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ORIGINAL PAPER

Gordon Tullock's ill-fated appendix: "Flatland Revisited"

David M. Levy[1] · **Sandra J. Peart**[2]

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Abstract In an unpublished appendix to his *Organization of Inquiry* ("Flatland Revisited") Gordon Tullock develops and extends ideas from both Ludwig von Mises and Karl Popper. We first discuss these commonalities and extensions, which center on the notions of necessary truth and reciprocity. Then we recover the manuscript history as well as comments from James Buchanan and provide an answer to the question of why the manuscript was never published.

Keywords Gordon Tullock · Ludwig von Mises · Karl Popper · Flatland

JEL Classification B31 · B41 · Y92

1 Introduction

Tullock (2002) once began an essay on the theory of public choice with a section "People are people." Although published in the volume, *Government Failure*, the radical message of Tullock's aphorism is that there really is no such thing as government to fail. There are only people in government and people are people. We ask where this doctrine—that for analytical purposes people can be treated as equals—so central to his constitutional approach, comes into Tullock's thinking about economic inquiry. In light of the conventional treatment of the Virginia

✉ David M. Levy
davidmlevy@gmail.com

[1] Center for Study of Public Choice, George Mason University, Fairfax, VA, USA

[2] Jepson School of Leadership Studies, University of Richmond, Richmond, VA, USA

School as a Chicago School spinoff, it is important to establish that Tullock's analytical egalitarianism originates in a different source. The test case for him is the motivation of scientists and economists and that in turn points to the centrality of his *Organization of Inquiry*.

One significant difference between Tullock and Buchanan is whether economists themselves are subject to the same motivation as everyone else. For both Frank Knight and Buchanan it was important that economists are public spirited so they can be modeled as truth-seekers (Levy and Peart 2017). Tullock's (1966) contrasting views on the motivation of economists are expressed with complete clarity in his *Organization of Inquiry*. We have previously noticed the oddity that readers of *Organization of Inquiry* failed to notice his denial that economics is a science—he calls it a "racket" instead. Economics, lacking the critical institution of replication in Tullock's account allows economists to trade public results for private material income (Levy and Peart 2012).

If not Chicago where? We argue in this paper that Tullock's (1971c) originality in "Flatland Revisited" is to be found in his separation of purposive behavior from consciousness. The same separation of consciousness from purpose occurs in his constitutional thinking when he supposes people have a *common* purpose. They may think their purpose is more noble than the purpose of others but that is not how Tullock encourages us to bet. The supposition of common purpose underlies Tullock's statement that "people are people" and gives structure to the search for what that purpose is.

In what follows we focus on the unpublished appendix to his *Organization of Inquiry*. Here, in addition to separating purpose from consciousness of purpose, Tullock takes a radical step by allowing the necessary truth to be only in our mind, not in the world. So, unlike traditional accounts, we cannot simply infer truth from necessary truth. But even so, when a necessary truth is false, if the critical scientific institution of replication is effective, Tullock suggests we approach the truth even with our false axioms. This unpublished essay helps explain Tullock's practice as editor *of Public Choice* when he published papers in hope of stimulating discussion.

2 Flatland Revisited

"Flatland Revisited" was proposed as an appendix to *Organization of Inquiry* but it was rejected by the editor at Duke University Press. We discuss the correspondence and the manuscript history in the appendix. The manuscript is a seemingly simple addendum to Edwin Abbott's famous *Flatland* in which Tullock supposes that Flatland is not really flat but the minds of its inhabitants have evolved so that all their perceptions are filtered through the supposition that the world is flat. A crisis occurs when one of the scientists in Flatland compares the implication of their axioms with that which can be measured. As the axioms hold when flat but the world is not flat, there is, not surprisingly, a mismatch. The scientists struggle to find theoretical accounts that predict what they measure without ever challenging the flatness axioms. They behave in a completely transparent fashion where all claims can be and are replicated. Replication is the central scientific institution both in

Flatland" and throughout the *Organization of Inquiry*.[1] In Flatland, replication allows the scientists to create ever more powerful systems in which flatness holds only in a piecewise fashion. Tullock is optimistic that the theories will continue to improve even when our minds are disposed to see things in another way.

One might be tempted to read "Flatland Revisited" through the framework of Kuhn's (1962) *Structure of Scientific Revolution* except that Tullock tells us that Kuhn's book did not influence him.[2] We restrict out interpretation to those authors Tullock said influenced him, specifically Popper and von Mises.[3]

Admirers of Tullock's published work know that his simple presentations often cloaked very deep issues. Tullock asks in his "Flatland Revisited" what follows from a necessary truth. He imagined a world in which what is necessarily true—a flatness axiom—is nonetheless false. This is clear to his readers but not to the Flatlanders, because Tullock's readers can view the Flatlander's world and the Flatlander's minds from the outside. Apodictic certainty, the term von Mises (1949) uses to describe a necessary truth (Kirzner 2001, pp. 81–88) is certainty about only deductions, not about the world. In Tullock's "Flatland"—which he is at pains to distinguish from Abbott's—the flatness axiom emerges from something akin to von Mises's monologism. There is only one logic in Tullock's Flatland because that is how everyone's mind evolved.

