Synthese (2023) 201:40
https://doi.org/10.1007/s11229-022-04018-w

ORIGINAL RESEARCH

Ludwik Fleck's reasonable relativism about science

Nicholas Binney[1]

Received: 19 August 2022 / Accepted: 18 December 2022 / Published online: 21 January 2023

Abstract
An ongoing project in the philosophy of science and medicine is the effort to articulate a form of relativism about science that can find a path between strongly realist and pernicious relativist poles. Recent scholarship on relativism has described the characteristics a philosophy must have in order to be considered a thoroughgoing relativism. These include non-absolutism, multiplicity, dependence, incompatibility, equal validity and non-neutrality. Critics of relativism maintain that these requirements cannot be met without collapsing into a pernicious form of relativism and that attempts to do so have failed. Against this view, I argue that the early twentieth century philosophy of Ludwik Fleck satisfies these requirements. Paying attention to the scientific details of Fleck's account of active and passive elements of knowledge, and the resistance generated by them, reveals a thoroughgoing and yet reasonable relativism about science.

Keywords Ludwik Fleck · Relativism · Wassermann reaction · Syphilis · Social constructivism · Pragmatism

1 Introduction

In both the philosophy of science and the philosophy of medicine, philosophers are searching for a middle-way account of science that rejects traditional aspirations of realism and objectivity, whilst avoiding the pitfalls associated with relativism and constructivism (Chang, 2016; Gagné-Julien, 2021; Giere, 2006; Kusch, 2020b; Longino, 2002; Veigl, 2021). On the traditional account of science, the objects and facts described are understood to be independent of human culture, and part of the world-in-itself (Gagné-Julien, 2021). This account of science has been challenged, especially by historians and sociologists of science and medicine (Boorse, 1997; Giere, 2006). Some of these scholars have argued for radical forms of social constructivism, which

✉ Nicholas Binney
n.binney@erasmusmc.nl

[1] Department of Medical Ethics, Philosophy and History of Medicine, Erasmus MC, Room Na 24-15, PO Box 2040, 3000 CA Rotterdam, The Netherlands

deny that the objects and facts of science are independent of human culture or capture the way the world is in itself (Cunningham, 2002). This has led to the concern that such radical constructivist positions are "silly" forms of relativism (Giere, 2006), in which knowledge is nothing more than what people agree is the case or find expedient to believe. Such forms of relativism are pernicious and must be avoided.

Although overlooked in the recent literature on relativism (Baghramian & Coliva, 2020; Kusch, 2019, 2020b), Ludwik Fleck's epistemology (Fleck, 1979) provides just such a reasonable relativism about science. In Sect. 2, I discuss the requirements that contemporary scholars have argued a philosophy of science must satisfy to be considered as a form of relativism and identify the main points of contention that make many see relativism as untenable. I discuss how Fleck's epistemology satisfies these requirements and addresses these issues. However, an abstract discussion of these matters does not allow a proper understanding of Fleck's epistemology.

In Sect. 3, I provide a concrete presentation of Fleck's philosophy, as presented in his monograph *Genesis and Development of a Scientific Fact*, published in German in 1935. Fleck's monograph concentrates on the fact that a serological test, the Wassermann reaction, could be used to detect syphilis. Fleck argued that facts only existed within culturally contingent networks of beliefs and practices, that comprised the thought style of researchers. Step by step, I go through the experimental work that Fleck argued inspired the central tenets of the serological thought style, showing how Fleck linked these together, reconstructing the network that Fleck described. I clarify how objects and practices such as patients with syphilis and the Wassermann reaction were created within this network, explaining why Fleck thought that they "cannot be justified" by empirical experience (Fleck, 1979, p. 59). These objects are not natural objects that correspond with an absolute reality. Rather, they are brought into being by the interaction of these central tenets, which were part of early twentieth century serological culture. Understanding how this network constrained researchers is essential for properly understanding Fleck's epistemology.

In Sect. 4, I discuss two different forms of constraint in detail. Even though the adoption these central tenets was inspired by empirical work, Fleck argued that their adoption was still an encultured choice. As such, which tenets to adopt was for these researchers to choose—their will determined the central tenets of serology. Fleck called these beliefs and practices that responded to the will of researchers *the active element of knowledge*. The logical consequences of these choices constrained researchers, but this constraint was self-imposed. Having adopted these beliefs, however, researchers experienced a different form of constraint that resisted their will. Fleck called this *the passive element of knowledge*. Initially, this passive resistance is weak and indistinct. Fleck called this the *widerstandsaviso* (the early signal of resistance). As more and more active elements are adopted, this passive resistance becomes stronger and stronger, until a fact emerges from the network. Crucially, this passive resistance can conflict with the active elements that gave rise to it, showing them to be mistaken even within the thought style they comprise. Thus, Fleck did not contradict himself by claiming that early twentieth century researchers were mistaken, and his choice of the Wassermann reaction's ability to detect syphilis as an example of a fact that emerges from a culturally conditioned network of beliefs and practices was apt. In

the conclusion, I detail how Fleck's philosophy meets all the requirements of a reasonable relativism about science. Fleck's epistemology is coherent, and of great value to philosophers searching for a middle way between realist and pernicious relativist poles.

2 Contemporary discussions of relativism and Fleck

Many candidate middle-way philosophies, be they examples of relativism, sociology of knowledge, feminist epistemology, perspectivism or pragmatism, share many of the themes discussed in the literature of relativism about science (Kusch, 2020b, p. 64). Several recent books have been published on relativism in science, revealing that the possibility of a non-silly form of relativism is still a live topic of discussion (Baghramian & Coliva, 2020; Kusch, 2019, 2020b). Although there are many forms of relativism, they by and large share a set of characteristics. I summarize the ones described by Maria Baghramian and Annalisa Coliva (2020) for my purposes here:

(1) Non-absolutism: the view that factual knowledge does not correspond to a mind and culture independent world.
(2) Dependence: the view that factual knowledge is dependent upon some sort of framework, such as a paradigm, a conceptual scheme, or a linguistic framework.
(3) Multiplicity: the view that there are many frameworks upon which factual knowledge might depend. There can be many different paradigms, or conceptual schemes, or linguistic frameworks, etc.
(4) Incompatibility: the objects and facts produced in these frameworks conflict with each other. This incompatibility might be strong or weak. Strong incompatibility is the claim that the same fact is true in one framework, but false in another. Weak incompatibility is the claim that a fact may be true in one framework but false in another because it is not available or inexpressible in the latter framework.
(5) Equal validity: the view that different facts produced by different frameworks are equally correct, and thus are genuinely facts.
(6) Non-neutrality: the view that there is no neutral set of criteria—no Archimedean point—that can be used to evaluate knowledge claims.

