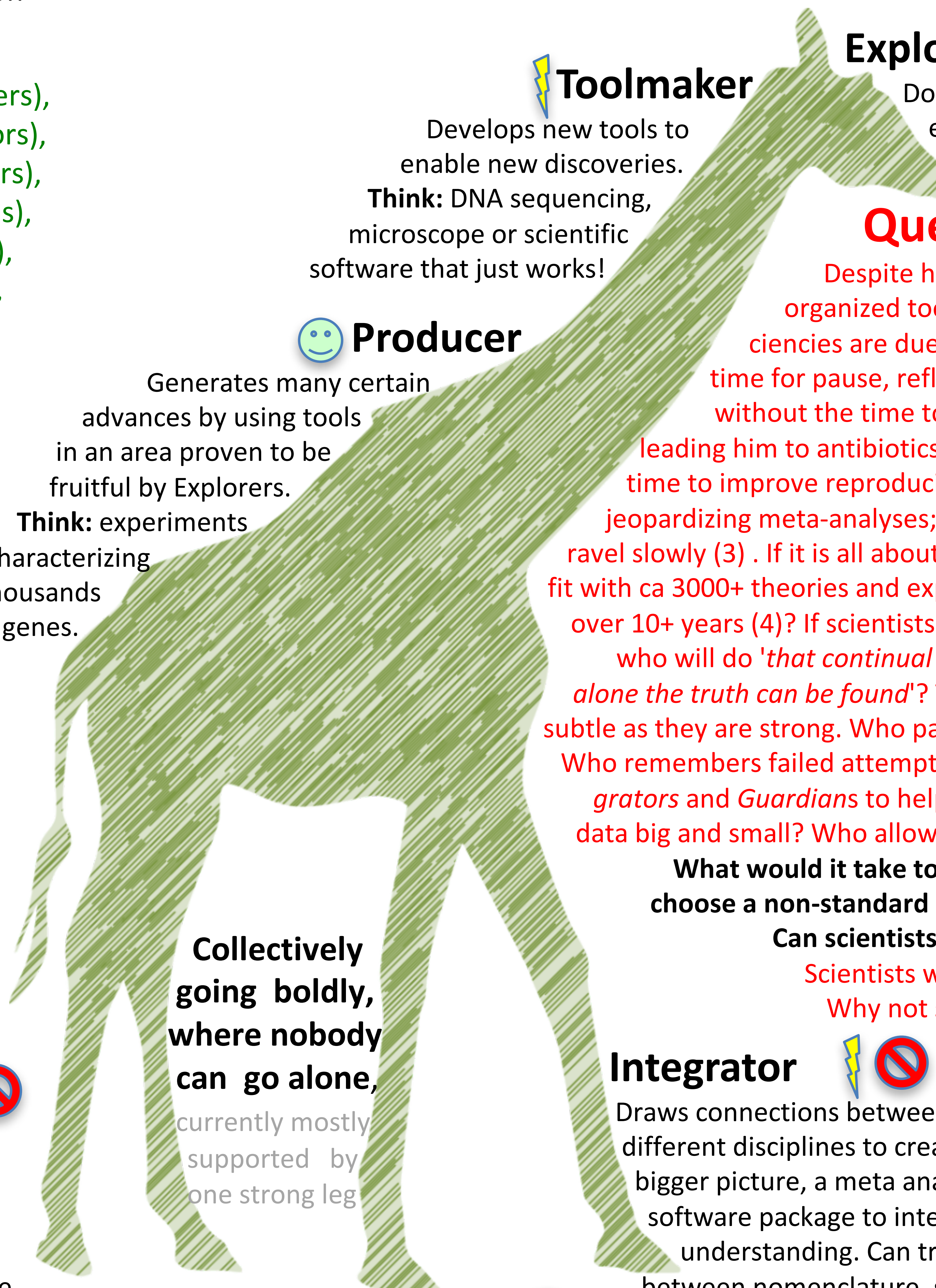
Returns on investments

across the system could be huge, but only if all changes are introduced carefully, if supported by the innovative, reliable, FAIR data sharing solutions necessary, if financed by neutral players, and used for ranking grants.