How might a necessary truth not be true? The traditional approach to modal logic takes necessary (*alternatively* possible, strict implication) as primitive, and then defines all other terms by means of the selected primitive. To mark that a proposition (*alternatively* a sentence) α is necessarily true, we write $\Box\alpha$. From

[1] Feigenbaum and Levy (1993) make clear their debts to Tullock for long discussions about the problem of replication in economics.

[2] Tullock ([1966] 2005, p. xix]. Tullock tells us that he'd never met Michael Polanyi. Polanyi gave a lecture series for the Thomas Jefferson Center in November 1961 but there is correspondence in which Tullock writes about the manuscript he gave Polanyi. Tullock's well-known problem with memory may have started very early. We thank John Nye.

[3] Where does Organization fit in the Tullock opus? We know from Jeremy Shearmur's reconstruction of Karl Popper's lecture series at Emory University (25 June–6 July 1956), which Tullock attended, that the Tullock–Popper connection is much earlier than Tullock's association with the economists of the Thomas Jefferson Center. In a letter to Popper and Joseph Agassi of July 9, 1958, Tullock writes about his upcoming fellowship at the University of Virginia where he planned to work on a book entitled Organization of Inquiry: "I have been giving some thought to coming over to London. My program would call for writing a book essentially based on the Logic [of Scientific Discovery?] I think maybe I have discovered a third system of Positional Logic the subject matter of which may be indicated by my provisional title: The Organization of Inquiry. The problems are two, in the first place I am not certain my theory of right, and secondly, it may be too trivial to bother with. The positional logic of Inside Bureaucracy is much less elaborate than that of economics, and my latest theory is even less so. At any event, I would like to get the Logic as soon as possible, and after further thought in Virginia I might be able to decide definitely." The predatory aspects we discuss in Levy and Peart (2012), the analysis of tariffs and the unlocated reference in Hobbes, were initially in a third appendix—"On the Backwardness of the Social Sciences." (Tullock Papers, Box 91). The initial reader's report to Duke University Press, suggested making it into a chapter (16 April 1963). Tullock Papers, Box 108 Correspondence Folder. Copyright Stanford University.

antiquity through the 1940 s it seems to have been taken for granted that $\Box\alpha \rightarrow \alpha$.[4] What is necessarily true is true (or actual). Kurt Gödel, however, proposed to think about the necessary in terms of the demonstrated, a point we capture using the assertion mark $\vdash$ for demonstrated; thus, $\vdash\alpha \rightarrow \Box\alpha$ (Gödel [1933] 1986). This ratifies the intuition in von Mises that what is necessary is that which is demonstrated. While Gödel's immediate purposes were limited, his technical step helped clarify that $\vdash\alpha \rightarrow \Box\alpha$ and $\Box\alpha \rightarrow \alpha$ are independent issues.[5] In the years that followed it was made clear that there are systems in which the necessary only entails the possible, not the actual; thus: $\Box\alpha \rightarrow \Diamond\alpha$.[6]

Karl Popper Karl Popper, with whom Tullock was quite close, enters into the picture because of the concern over propositions that could not be falsified.[7] Falsification is of course Popper's distinction between the scientific and the metaphysical ([1959] 1974, pp. 34–35.) Long before Popper's *Logic of Scientific Discovery,* Pierre Duhem made the case that there are no critical experiments in physics; one can always find (to use Popper's terminology) an "ad hoc" premise on which to blame the failure (Popper [1959] 1974, p. 81). Scientists preserve what is important to them and they discard what is not important. When he wrote *Logic of Scientific Discovery,* Popper was optimistic, at least in some passages, that Duhem's claim could be avoided by the falsification approach.[8] By the time he wrote the *Postscript,* Popper's confidence was replaced by an almost holistic Quinean focus on context in which elimination of the reasons for the falsification is seen as a major undertaking. In the *Postscript* Popper (1983, pp. 189–93) introduced the term

[4] The traditional view is discussed in Lemmon ([1966] 1977, pp. 1–11). All of the systems Lewis proposed allow this inference. Prior ([1955], 1962, p. 311) gives the axioms for the original Lewis systems and (pp. 312–13) for Lemmon's Gödelized reaxiomatization. In Lewis's axiomization taking "strict implication" as primitive, the actual strictly implies the possible; the Gödelized version has the necessary implying the actual.

[5] von Wright describes his contribution: "… the conception of modal logic as a superstructure, or 'second story', to be erected—like quantification theory—on the basis of the logic of propositions … (I later learnt that the idea was not entirely novel. It can be traced back to a short paper by Gödel from the early 1930s and to a paper by Feys from 1937)." Von Wright (1989, p. 29).