I should note that Baghramian and Coliva are critical of this relativist position. Other philosophers, such as Martin Kusch (2019a, 2019b), defend relativism about science, but describe these criteria slightly differently. Kusch describes non-absolutism, dependence, pluralism, and conflict as essential elements of relativism, which are similar to non-absolutism, dependence, multiplicity and incompatibility already described. Kush also requires at least one type of what he calls 'symmetry'. Amongst the types of symmetry, we find equal validity and non-neutrality, but we also find 'locality': the view that knowledge, epistemic standards, etc., are local to culturally specific times and places, and 'non-appraisal': the view that different knowledge claims, epistemic standards, etc., are impossible to rank because the epistemic standards that would be used to do this are unintelligible in different frameworks. This is different to non-neutrality because non-appraisal requires that the epistemic standards used in different

frameworks be mutually unintelligible, whereas non-neutrality only requires that they be different.

Of these characteristics, one of the most contentious is equal validity. Equal validity is seen as something of an Achilles heel for relativists (Boghossian, 2006). If we accept that there are multiple, incompatible, culturally relative sets of facts, then (it is assumed) we must allow any belief to be sanctioned because it is accepted within some culture or other. The fear is that knowledge collapses into whatever is culturally accepted: that knowledge is reduced to belief.

Some scholars, such as Baghramian and Coliva (Baghramian, 2019; Baghramian & Coliva, 2020), claim that equal validity is a necessary requirement for an account of science to be a form of relativism, whilst others, such as Martin Kusch, claim that this is not the case because no actual relativist accepts equal validity as characteristic of their view (Kusch, 2019a). Kusch only requires that a relativist accept at least one other form of symmetry (locality, non-neutrality and/or non-appraisal). This discussion is complicated by disagreements about what equal validity means. According to Baghramian the claim is that "there can be more than one equally true, rational or justified, but mutually incompatible, judgement on a given topic or in a given domain" (Baghramian, 2019; see also Baghramian & Coliva, 2020, p. 9). According to Kusch, however, the claim is that "the different epistemic frameworks (their standards and the judgements they license) are all equally valid" (Kusch, 2019b; see also Kusch, 2020a, p. 196, 2020b, p. 4). Kusch takes this latter formulation of equal validity to entail that any set of putative facts that are accepted by a group of researchers is just as correct as any other set of putative facts, which is the hallmark of silly relativism. This is why he is keen to reject this view, and to point out that no actual relativist holds this position. The more modest view that only some sets of facts are just as correct as each other leaves open the possibility that some other sets of putative facts do not deserve the status of factual knowledge. This view may be more tolerable to actual relativists and may be defensible.

Baghramian and Coliva (2020, p. 10) hold that equal validity follows as a logical consequence from accepting non-absolutism and non-neutrality. Kusch and others disagree, arguing that accepting non-neutrality entails that different frameworks *cannot be* neutrally evaluated, whilst accepting equal validity entails that frameworks *have been* neutrally evaluated and found to be equally good (Ashton, 2020; Kusch, 2019b; Veigl, 2021).[1] Far from entailing equal validity, these scholars argue that non-neutrality is incompatible with equal validity. This allows the relativist to accept non-neutrality whilst rejecting equal validity, in an effort to maintain their relativist credentials without reducing knowledge to belief. So, we have two further ways of understanding equal validity. On the one hand, frameworks are equally valid because there is an absolutely correct way to rank frameworks, and they happen to have the same rank. On the other hand, there is no such way to rank them, so one framework cannot be said to be better or worse than another. However, if this is true, what stops people from just asserting

[1] Note that these scholars do hold that it is possible for relativists to rank different epistemic systems, but that this is only possible to do having accepted some epistemic system or other. Neutral ranking is not possible. They also hold that researchers' seeing that other epistemic systems are coherent and valuable according to some other epistemic system need not lead to their acceptance of, or conversion to, that other epistemic system.

that they will continue to believe in the framework they do because no one can show them that it is worse than any other? This conceptual analysis of equal validity may not address the central concern about relativism, which is the reduction of knowledge to culturally accepted belief. What the relativist needs to explain is how they avoid such silly forms of relativism.

Even so, concerns have been raised that previous attempts to articulate a reasonable, non-silly form of relativism have failed. Thus, Richard Rorty's linguistic relativism "remains trapped in the shifting sands where linguistic constructivism about facts becomes indistinguishable from the type of relativism he wishes to avoid" (Baghramian & Coliva, 2020, p. 126). Nelson Goodman's ontological constructivism is "a really implausible form of linguistic idealism", in which we all ought to be able to fashion the world in which we live in any way we want (Baghramian & Coliva, 2020, p. 134). Bruno Latour is said to have recognized that his version of relativism has pernicious consequences, allowing propagandists to cloak themselves in the mantel of science (Baghramian & Coliva, 2020, p. 138).[2] Without traditional notions of objectivity, truth and reason "to act as a compass, we are cast adrift in a sea of conflicting information" (Baghramian & Coliva, 2020, p. 139). Proponents of the sociology of scientific knowledge "have exaggerated the purely social dimension" of science by treating knowledge as collective belief (Baghramian & Coliva, 2020, pp. 159–161). Feminist epistemologists are looking for "a well-articulated and coherent form of relativism that is also sensitive to the calls of reality and objectivity", and yet they "have not been able to give an account of relativism that meets these desiderata" (Baghramian & Coliva, 2020, p. 166). Scholars from many schools of thought are trying to articulate a form of relativism in which no aspect of knowledge is independent of human culture, and yet which does not collapse into a silly and pernicious relativism. Nevertheless, other scholars remain deeply sceptical about this possibility, and are concerned that adopting it would blur the distinction between scientific discourse and propaganda. "If there are no absolutes, everything is permitted. It's Karamazov all over again" (Kusch, 2019b). Relativism might even promote 'epistemic insouciance'—not caring about what is true (Baghramian, 2019; Kusch, 2019b).