Guards areas, old-school or new, curates all related public knowledge from past to present.

Training Guardians takes decades: they need to walk in the shoes of all other scientific roles. A group of designated qualified Guardians keeping their area alive facilitates efficiently answering questions in that area and reduce rediscovery – without overloading curricula. Guardians collaboratively curate scientific expertise, learned to put the common good first, follow high ethical standards, usually serve for life, often with little time for other roles. They act as mentors for other scientists, improve research proposals, find gaps, open problems, remember results, redirect questions, and peer-review research. **Think:** Like Scholarpedia, but with links to versioned information resources, storing high-quality data curated by Debuggers and Integrators. Guardians are world-class leading scientists, so passionate that they continue to document expertise, gaps, cross-links when retired, like James F. Crow, Donald E. Knuth.

Guardian



Toolmaker

Develops new tools to enable new discoveries. **Think:** DNA sequencing, microscope or scientific software that just works!

Explorer

Does what some think is impossible by exploring entirely unknown realms. **Think:** genetic code.

Questions about efficiency?

Despite huge successes, many experts think science is organized too inefficiently (1). Paradoxically, many inefficiencies are due to attempts to increase efficiency, reducing time for pause, reflection, quality & reliability. Imagine Fleming without the time to check the odd 'contamination' *accidentally* leading him to antibiotics? Many 'rush for rewarding results', without time to improve reproducibility (2) or to document negative findings – jeopardizing meta-analyses; the statistical implications are huge and unravel slowly (3). If it is all about 'low-hanging fruit', where does Tom Edison fit with ca 3000+ theories and experiments trying to build a lightbulb ($P < 10^{-3}$) over 10+ years (4)? If scientists have to compete in an 'attention economy', who will do 'that continual and fearless sifting and winnowing by which alone the truth can be found'? The undercurrents favoring Producers are as subtle as they are strong. Who pays for the 3000 lightbulbs that do not work? Who remembers failed attempts to help reduce repeats? Who enables Integrators and Guardians to help others to efficiently navigate mountains of data big and small? Who allows Debuggers to find errors in data pipelines?

What would it take to better support Principal Investigators who choose a non-standard Scientific Role to serve the Common Good?

Can scientists produce a more efficient division of labor?

Scientists work in many roles. Always have. Always will. Why not support more diverse scientific roles better?

Collectively going boldly, where nobody can go alone,

currently mostly supported by one strong leg

Producer

Generates many certain advances by using tools in an area proven to be fruitful by Explorers. **Think:** experiments characterizing thousands of genes.

Teacher

Introduces to a new area, method, source of expertise. Keeps an introduction, course, teaching website, text book, MOOC updated. **Think:** Lehninger Biochemistry.

Debugger

Questions. Tests details of results from new angles to help see blind spots, that else remain undetected at high productivity **Think:** cancer drug effect reproducibility.

Integrator

Draws connections between different disciplines to create a bigger picture, a meta analysis, a software package to integrate our understanding. Can translate well between nomenclature, semantics and disciplinary jargon to connect the dots. Often uses math, code, or databases for integration. **Think:** Neo-Darwinian Synthesis.

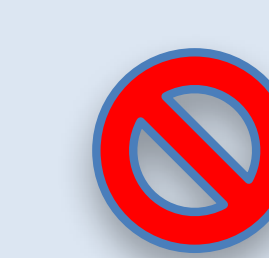
Current career risk of overly emphasizing one scientific role



Low Risk



High Risk



Career Danger

Role is hard to teach, learn, or fund; it may compromise careers

Exemplary References
 (1) Alberts et al. 2014, *PNAS* 111:5773-5777.
 (2) Reproducibility@XSEDE <http://arxiv.org/abs/1412.5557>
 (3) Leek & Peng 2015 "P values are just the tip of the iceberg". *Nature* 520:612. (4) see <http://edison.rutgers.edu/newsletter9.html>

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