[6] Lemmon ([1966] 1977, p. 50) credits the weakening from $\Box\alpha \rightarrow \alpha$ to $\Box\alpha \rightarrow \Diamond\alpha$ to von Wright's deontic logic in which "necessary" is taken as "obligatory." In this context it is implausible to suppose that the actual follows from the obligatory (von Wright 1951, p. 41). In Robert Feys' comprehensive account, "System 1" [Lewis S1] is constructed from a modal grammar developed in "System 1^0 "plus the axiom that the actual strictly implies the possible (Feys 1965, p. 64). Tullock's contribution might be seen as proposing a non-normative interpretation as an alternative to von Wright's.

[7] Boettke and Leeson (2006, p. xv) oppose von Mises's and Popper's views. Popper's attitude toward purposive behavior seems not to differ from that of von Mises or Tullock, much to the alarm of some admirers (Levy and Peart 2012).

[8] Popper ([1959] 1974, p. 78): "Duhem denies (Engl. Transl. p. 188) the possibility of crucial experiments, because he thinks of them as verifications, while I assert the possibility of crucial falsifying experiments." In the Postscript Popper (1983, p. 178) offers an holistic approach in which theoretic systems are tested as wholes. It is unclear that there is any difference between a later Popperian approach and that of Quine (1960). In his letter to Popper and Agassiz of July 9, 1958, Tullock acknowledges receipt of reprints of Popper articles. He writes that he has seen the one on Duhem. Taking Duhem seriously, then we can explain Tullock's giving more emphasis on replication and less on testing than is common. Replication for Tullock is testing without the desire to find one's own model true. Congleton helped us here.

"metaphysical programmes for science" to describe the possibilities of theoretical systems that contain nonfalsifiable elements. The Flatlander's flatness axiom is, in Popper's terminology, metaphysical since it cannot be falsified. But that does not imply that the system is not progressive.

In Tullock's telling, the crisis in Flatland reveals a Duhem moment; one result upon which all the revisions agree, a result that allows the flatness axiom to be maintained:

> Making careful measurements of various figures on the surface which is thought to be flat, and then trying to develop theories fitting these measurements is a major scientific activity. Probably the most important and certainly the only generally applicable of these theories is the theory which "proves" the existence of inherent limitations on the accuracy of measuring instruments. Needless to say, this is a great help in fitting other theories to the measured data.

Tullock describes a process by which scientific progress is real:

> As far as accuracy goes, some few of the Flatlanders' theories use equations which are exactly those we would use ourselves, although they have derived them differently. In a few more cases, they use equations which lead to the same results as ours but which are more complex. In most cases, however, the theories developed by the Flatlander scientists are mere approximations of reality and many of them are not even close approximations.

He then reports that the Flatlanders are hard at work improving their approximations. While the outside observer may be skeptical, this is not the attitude of the Flatlanders:

> the scientists of Flatland have so far shown undoubted ingenuity in applying their incorrect theories to reality and the possibility that they will eventually solve their problems cannot be disregarded. If they do find their "general surveying theory," it will be an interesting example of a theory which is completely incorrect, yet which explains all of the observed data in terms of its own, improper, assumptions.

3 Tullock's starting point

We report a conversation with Tullock that was prompted by his off-hand remark that von Mises's *Human Action* greatly influenced his work. We were puzzled, so we asked if we had understood correctly:[9]

> Yes. In the first place, let's begin with the fact that at the time I had one course in economics, which lasted 12 weeks, it was supposed to last 13 weeks but I

[9] Alex Tabarrok and Peter Boettke tell us they had similar conversations. Ours (August 31, 2006) was prompted by a conversation earlier that summer between Tullock and James Buchanan about the *Calculus of Consent* at a session of the Summer Institute for the Preservation of the History of Economics.

> was drafted, and that had got me to reading economics journals. I saw at the Yale Co-Op, when I was studying Chinese at Yale, I saw a pile of books bound in red that said *Human Action* and I picked one up. The thing which made a big impact on me was the early part where he talked about that you can use the same kind attack on things other than economics. I'd never heard anyone say that before. I read the book actually three times and during that time I came to the conclusion that I was going to write a book about bureaucracy on the same kind of self-interested motives on the part of the participants as economics. *He did not maintain that it also led to good results even though it did in economics.* [our emphasis]

Save for the last sentence and some autobiographical detail, Tullock's published tribute to von Mises says much the same thing.[10]

We start where Tullock tells us he started. After the introduction to *Human Action,* von Mises introduces what he means by "purposeful behavior":

> Human action is purposeful behavior. Or we may say: Action is will put into operation and transformed into an agency, is aiming at ends and goals, is the ego's meaningful response to stimuli and to the conditions of its environment, is a person's conscious adjustment to the state of the universe that determines his life (von Mises 1949, p. 11).