Fearful of the deficiencies of relativism, some have sought to reject traditional ideals of objectivity and truth whilst preserving some sense of realism. David Stump (2022), for example, has recently championed a pragmatic fallibilism, which he argues can mediate between strongly realist and relativist poles. Stump, in order to protect his pragmatism from slipping into a silly pernicious relativism, proposes a pragmatic account of objectivity. "What I mean by saying that our judgements can be objective is simply that results are not built into our sets of practices" (Stump, 2022). This is a very valuable insight. Stump also argues that empirical experience can be dependent upon systems of beliefs and practices, without being determined by them.[3] This is another very valuable insight. However, the possibility of finding such unexpected things is presented by Stump as the result of getting beyond the frameworks to which

[2] Others do not agree that Latour made any such recantation (Kusch, 2020b, p. 66).

[3] Stump (2022) argues that the difference between relativism and pragmatism is that for the relativist knowledge is dependent upon and completely determined by the framework of beliefs and practices, whereas for the pragmatist knowledge is dependent upon but not completely determined by this framework. This defines all forms of relativism as silly and pernicious, which relativists deny is the case.

knowledge is relative. "You must go outside of the system of practices and do things in the world" (Stump, 2022). But the whole problem is that pragmatists and relativists alike (whether or not there is a difference) do not accept that it is possible to get outside of the frameworks to which knowledge is relative and "do things in the world". The phenomena created by systems of beliefs and practices are not "stable" in the sense of managing to become independent of the systems that generated them (Stump, 1988, 2022). This account of how we encounter things that are not built into our frameworks is not satisfactory.

In summary, both philosophers of science and medicine are struggling to find an account of science that rejects the traditional realist view of science, but which does not collapse into a silly and pernicious form of relativism. Scholars do not see how it is possible to have factual knowledge, which is dependent upon but not determined by frameworks of beliefs and practices, without being able to get outside that framework to access an autonomously existing world. I argue here that Ludwik Fleck's epistemology shows us how this is possible.

Fleck rejected the possibility of absolute knowledge of how the world is in itself. He also endorsed dependence, multiplicity and incompatibility. I argue that Fleck's epistemology even allows for a non-pernicious form of equal validity, which may satisfy those who see equal validity as a requirement for relativism about science. By the standards of contemporary discussions of relativism, Fleck's epistemology is a form of relativism. However, Fleck denied that he was a relativist, as (for him) relativism entails that the same claim could be both true and false in different frameworks (Fleck, 1979, p. 100). For Fleck, facts produced in different frameworks are never the same, even if they use the same words to express them. Thus, Fleck endorsed only a weak form of incompatibility, which according to Baghramian and Coliva (2020) makes his relativism a weak form of relativism. And yet, the reason Fleck says that facts produced in different frameworks are never the same is because, for him, the world we experience is literally created within each framework, so that different frameworks create different worlds. Baghramian and Coliva (2020, p. 139) concede that this is a particularly strong form of relativism, even if it leads to a weak form of incompatibility. In any case, that facts are not built into the framework upon which they are dependent is central to Fleck's work, and his epistemology if thus not a silly and pernicious form of relativism.

Fleck argued that the notion of the culture-independent world-in-itself is not intelligible and preferred not to speak about things he did not think could be understood.[4] He does, however, occasionally refer to uninterpreted experience as "a complex confusion and chaos" (Fleck, 1979, p. 75). There is an ancient tradition in poetry and mythology of referring to the substrate from which a god may create the world as "chaos". This chaotic substrate is pure potential—it is not anything in particular but can become anything at all, according to the will of the creator. John Milton in *Paradise Lost*, for example, described it as a "wilde Abyss, The Womb of nature and perhaps her Grave,

[4] Fleck shared the view that things-in-themselves were unintelligible with several early twentieth century philosophers, including Ernst Cassirer (1950), Heinrich Rickert (1986) and Otto Neurath (1931). For a discussion of Rickert's use of 'chaos' see Kulyk (2019). For a comparison between Fleck and Neurath see Koterski (2002). For a history of relativisms in the German speaking world, see Kusch, Steizinger, Kinzel and Wildschut (2019).

Of neither Sea, nor Shore, nor Air, nor Fire, But all these in thir pregnant causes mixt Confus'dly, and which thus must ever fight, Unless th' Almighty Maker them ordain His dark materials to create more Worlds" (Milton, *Paradise Lost,* Book II, line 910). Only after this act of creation does the potential become actual. So, even if we cannot describe this chaotic substrate in prose, perhaps we can describe it in verse. Whilst I do not suggest that Fleck drew on this poetic and mythological tradition, it is nonetheless helpful to have it in mind when interpreting his epistemology.

In this poetic mode, we (in place of The Almighty) face chaos and order it according to our will. We generate the objects that populate the world we experience. Fleck called this culturally informed activity "the active element of knowledge" (Fleck, 1979, pp. 10, 82, 90). These active elements form the "thought style" of a group of collaborating observers, which Fleck calls a "thought collective" (Fleck, 1979, p. 25). However, once we have brought these objects into being, we find that these objects do not necessarily behave, and do not necessarily relate to each other, as we would wish. We find that these objects, created according to our will, then resist our will. Fleck called this resistance to our will "the passive element of knowledge". The passive element of knowledge does not exist without the active element of knowledge and changing the active element of knowledge changes how the passive element resists our will. The passive element of knowledge is dependent upon the culturally informed active element. However, the passive element resists our will, and thus is not fully determined by the active element of knowledge. As we shall see, the passive resistance can even undermine the very active elements that brought them into being. Thus, although all passive facts are dependent upon the active framework, what these facts are is not built into the framework.