Appeal to the "will" is central to von Mises's adoption of the reciprocity principle expressed by Kant's categorical imperative. He makes this completely clear in *Liberalism*.[11]

Von Mises lifelong defense of the claim that the theorems of praxeology are matters of apodictic certainty is what students of economic methodology find unique to his labors. "Praxeology" is the name given to the study of the connection between ends and means, so that in and of itself ought not to be a matter of controversy (Gasparski 1996). Apodictic is a transliteration of the Greek word for "demonstrated," so, when von Mises uses the phrase "apodictic certainty," he claims that there is no doubt about praxeological theorems because they are demonstrated from axioms that cannot be denied (von Mises 1949, p. 5). To use traditional terms, for von Mises praxeological theorems are necessary truths.[12] This claim separates von Mises and his disciples into a school at odds with the vast

[10] Tullock 1971a, 2:375: "(It may seem odd to place an article originally designed for publication in a biological journal in a collection of articles to Ludwig von Mises. Among his other distinctions, Professor von Mises was among the first to point out that economics can be expanded to deal with many areas outside of its traditional scope. In my own case, my work in expanding economics into new areas was, in a real sense, begun by my reading of *Human Action*. The article below, then, represents my most extreme application of economics outside its pre-von Mises boundaries)".

[11] Von Mises ([1927] 1966, p. 176): "For the few who apply higher standards to the activities of political parties, who demand that even in political action the categorical imperative be followed ('Act only on that principle which you can will at the same time to be a universal law, i.e., so that no contradiction results from the attempt to conceive of your action as a law to be universally complied with'), the ideology of the parties of special interests certainly has nothing to offer." Emphasis added.

[12] When Scott Scheall's research is published we will know much more about the discussions concerning logic between von Mises and the formidable mathematician Karl Menger.

majority of the economics community. To give one instance, Milton Friedman (1991) took issue with von Mises over this claim.

3.1 Purposive predation

Tullock's (1959) sequence of accounts of purposive predation, whether it be the majoritarian exploitation of the democratic commons, or what would be called rent seeking (Tullock 1967), are so well known that we need not elaborate. His account of expressive voting, a concept that explains what he called "charity of the uncharitable," is another example of the exploitation of the democratic commons. Here, discussion itself is severed from consequence (Tullock 1971b). This challenges the view that democracy is government by discussion (Peart and Levy 2008, 2015; Levy and Peart 2017).

The 1966 *Organization of Inquiry* contains an example of such predation that is less well-known. In this work, Tullock analyzes purposive behavior by economists that preys on other occupants of a commons. His target is economists who function as so-called scientists participating in a "racket," rather than science, and who generate results to support their private ends (Tullock [1966] 2005; Levy and Peart 2012).

Why did Tullock depart from von Mises on whether purposive behavior led to "good results?" Von Mises starts by taking purposive behavior as a matter of consciousness and will. In *Liberalism* as we have noted, von Mises uses a Kantian step to universalize will and obtain a reciprocity principle. For Tullock, purposive behavior may not be a matter of consciousness and will. In his view, what is purposive is common to us all but we might not be aware of that commonality. More than this, there is no way to universalize will-less purpose. In practice, Tullock seems remarkably close to Walter Eucken's worries about power that enables the state to prey upon citizens.

Von Mises takes purposive behavior of as matter apodictic certainty and supposes that this necessary truth entails truth. In "Flatland Revisited" Tullock holds that apodictic certainly is only about our minds; not about the world.

Is there a relation between these two aspects of Tullock's system?[13] In the first case, Tullock simply dropped reciprocity when dealing with empirical economics; in the second, he dropped the assumption that what our minds conceive of as "necessary" binds the empirical world. What remains is the hope that if we work hard enough we can find the *common* purpose behind individuals' action in the empirical world. "Flatland Revisited" sketched how that might be possible.

4 Conclusion

Tullock's view of government is wonderfully caught by the phrase "There is no 'government'; only people in government." The argument of *Organization of Inquiry* could be characterized as "There is no 'science'; only people in science."

[13] Daniel Nientiedt first asked this question.

And people are people. Tullock's originality lies in his insistence in *Organization of Inquiry* that science may become "racket" or that even with uncorrupted people, as in Flatland, the truth may not emerge in finite time.

What is remarkable about the scientific practice in "Flatland Revisited" is that progress is the result of a rapid Popperian falsification of almost everything other than the flatness axiom. This may go some distance towards explaining Tullock's choices as editor of *Public Choice:* articles he published, judging they would be important *if* they were correct. Judgments about correctness would result from the ensuing discussion. Tideman witnessed one remarkable episode that led to Tideman and Tullock (1976):

> In 1970 Edward Clarke, then a graduate student at the University of Chicago, submitted a manuscript titled, "Introduction to Theory for Optimal Goods Pricing" to *Public Choice* which Gordon Tullock edited. The manuscript claimed to have a solution to the problem of motivating people to report their preferences for public goods honestly. Tullock could not understand Clarke's argument, he later told me, but he decided that if Clarke was right the paper was important, so he would publish it. As editor of *Public Choice*, Tullock was free to make editorial decisions as he chose. The paper appeared Volume 11 (September 1971) of Public Choice under a title that had become "Multipart Pricing of Public Goods." (Tideman 2015).