Researchers rarely (or perhaps never) work directly with chaos. Rather, they adapt previously held sets of active elements in the light of their passive experience. Nevertheless, in Fleck's epistemology, the active element that responds to our will is epistemically prior to the passive element that resists our will. Many other attempts to articulate a satisfactory relativism have this priority reversed, such that the thing that resists our will is treated as given for all observers, who then act upon it according to their values and culture. So, some accounts may take a certain set of brute observations as given, and then interpret them differently, whilst others may appeal purely "object-sided" stimuli, which then interact with "subject-sided" factors, to produce knowledge (Brorson & Andersen, 2001). Such accounts inevitably separate something that is given by the nature of the world-in-itself from cultural interpretation, rather than showing how facts and values are fully integrated. They also have the disadvantage of appealing to something given by the world-in-itself, which contradicts their relativist aspirations. Fleck's account of the active and the passive elements of knowledge manages to fully integrate facts with values, such that all factual knowledge is inseparable from and constituted by human culture, without collapsing into a silly and pernicious form of relativism.

Even though Fleck's epistemology is valuable to many contemporary philosophical discussions, his work has proved difficult to interpret. On the one hand, Fleck is considered a pioneer of radical social constructivism (Jasanoff, 2012; van den Belt, 2011; Zittel, 2014). He is understood to be the amongst the silliest of relativists (Cunningham, 2002, p. 15; Harré & Krausz, 1996, p. 11) and is linked to the rise of a "post-truth"

era (Kienhues et al., 2020; Omodeo, 2020; Strong, 2019). On the other hand, some call Fleck's relativism a myth, arguing that he took an epistemic position outside of history in order to criticise scientific positions he did not agree with (Zittel, 2014). Fleck certainly did argue that some scientific claims were mistaken (see below), leading some scholar to interpret the passive element of knowledge as "the hard residue of material reality" (Löwy, 2004a). These seemingly contradictory elements in Fleck's work have led other scholars to argue that Fleck contradicted himself (Brorson & Andersen, 2001; Harwood, 1986; van den Belt & Gremmen, 1990). "One possible interpretation is that the inconsistencies in Fleck's writings reflect an unresolved tension between Fleck the philosopher that stresses relativism and idealism and Fleck the scientist that stresses realism and materialism" (Mulinari, 2014). Others still have argued that Fleck's work in unintelligible (Hedfors, 2006). Whilst several scholars have been supportive of it (Brorson & Andersen, 2001; Latour, 2007; Smith, 2006), Fleck's work still requires further clarification to reveal its power. Whilst Fleck's work is complex, I seek to clarify his argument and recommend his epistemology for application in the present day.

When clarifying Fleck's epistemology, it is important to attend closely to the concrete details of the science Fleck used to present his epistemology (Babich, 2003). Fleck did not provide an entirely abstract account of his epistemology, instead providing an analysis of the "thought style" of serologists in the early twentieth century and reflecting on the philosophical consequences of this analysis. There are good reasons for following his example. Any general or abstract account of science, divorced from the particulars from which it is drawn, is easily misunderstood and misinterpreted. Failure to engage with these particulars led to the misunderstanding of Fleck's position immediately after the publication of *Genesis and Development of a Scientific Fact* in 1935. Some National Socialists were supportive of this aspect of his work, as they interpreted it to show that there could be one distinct science for Arian Germans, who adopted one set of active elements of knowledge, and another science for Jewish Germans, who adopted a different set of active elements—that there were distinct "new German" and Jewish thought styles (Borck, 2004; Fehr, 2012; Ginev, 2015).[5] Attention to the particulars of Fleck's would have shown the opposite. Membership of the serological thought style was not predicated upon race, but rather upon receiving a serological training, and the adoption of the relevant active elements of knowledge, which people of any race or nationality might (or might not) undertake. Separating a general and abstract philosophical account of science from a particular and concrete empirical account of it diminishes our understanding of both. In Fleck's epistemology, this separation of philosophy and historical experience would be as damaging to understanding the science as trying to separate the active and passive elements of knowledge. Without the active element, the particulars of the passive element do not exist. And yet, researchers learn how to formulate the active elements that they adopt by generalizing from their passive experiences. "Who does not see, in fact, that by separating these two sciences we mutilate both" (Poincaré, 1905, p. 154).

[5] Fleck was a Polish Jew. He and his family were persecuted by the Nazis and he was interred at both Auschwitz and Buchenwald concentration camps (Schnelle, 1986). Fleck rejected the authoritarian vision of science promoted by Nazis, promoting a democratic vision of science instead (Fehr, 2012). For discussion of the connection between relativism and National Socialism see Steizinger (2019).

Fleck's monograph provides an historical and philosophical investigation of the Wassermann reaction as a test for the disease syphilis. The Wassermann reaction is a blood test for syphilis developed in the early twentieth century. It quickly captured the imagination of research and medical communities internationally, becoming a trusted tool in syphilis control strategies (Löwy, 1993). It was originally thought to detect antibodies produced by infected patients, which would bind to the syphilitic pathogen *Spirochaeta pallida* (later called *Treponema pallidum*), and to this pathogen alone. Antibody/antigen reactions were supposed to be *immunologically specific*. Antibodies lead to the destruction of this pathogen by binding to it. This allows another blood chemical, known as complement, to bind to the pathogen, punching holes in the pathogen's cell membrane, destroying it. In a sample of the patient's blood, there is only a limited supply of complement, which can be used up, or *fixed*, by immunological reactions. Hence, the fixation of complement can be used to detect specific immunological reactions. Serologists tested for syphilitic antibodies, and thus for cases of syphilis, by taking a sample of blood, adding antigen from the syphilis pathogen (which would bind to the antibodies if they were present and fix the complement), and then test to see if the complement was fixed. If it was, then the antibodies were present, indicating the presence of the pathogen and the disease.

Soon after the development of this serological test, however, researchers made a surprising discovery. Positive test results were supposed to be produced by an immunologically specific reaction between syphilitic antigen and the corresponding antibodies. This was one of the active elements of knowledge upon which the test was premised. Researchers quickly found, however, that the test would still distinguish patients with and without syphilis even if no syphilitic antigen was used to test for antibodies that were supposedly specific for syphilis. This finding is an example of the passive element of knowledge and it is catastrophic for the thought style from which it emerged. This is Fleck's main example of the passive element undermining the active elements that generated it.