Tullock's Flatlanders are devoid of self-seeking. They are von Mises's liberals in search of the greatest happiness via truth seeking. Perhaps had Tullock published "Flatland Revisited" we would have been able to more fully appreciate Tullock's originality in the analysis of scientific inquiry.

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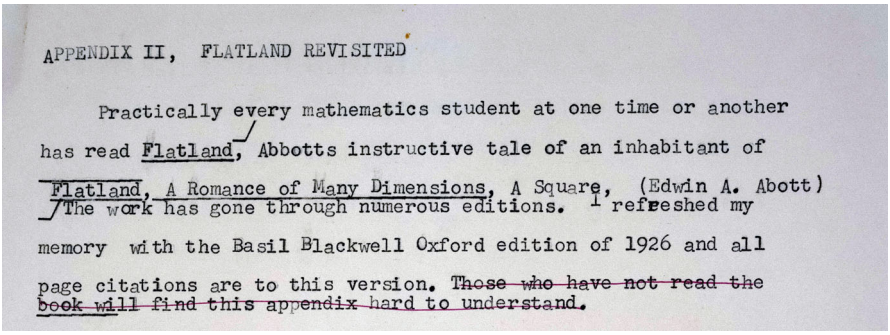
Appendix: The manuscript and James Buchanan's comments

Correspondence between Tullock and Duke University Press demonstrates that "Flatland Revisited" was excluded by editorial decision because it would have been too demanding on the reader. The letter from Duke University Press's editor (Ashbel Brice) on 13 August 1965 writes about the decision: "I think the


APPENDIX II, FLATLAND REVISITED

Practically every mathematics student at one time or another has read Flatland, Abbotts instructive tale of an inhabitant of Flatland, A Romance of Many Dimensions, A Square, (Edwin A. Abott) The work has gone through numerous editions. I refreshed my memory with the Basil Blackwell Oxford edition of 1926 and all page citations are to this version. ~~Those who have not read the book will find this appendix hard to understand.~~

Fig. 1 State one of "Flatland Revisited"

explanation of why "Flatland Revisited" loses me is to be found in your opening sentence: 'Practically every mathematics student…' That eliminates me. In looking for our reader's advice that these be eliminated, I noted that our critic admonished you not to overestimate the information of your readers." The photograph of the opening footnote (Fig. 1) has a struck out sentence predicting the fate of the appendix.

The decision not to ask Hayek for the preface that he offered, something Tullock noted in the letter submitting the manuscript to Duke (Tullock 3 January 1963) seems to have been made because of the predicted controversy (Brice to Tullock 23 March 1965). One ought to note that Tullock was enormously pleased by "extraordinarily handsome book" which the Press created (Tullock to John Langley) on 15 December 1966. All of these letters are in the Tullock Papers, Box 108, Correspondence Folder in the Tullock Papers.

We can identify four states of the manuscript of "Flatland Revised" in the Tullock papers. First, there is a hand-corrected typescript with a color pen which surely was not produced professionally.[14]

This is of interest because it was the manuscript upon which James Buchanan comments. The line struck out in red suggests the problem Tullock would face with Duke's editor.

The second state is a professional typescript. This exists in the original form, the cutting of the paper by metal strikes is decisive, and in several reproductions.[15] The third state is a hand-corrected carbon copy of the second state:[16] This is the basis for our transcription of the manuscript below. The difference between a typescript and a carbon copy is clear by observing the relative sharpness of the letters (Fig. 2).

[14] Tullock Papers, Box 107, Folder labeled: "G. Tullock Organization of Inquiry (3/3) Draft w/comments". Copyright Stanford University.

[15] The original typescript is found in the Tullock Papers, Box 109, Folder "Tullock Organization of Inquiry (3/3)." Reproductions are found in the Tullock Papers, Box 91, Folder "Organization of Inquiry Appendices" and Box 389, Folder 389.8 among others. Copyright Stanford University.

[16] Tullock Papers, Box 42. This in an orange binder in an unlabeled folder. Copyright Stanford University.

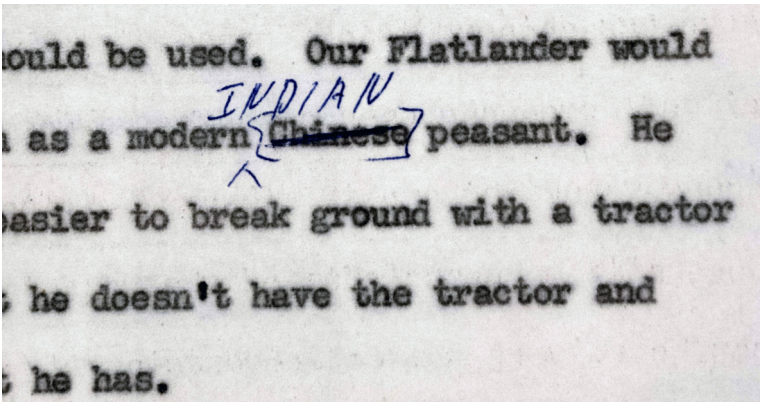


Fig. 2 State three of "Flatland Revisited"

There is also a typescript that encompasses these hand-marked corrections (State Four).[17] We find this an unreliable text. Tullock writes to Brice at Duke (15 April 1964) that "the Flatlanders parable, has also been omitted. Since I liked this appendix I have arranged the draft so that it could be easily replaced." He goes on to describe the problem he had finding a competent typist: "After seeing the product I have decided she will never work for me again." Indeed, we found omitted lines in the typescript that were not corrected. Even though State Four is surely made from State Three, we trust it only as a guide to Tullock's oblique directions in his hand correction.