Fleck used this finding to argue that the active elements adopted by early twentieth century serologists were "completely mistaken" (Fleck, 1979, p. 74). This claim more than any other has confused the interpretation of Fleck's work. Scholars have assumed that if all knowledge is relative to culturally contingent active elements then it is impossible for researchers to be mistaken (Harwood, 1986; van den Belt & Gremmen, 1990). According to these scholars, Fleck contradicted himself by claiming both that serological knowledge was relative to the serologists' thought style and that serologists were mistaken to believe what they did. Furthermore, scholars have claimed that the fact of the non-specificity of the Wassermann reaction was a poor example of Fleck's philosophy, because it undercut the central tenets of the thought style from which it arose (van den Belt & Gremmen, 1990). These scholars assume that a fact that undercuts the central tenets of a thought style cannot be relative to that thought style. In effect, these scholars assume that all forms of relativism, including Fleck's, must be pernicious. What they have missed is that Fleck presented a non-pernicious form of relativism and did so without contradicting himself. The key to understanding this is to grasp why Fleck thought belief in the immunological specificity of the Wassermann reaction was mistaken, which requires a thorough understanding of his account of the Wassermann reaction.

3 The network of serological knowledge

Fleck's account of thought styles is rich, and I will not do it justice here. I ignore elements such as the format and style of scientific writing that different scientific communities find acceptable. I also ignore Fleck's discussion of how knowledge needs to circulate through expert and lay communities, and of how knowledge develops historically. I pay no attention to how Fleck saw literature, poetry, painting and music as capable of producing and expressing knowledge. These are all important parts of Fleck's work. However, here I focus on the particular beliefs Fleck highlighted as central tenets of the thought style of serologists. Fleck has been criticized for saying that these central tenets "could not be justified", as this sounds like he is claiming that serologists were wrong to hold them. But he is not. These central tenets are the active elements of the serologists' thought style, which Fleck thought needed to be adopted to make their empirical experiences possible. As such, the adoption of these active elements was not dictated by experience. However, their adoption was not unconnected to experience either. Prior experience, produced using other active elements, inspired the adoption of these central tenets, but did not dictate that they must be adopted. As such, these active elements went beyond experience, and it is in this sense that they "could not be justified". Fleck is not criticizing serologists for adopting these active elements, he is telling us what to look out for when identifying active elements—things that are taken for granted without being dictated by observation. To see this, and to properly understand the character of the active elements of knowledge, it is important to explore why Fleck argued they were adopted by serologists and how they interacted with each other.

Scholars have highlighted the six central tenets of the serological thought style identified by Fleck (van den Belt & Gremmen, 1990). These scholars correctly recognize that there is an important theme that unites these tenets: *specificity*. Specific disease entities, species of pathogen and specific immune responses are all united by the overarching regulative principle of specificity (van den Belt & Gremmen, 1990, p. 468). I represent these central tenets as follows:

(1) The specificity of serological reactions—antibodies will only react with their corresponding antigen.
(2) The specificity of diagnosis—there are distinct species of disease that can be distinguished using clinical and laboratory observations.
(3) The specificity of pathogen—there are distinct species of aetiological agent, which are foreign organisms that invade the host's body and cause disease (the battle metaphor).
(4) The distinction between cellular and humoral immunity—the immune processes involving the host's cells and involving the host's serum can function entirely independently.
(5) The importance of controls—without appropriate control experiments serological results cannot be trusted.
(6) The action of blood chemicals—each immune effect of serum is the result of the action of a chemical substance in the blood.

Fleck described the observations which inspired the adoption of these central tenets, and how they were assembled into a network. These included observations of contagious diseases, where healthy people would develop the same symptoms as sick people with whom they had come into contact. This inspired the notion that there were distinct species of disease (tenet 2) (Fleck, 1979, p. 15). Macroscopic disease-causing organisms, such as intestinal worms, were known to invade their host causing symptoms, inspiring the notion that diseases were caused by creatures invading the body (tenet 3). Inoculation experiments, in which pus from diseased patients is injected into healthy patients who then develop the same disease, inspired the idea that infectious material that caused disease could be transferred from one individual to another (Fleck, 1979, p. 15). Bacteriological theories of microscopic pathogens, when they emerged in the late nineteenth century, fitted neatly into this framework (Fleck, 1979, p. 15). Fleck discussed how observations made in clinical and laboratory medicine, bacteriology and pathology all contributed to the view that different species of pathogens cause specific disease entities by invading patients' bodies (linking tenets 2 and 3).

Importantly, Fleck emphasised that these observations did not force researchers to accept the reality of pathogens which caused disease in those they infected. He noted that asymptomatic infections, disease carriers, and marked differences in pathogen virulence and patient response to the same pathogen, all showed that the notions of specific disease entities caused by different species of pathogen need not have been accepted by serologists. "Today it can be claimed almost with impunity that the "causative agent" is but one symptom, and not even the most important, among several indicative of disease" (Fleck, 1979, p. 18). Although such notions were inspired by empirical work, alternative interpretations were available. The adoption of these tenets was part of the serologists' culture (Fleck, 1979, pp. 21–22, 64, 121–122).

The same insight applies to syphilis itself. Patients with syphilis were identified as patients with venereal disease (who had symptoms involving their genitals), but who did not have either gonorrhoea or soft chancre (as recognized from the presence of the pathogens that defined those two diseases). "The agents causing gonorrhea and soft chancre had been discovered earlier, so that these two diseases could be excluded from the picture of syphilis" (Fleck, 1979, p. 17). So, the disease entity syphilis was a sort of left-over category, formed by taking patients with a clinical problem (venereal disease) and subtracting those patients with certain disease-causing organisms. As a clinical problem was central to the definition of syphilis, Fleck argued that syphilis was not a natural object, existing independently of human experiences, judgements and interests. The disease entity syphilis was part of serologists' culture.

This also applies to the pathogen of syphilis. The pale spirochaete was found in patients with syphilis, and inoculation experiments confirmed that this pathogen could indeed produce the symptoms of syphilis in animals (Fleck, 1979, p. 17). However, bacteriologists could not distinguish this pathogen from other similar microorganisms by its microscopic appearance alone, as there were many similar looking organisms that did not produce disease in inoculation experiments. The species of spirochete could only be recognized from the clinical syndrome it produced in experimental subjects. Consequently, the disease entity syphilis was not defined by its pathogen, the pathogen was defined by its disease entity. "*Spirochaeta pallida* should therefore

be defined by syphilis instead of the other way around" (Fleck, 1979, p. 18, see also p. 21). As the disease entity was part of serologists' culture, so was the pathogen.

So, we already have a little network, showing how knowledge of several venereal diseases and their pathogens are interrelated. Even though the infectious agents for gonorrhea and soft chancre needed to be known to define the clinical syndrome of syphilis, it is the clinical syndrome of syphilis that defines its pathogen. This shows the *mutual* dependence of ideas about species of pathogen (element 3) and specific disease entities (element 2). Fleck argued that syphilis should not be understood as a natural object, discovered by objective research. Rather syphilis should be seen as the product of early twentieth century serological culture, and its historical development (Fleck, 1979, pp. 21–23).

With this knowledge of syphilis in place, it became possible to design a test to detect patients with the disease. Fleck described the experimental observations that inspired the development of the Wassermann reaction as a complement fixation test, which was used to detect antibodies to the syphilis pathogen. Immunization experiments had shown that the serum of subjects inoculated with killed bacteria acquired the ability to destroy that species of bacteria (Fleck, 1979, p. 65). This effect was interpreted to show that immunized patients produced special chemicals in their blood (tenet 6), antibodies, which had the power to destroy that pathogen, *and that pathogen only*. "The amboceptors [antibodies] are specific; their effect is confined to the particular antigen used in the immunization—being effective only on the blood corpuscles of the ram, only on cholera bacilli, etc." (Fleck, 1979, p. 66). Fleck doubted that there were such chemicals produced in the blood, as did other contemporary immunologists, but there is no need to discuss early twentieth century debate about the causes of immune effects here (Mazumdar, 1995, pp. 22–25). It is enough to understand that antibodies were supposed to form specific immune complexes with antigen from only one species of pathogen (tenet 1). In presenting these experiments, Fleck connected different species of pathogenic organism (tenet 3) with the production of chemical substances in the blood that produced immune effects (tenet 6), these effects being the result of immune complexes forming between antigen from those species of pathogen and their specific antibodies (tenet 1).

In addition to antibodies, complement fixation tests require knowledge of complement. Fleck described how this knowledge emerged from experiments with immune serum. Serum from subjects that had acquired the ability to destroy a particular species of pathogen would lose this ability if it was heated or if it was left to stand for a long period of time (Fleck, 1979, p. 65). Immune serum could be deactivated by heating or time. Curiously, researchers also observed that this deactivated serum could be reactivated by the addition of *fresh* serum from an animal that had not been immunized, *whose serum could not destroy the pathogen in question*. This result was interpreted to show that there must be two sorts of substance involved in the production of the destructive power of immune serum. The first is the antibody, which, because it is specific for each form of pathogen, only exists in immune serum. But, in order to exhibit their destructive capacity, antibodies need the help of a second substance, which became known as *complement*. Antibodies are stable over time and with heating, whereas complement is not. Antibodies are specific to immune serum, whereas complement is

generic and found in the blood of all mammals. Hence, heating destroyed the complement but not the antibodies, deactivating the immune serum, and adding fresh serum from any mammal replaced the complement, which along with the antibodies could destroy the corresponding pathogen.

Today, immunologists do not describe complement as a single substance. Instead, this immunological effect is ascribed to a complex system of over thirty interacting chemicals, which have a complex role in the immune system. In accordance with the belief that each immune effect is produced by a specific chemical substance in the blood (tenet 6), early twentieth century researchers invoked the substance complement to explain this experimental observation. Thus, whilst the invocation of complement is inspired by the observation of this immunological effect, this was not the only possible interpretation of it. It might be interesting to explore how and why the complement system is described as it is today, but there is no need to do this here. It is enough to understand that the notion of the substance 'complement' was a product of the culturally contingent belief that each immune effect had its own chemical in the blood.

A further experimental observation is required to inspire a way of detecting complement in immune serum. If foreign red blood cells and their corresponding antibodies are added to fresh serum containing complement, the red blood cells will be destroyed. Similarly, if bacteria and their corresponding antibodies are added to the fresh serum, the bacteria will be destroyed. However, if red blood cells and their antibodies are added to serum that has just been used to destroy bacteria, the red blood cells will not be destroyed. The explanation given for this was that the destruction of the bacteria used up, or *fixed*, the complement (Fleck, 1979, p. 65).

Serologists used this phenomenon to develop a kind of diagnostic test: the *complement fixation test* (Fleck, 1979, p. 68). If immune complexes formed between antigen from pathogenic bacteria and their corresponding antibodies, then these complexes would fix the complement and prevent the haemolysis of the red blood cells. The haemolysis, or lack thereof, could be seen by visual inspection of the reaction mixture, which provided a test result: haemolysis for negative, no haemolysis for positive. If serologists had antibodies to a particular species of pathogen, then they could test the blood of patients for antigen from that pathogen. Conversely, if serologists had antigen from that species of pathogen, they could test the blood of patients for the corresponding antibodies. The complement fixation test linked ideas about species of pathogen (element 3), their antibodies and complement (element 6), the formation of specific immune complexes (element 1), and the laboratory diagnosis of different species of disease (element 2) together.

One final set of experiments is required for a diagnostic test to emerge from this network. The immunological specificity was crucial to the diagnostic value of a test. If the test was not immunologically specific, then positive tests could occur in the absence of pathogenic antigen/antibody immune complexes, and thus in cases that did not have the disease in question. Serologists established that tests only returned positive results for samples from diseased patients using *control reactions* (tenet 5). In control reactions, the presence or absence of pathological extracts or antibodies is known, and the results of the reaction can be judged as true or false accordingly. "Work done without the controls necessary to eliminate all possible errors, even unlikely ones, permits no scientific conclusions" (Fleck, 1979, p. 59, quoting Citron). Serologists

working on the Wassermann reaction initially focused on the negative control, which tested samples from non-diseased patients, who should not return positive results.