What we reprint next is in our judgment the final state of Tullock's ill-fated appendix.

Appendix 2: Flatland Revisited

Practically every mathematics student at one time or another has read FLATLAND,[18] Abbott's instructive tale of an inhabitant of a two dimensional world and of how he had the existence of a third dimension proved to him by a being who removed from his two dimensional world, "Flatland," and showed him a three dimensional continuum. The book, as written, gives a false impression, particularly through its title. The land in which A. Square lived was not flat. If we were to view his two dimensional world from the outside, we would quickly recognize that it was as irregular in shape as the surface of any other world. The failure of Mr. Square to notice this fact during the period when he was outside the two dimensional world

[17] This is found in the same orange binder in the unlabeled folder in Tullock Papers, Box 42 in which we found State Three. State Four is also of interest as it is no longer labelled as Appendix 2. Copyright Stanford University.

[18] Flatland, A Romance of Many Dimensions, A. Square, (Edwin A, Abbott). The work has gone through numerous editions. I refreshed my memory with the Basil Blackwell Oxford edition of 1926 and all page citations are to this version.

may be put down partially to the limitations on his opportunities for observation and partly to the hereditary constitution of the mind of an inhabitant of this universe which might better be called "Bentland."

Mr. Square was only outside his two dimensional world for a short time, and his state of emotional and intellectual shock during that period was such as to make it unlikely that he would make any very careful observations of the environment in which he found himself. Further, he seems mostly to have been interested in observing the inhabitants and structures of his native land rather than the physical structure of the land itself. In addition, when he first left his two dimensional world, he was quite incapable of appreciating the nature of any surface other than a flat one. It was only after his guide, Mr. Sphere, had carefully explained this idea to him with the help of a cube that he began to perceive the possibility of non-flat surfaces. In the short and exciting period remaining he can be excused for not noticing the irregular nature of his native world.

The question remains of why his instructor, the sphere, did not acquaint him with this feature of his world. As a being fully conversant with the three dimensional world within which the two dimensional "Flatland" lay, he can hardly have been unaware of its irregular nature. Indeed, he refers to "the plains of Flatland"[19]* and plains are not absolutely level areas, but gently rolling nearly flat areas. Further, "plains" naturally is put in opposition to other terms like mountains, canyons, and hills, and Mr. Sphere, therefore, must be taken to have known that, while the bulk of the inhabitants of Flatland lived in a relatively level area, there were numerous pronounced irregularities in their two dimensional world particularly in its less settled parts.

Shortage of time, as we have said, may have led the sphere to avoid this subject, but it may also have seemed useless to him in view of his great knowledge of the inhabitants of "Flatland." For it is a fact that the minds of these dwellers is so constituted that they cannot conceive of their land as anything except flat. It is possible that the sphere might have succeeded in convincing Mr. Square that deviation from flatness was theoretically possible, but he could never have given him a real appreciation of what a two dimensional continuum which was irregular rather than flat when viewed from a three dimensional space was like. This peculiarity of the minds of Flatlanders has occasioned much interest among the inhabitants of "Spaceland" and the savants of the area have devoted much time to speculating on its origin. To an account of the results of this discussion, I shall shortly turn. After briefly indicating the principle points of view expressed in this debate, I shall then describe the effect of the concurrence of irregularities and minds inherently unable to think of such things on science in "Flatland." Finally, I shall explain what may not be obvious to some of my readers, what all of this has to do with us.

Among the scholars of spaceland there are quite a number of views on how the "Flatlanders" came to have minds which are incapable of thinking of their world as anything but flat. One thread unites all of these theories, however; all the savants are agreed that the Flatlanders evolved from lower forms and that the present

[19] P. 79.

constitution of their minds must be the product of that evolution. The exact evolutionary process is the only matter which divides them although there are sufficient grounds for division within this sphere to permit the development of a large number of warring schools of thought.

The first and, in some ways, most influential of these schools of thought holds that evolution necessarily proceeds from the simple to the complex. One-celled species necessarily preceded multi-celled and the Amphibia preceed the lizards. It seems likely, therefore, that the first brain which could really think, in the course of evolution would be the simplest type. Clearly, it is easier and simpler to think in terms of a flat two dimensional surface than in terms of an irregular one. It is, therefore, easy to see why the Flatlanders all have such simplified brains. Whether, in time, further evolution will lead to further development is, of course, a mere matter of opinion.[20]

A second school of thought, in part allied with the first, holds simply that a brain which could think in terms of a wavy two dimensional continuum would have had little evolutionary value at the time the race originally was formed. It is an undoubted historical fact that the race of Flatlanders first developed in the relatively level part of their world, and in this area an appreciation of the minor irregularities in the landscape would have been of little help to primitive tribesmen trying to catch wild animals while at the same time avoiding being caught themselves. While such a set of mental equipment would have had little or no positive evolutionary value, this school points out that it would most certainly have had a negative value. In the first place, the mind which was capable of considering that its two dimensional world varied in an almost inconceivable third dimension would necessarily be larger than one which could not, and this would be an additional weight for the organism to carry around. Further, most genes have multiple effects. The genes which gave the mind this power, then would probably have other effects on the organism, and, if these were negative, even if only mildly so, the whole effect would be to secure the elimination of individuals with such equipment from the race in its earliest stages of evolutionary development.

Once the race had developed with this type of mind, any mutation to another type with an ability to think in other terms than a completely flat universe would have been of negative evolutionary value due to the fact that the non-mutated members of the race would undoubtedly consider the mutant insane. Further, the advantage which such a mutation would give would be very slight to non-existent since only a very small part of the race would, at any given time, be doing things which required the new type of mind. The mutant, being different from his fellows in precisely such a field would probably find that, in those areas where he had a superiority, he would be distrusted by his colleagues, and, consequently, would not be permitted to work, or if he did, his results would not be accepted. Altogether, the "civilized" environment is most unfavorable to the survival of genetic mutations radically different from the prevailing type of mentality, and once a race of one basic mind type has become established, it is unlikely to be replaced by another.

[20] See "Explanation and Prediction in Evolutionary Theory" by Scriven, Science, August 28, 1959, p. 477.

The two remaining schools of thought are less influential than the two we have discussed so far. One holds that there are quite a number of mind types possible for such a race as the Flatlanders, and that it is largely a question of chance and the detailed historical development of the evolutionary process which determines which one any race will have. Once a mind of any type is achieved, however, it immediately gives the species holding it a major competitive advantage over the other, less intelligent, species. This species is then likely to establish its dominance over its environment and, for reasons similar to those given by our previous group of scholars, it forms an unfavorable environment for any mutation which might lead to a different way of thinking.

The last group of savants, in radical opposition to all of the others, holds that the limitation on the Flatlanders' minds which makes it impossible for them to think of their world as other than flat arises essentially from chemical rather than biological factors. They point out that a brain is essentially a carefully arranged collection of chemicals, and they point out that only some chemicals can exist in Flatland, those which have molecules in which the atoms are arranged in three dimensional lattices being, ex definitione, ruled out. This means that there are natural limits on the types of mind which can be constructed, and these savants hold that these limits happen to forbid the construction of a mind which can think of its environment in other than flat terms.

Clearly, our present knowledge of the nature of biological organisms is not great enough to permit us to determine which of these schools of thought is correct. Perhaps none of them are or perhaps the truth involves some sort of compromise between them. Nevertheless, it would seem clear that the development of such a limited mind as the Flatlanders have would be evolutionarily possible. Certainly, the Flatlanders have these limits built into their minds, and never succeed in thinking of their world as anything but flat.

The effect of this limitation on the minds of the Flatlanders has been most peculiar. In the early days of their civilization, it had almost no influence. They learned to make various things and used simple geometric forms in their construction, but surveying did not develop as a science due to the fact, of course, that forms of any size would have widely varying characteristics, depending on where it happened to be located. Eventually, formal geometry was invented (although it was not called "earth measuring") and carried to quite a high level of development. This development, however, eventually led to a crisis which destroyed the simple symmetry of the geometric view of nature. A leading geometrician decided to apply his learning on a large field and attempted to determine the distance between two points by triangulation. The irregularity of the surface at this point was such that his computed results were greatly different from directly measured distance. The experiment was repeated by a number of other scholars at other points and the uniformly disappointing results may be said to have constituted the most important revolution in scientific thought in the entire history of Flatland. The eventual outcome was the conclusion by most scientists that simple geometry was only an approximation of reality. Although normally a close approximation for small figures, even there it was not exact and for larger figures it was almost useless.

The result of this revolution in science was the development as the largest, most important, and most difficult area of scientific investigation of the field of surveying. Mr. Square does not mention this in his brief summary of the characteristics of his land for much the same reasons which would lead an average inhabitant of our country to omit the Einstein theory from a brief account of its nature. Among the scientists, however, the various problems of surveying are a continuous preoccupation. Making careful measurements of various figures on the surface which is thought to be flat, and then trying to develop theories fitting these measurements is a major scientific activity. Probably the most important and certainly the only generally applicable of these theories is the theory which "proves" the existence of inherent limitations on the accuracy of measuring instruments. Needless to say, this is a great help in fitting other theories to the measured data.