The Wassermann reaction was designed to be a complement fixation test for syphilis, employing all these tenets in concert. Initially, Wassermann and his team published results that seemed to show that the test was much more promising for the detection of antigen in patients' blood than for the detection of antibodies. Sixty-four out of sixty-nine extracts from syphilitic patients[6] tested positive, and all fourteen extracts from non-syphilitic patients tested negative (Fleck, 1979, p. 76). This led Wassermann to conclude of the test "that it is a specific reaction between syphilitic antigen and syphilitic antibodies" (Fleck, 1979, p. 71, quoting Wassermann et al. 1906). Fleck also noted that the bacteriologist Edmund Weil wrote of the Wasserman et al. 1906 paper that "The study of this paper could not fail to convince everybody firmly that here was a reaction which functioned with wonderful precision, especially in the demonstration of spirochaete antigen" (Fleck, 1979, p. 175, quoting Weil 1921, p. 967). By incorporating control reactions into the network of practices and beliefs that comprised the serological thought style, the Wassermann reaction was brought into existence.

The serological thought style was composed of these central tenets (tenets 1–6).[7] Even though they were inspired by experimental findings, these observations did not force researchers to adopt them. Fleck denied that observation compelled researchers to accept the existence of specific disease entities. All patients are different, to see them as suffering with the same affliction is at least partly a creative act (Fleck, 1979, p. 22). Fleck denied that researchers were forced to accept microbes as the cause of disease. A species of microorganism causes symptoms in one person, but has no effect on another (Fleck, 1979, pp. 18, 30). Given this, why see the microorganism as the cause of disease, rather than the patient's constitution, or some combination of the two? Fleck also denied that microbiology forced researchers to see the species of microbe that they did, and even that microbes had to be divided into species (Fleck, 1979, pp. 59–62). Antibodies can only be specific to species of pathogen if there are species of pathogen. A control only counts as such if disease status can be determined. Complement need not have been understood as a single substance, responsible for a single immune effect. Although all the tenets described above were inspired by experimental work, Fleck denied that researchers had no reasonable choice but to adopt them given these results. This is why Fleck described these elements as those that "could not be justified" by empirical experience (Fleck, 1979, p. 69). They were part of the serologists' culture. Both syphilis and the Wassermann reaction were culturally contingent objects.

Furthermore, syphilis and the Wassermann reaction were used to construct each other. Without knowing that there were patients with syphilis and being able to identify at least some cases and negative controls, the Wassermann reaction could not exist. The culturally defined boundaries of the disease entity syphilis informed the definition of

[6] Sixty-four correct results out of seventy-six if the seven extracts from brain tissue are included (Fleck, 1979, p. 71).

[7] Fleck said very little about the distinction between humoral and cellular immunity (element 4). He only mentioned it as an example of the "many other habits of thought that cannot be objectively confirmed" in the serological thought style (Fleck, 1979, p. 63). This element plays no role in his account of the network of knowledge.

the Wassermann reaction, as a procedure that was expected to return positive results in cases and negative results in negative controls. Conversely, the Wassermann reaction was used to change the boundaries of syphilis. Syphilis presented in many different ways, initially with genital lesions in a primary stage, and then with skin and other lesions in a secondary stage. It could then enter a long, asymptomatic, latent stage, before in some cases developing into a tertiary stage affecting many organs including the nervous system. In the early twentieth century whether patients in this tertiary stage were genuinely cases of syphilis was disputed. The Wassermann reaction was used to settle that debate, bringing these patients with tertiary disease into the group of patients with syphilis (Fleck, 1979, p. 14). Positive Wassermann tests also brought many patients with latent disease into this group (Löwy, 1993). As these central tenets were formed into an interconnected network, the objects and practices created by this network were also interconnected.

The above discussion gives the impression that the beliefs and practices that comprised and emerged from this network could all be explicitly articulated, but this is not so. Fleck recognized tacit elements that contributed to the network. The Wassermann reaction was technically complex, and difficult to carry out. Laboratory workers needed to develop the "serological touch" to carry it out (Fleck, 1979, p. 97). Procedures needed to be carried out at just the right speed, for example. "An inexperienced individual obtains irregular results through having diluted the extract either too rapidly or too slowly" (Fleck, 1979, p. 97). Fleck claimed that the addition of a new worker to a team would often lead to different test results, even if that new member was skilled, because the "quasi-orchestral" coordination of the team was disturbed (Fleck, 1979, p. 97). The tacit knowledge of how to carry out the Wassermann reaction was part of serologists' culture, and these tacit elements formed part of this network of beliefs and practices.

As all these beliefs, practices, objects and skills were formed in this network, changes to any of these things also changed the others. For example, very quickly after the Wassermann reaction was developed, knowledge of what counted as an adequate control was thrown into uncertainty, which had consequences throughout the network. It was soon found (by Citron no less) that extracts from healthy persons, which contained no syphilitic antigen, would return positive test results (Fleck, 1979, p. 72). Antigen extraction from syphilitic tissue came to be seen as much less reliable than Wassermann thought (Fleck, 1979, p. 85). Consequently, both positive and negative controls used by Wassermann became seen as unreliable, which made Wassermann's early results untrustworthy. If researchers working even a few years after the Wassermann reaction's introduction managed to reproduce Wassermann's experimental procedure exactly, *they would not have known what to do with the results*. Were positive reactions due to the successful detection of antigen, or were they false positives? Were negative results due to the absence of complement fixation, or were they false negatives? Ideas about what counted as a positive or negative result also changed. Haemolysis is not an all or nothing event. There are *degrees* of haemolysis, opening the question about how to read the test's results (Fleck, 1979, pp. 72–73). The test procedure itself is complex, opening questions about precisely how to carry it out. Should 0.1 cc of patient serum be used, or 0.2 cc, or 0.04 cc? (Fleck, 1979, p. 72). Should alcoholic or aqueous extracts be made? (Fleck, 1979, p. 79). As time went on,

researchers modified the reaction, changing how its results were controlled, produced, and read.