All the other theories are regional in nature. That is the theory [which] will attempt to explain the variations in some particular locality. As of today, there are such theories for only a small part of the total area of the country, but the scientists of Flatland are most optimistic about the possibilities of further development. They point out that the history of surveying has been one of steadily accelerating progress. In the last 50 years, in particular, many new areas have been "explained," and many older, rather inaccurate, theories explaining areas have been replaced by new and better explanations, They look forward to an accelerating process of expansion of the area covered by their theories and hope eventually to find a "general surveying theory" which will provide a single equation which covers the whole country. To the outside observer, the problem appears more difficult. Since he knows that the present theories are, in fact, all wrong, he may be dubious about the possibility of extending them to the whole area. On the other hand, the scientists of Flatland have so far shown undoubted ingenuity in applying their incorrect theories to reality and the possibility that they will eventually solve their problems cannot be disregarded. If they do find their "general surveying theory," it will be an interesting example of a theory which is completely incorrect, yet which explains all of the observed data in terms of its own, improper, assumptions.

The presently existing local theories may be divided among three basic categories. In the first place, there are a few in which the theory simply consists of an equation with no explanation of why it should work. Those theories which are explanatory, and they make up the vast bulk of the total, normally depend either on an assumption that measures of length vary from place to place or that straight lines are actually bent is various ways.[21] Some combine elements of both these explanations or, in some cases, also combine unexplained elements with one or the other of these basic explanations. As far as accuracy goes, some few of the Flatlanders' theories use equations which are exactly those we would use ourselves, although they have derived them differently. In a few more cases, they use equations which lead to the same results as ours but which are more complex. In most cases,

[21] Bent within the plane in which the Flatlanders imagine themselves living, of course. Many of the lines are bent, as we third dimension dwellers can see, but they are bent quite differently than the Flatlanders believe.

however, the theories developed by the Flatlander scientists are mere approximations of reality and many of them are not even close approximations.

But, what, the reader may ask, has all of this to do with us? I am coming to that and as an introduction may I ask that you consider the possibility that some Flatlander might begin to doubt the flatness of his universe. While he could doubt its flatness, he could not, given his mental constitution, think at all in non-flat terms. He could only feel that possibly the universe was non-flat, but he would have no idea what that meant in positive terms. In support of this view that the world was non-flat, he could offer only two, rather feeble arguments. Firstly, it would seem unlikely that the type of brain which would evolve under primitive conditions would be particularly suited to scientific efforts to penetrate the real nature of the universe. Secondly, he could point out that most scientific theories, efforts to explain the universe in terms of this built-in flatness axiom, were mere approximations of the data obtained by measurement and that vast areas were completely unexplained.

Weak as these arguments are, those on the other side are even weaker. There is first the argument from hope—someday our theories may fit the measurements exactly. Secondly, there is the argument of non-comprehension. A great many of the scholars of Flatland could be depended upon to simply point out that the results of reasoning based on the flatness axiom which was part of their biological brains seemed perfectly logical and that no other line of reasoning was so logical. This would, of course, he quite true, but also beside the point. The contention would be quite simply that the minds of the Flatlanders were so constructed that what seemed logical to them was nevertheless not in exact accord with the reality of nature. The fact that Flatlander logical reasoning appeared logical to Flatlanders would be irrelevant.

Obviously, with such weak arguments on either side, it would be impossible for the Flatlanders to determine who was right; the problem would have to remain an open question. Possibly after a few hundred thousands of years, some conclusion might be drawn by considering whether the whole of Flatland were covered by a coherent explanation, but surely nothing can be decided now.

Nevertheless, even a Flatlander who became convinced that the world was, in fact, non-flat would have to continue investigations using the flatness axiom. As we have pointed out, their minds are so constituted that they can think in no other terms. It would be a question of thinking in terms of this axiom or not thinking at all, and as long as any progress at all was possible with the use of the false axiom, it should be used. Our Flatlander would be in much the same situation as a modern Indian peasant. He knows that it would be much easier to break ground with a tractor and plow than with a hoe, but he doesn't have the tractor and plow so he makes do with what he has.

The application of all of this to ourselves is, I suppose, obvious by now. We are biologically equipped with brains of a certain pattern. These brains permit us to think in certain ways, which are as much part of the biological equipment of the species as are arms and legs. Clearly, this thinking ability has positive evolutionary value and has given the human species a major competitive advantage over other species, but this does not prove that human logic and the real interrelations of things in this world are in a one-to-one relationship. Nevertheless, we have no choice but to

continue thinking in our natural way. It may or may not be the best key to the universe, but it is the only one we have.

Comments from J[ames] B[uchanan]: I find this to be a very provocative and amusing essay. I was reminded of the comment of Hoyle. He made the point that the birds should have been rulers of the universe except for the fact that they are not able to support in the air brains having enough to make them superior. But the idea of surveying food potential from the air was a great one he said. Also the elephant. But for a deficiency in blood supply to brain he might have out-evolved humans. After this conversation with Hoyle, I think a lot more of evolution and animals.

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