The key point is that what the Wassermann reaction *is* changed over time. After these changes, researchers could not see in Wassermann's early results what had once been seen. The results of the old procedures would come to be seen improperly controlled, incorrectly carried out and sloppily read. Even if it were possible to copy exactly what was done in these early experiments, to produce what in some diminished sense are the same results, these results would not carry the same scientific significance as they had before. They would in an important sense *not be the same scientific observations*. Following these changes, Wassermann's promising early results could never be produced again. "It would no longer even be possible for him to "demonstrate 64 times the presence of specific antigen in 69 extracts from syphilitic tissue" and obtain 14 negative control tests without exception" (Fleck, 1979, p. 76). The status of the extracts as "extracts of syphilitic tissue" would be doubted, so the sixty-four positive results would not count as instances of antigen detection, and the 14 negative tests would not count as controls. Following the changes to what the Wassermann reaction was, the possibility of producing those scientific observations was gone forever. "At any rate, the first experiments by Wassermann are irreproducible" (Fleck, 1979, p. 85). Fleck argued that the irreproducibility of the Wassermann reaction demonstrated the socially contingent nature of scientific knowledge (Fleck, 1979, p. 76).

The irreproducibility of Wassermann's early results is not simply due to the loss of the technical ability to carry out the test as Wassermann had in 1906, as has been suggested (Stump, 1988). The irreproducibility of these results is a consequence of changes to the configuration of the network. Changing controls literally changed what the Wassermann reaction was, which literally changed what syphilis was. The objects and practices formed in one part the network become different following changes made to another part of the network. Fleck argued that networks of knowledge were constantly fluctuating and changing, as elements were added and removed. "A universally interconnected system of facts is thus formed, maintaining its balance through continuous interaction" (Fleck, 1979, p. 102). When stating facts, Fleck argued that researchers were referring to the relationships between objects formed in this culturally contingent network. "This network in continuous fluctuation is called reality or truth" (Fleck, 1979, p. 79).

4 Active and passive resistance of the network

Scholars have assumed that facts should never conflict with the thought styles that produced them (Stump, 1988, 2022; van den Belt & Gremmen, 1990). They assume that if facts are relative to the thought style that produced them, then those facts cannot show that the thought style is wrong. Some have argued that by holding the Wassermann reaction up as a product of the serological thought style, and at the same time holding it up as proof of that thought style's failure, Fleck was trying to have things both ways and contradicting himself (van den Belt & Gremmen, 1990). They argue that Fleck was seduced by realism just as he was trying to promote an extreme form of relativism.

This interpretation of Fleck's epistemology is incorrect. A jewel of Fleck's epistemology is that it shows how it is possible for facts to conflict with the thought style that gives rise to them, and thus deserve to be called facts. Fleck's epistemology allows him to claim, without contradiction, that facts are the product of a thought style, and that those facts can show that the thought style is wrong. To understand Fleck's epistemology properly, we must distinguish between two different forms of constraint generated by the network. One which conforms to the will of researchers, the active element of knowledge, and one which resists the will of researchers, the passive element of knowledge.

We have discussed how the central tenets of the serologists' thought style "could not be justified" empirically. They were inspired by empirical observations, but not determined by them. Fleck called these elements that could not be justified "active" elements of knowledge, because in the absence of empirical justification they were actively held and maintained through social consensus. Remember though, these active elements were taken for granted, so researchers may not have seen them as the product of social consensus (Fleck, 1979, pp. 27, 107, 141). Rather, they may well have been seen as the only conceivable possibility, or as empirical discoveries so well confirmed that they had passed beyond all questioning. Nevertheless, the acceptance of active elements of knowledge is a form of encultured "choice", reflecting the collective assumptions of a group of people.

The acceptance of active elements of knowledge constrains researchers. Assuming that researchers want to remain logically consistent, the adoption of an active element of knowledge prevents researchers from adopting other contradictory active elements of knowledge. Accepting that there are distinct species of disease (element 2) prevents logically consistent researchers from believing that there are not distinct species of disease. Accepting that there are distinct species of microorganism (element 3) prevents logically consistent researchers from believing that there are not distinct species of microorganism.

By accepting active elements of knowledge, we constrain ourselves

On their own, such beliefs do not provide much constraint, only preventing the belief of their logical negation. For example, the view that one species of microorganism can cause two species of disease is allowable, so long as these beliefs are treated in isolation. However, when joined together, the constraint provided by the active element of knowledge increases. If the view that there are distinct species of disease (element 2) is joined to the view that there are distinct species of microorganism (element 3) to form the view that each species of disease is caused by its own species of pathogen, then the view that one species of microorganism can cause two species of disease is logically impermissible, as is the view that two species of microorganism can cause the same disease. To permit such views would be in direct logical conflict with the active elements in the network of knowledge.

Fleck scholars have presented present a lovely example of just such a logical conflict (van den Belt & Gremmen, 1990, p. 475). They describe how Aldo Castellani discovered another spirochaete, which he named *Spirochaeta pertenuis*, present in patients with the tropical skin disease yaws, at the same time that Schaudinn found *Spirochaeta pallida* in cases of syphilis. This new spirochaete, however, looked exactly the same

as *Spirochaeta pallida* under the microscope. As different species of pathogen were typically distinguished on the basis of their morphological characteristics, why should Castellani not have claimed that *Spirochaeta pallida* sometimes caused syphilis and at other times cause yaws? The answer is because to accept this would be to contradict the view that each disease had its own causative organism. These distinct species of disease each needed their own distinct species of pathogen, if the logical integrity of the network of knowledge was to be maintained.

Of course, another option would be to say that yaws and syphilis were in fact the same disease, which presented differently in different people and in different climates. Castellani entertained this option but dismissed it because he believed that yaws and syphilis were different diseases (van den Belt & Gremmen, 1990, p. 475). Accepting the distinction between yaws and syphilis is yet another active element of knowledge, making the network more rigid, further constraining researchers.

This example illustrates how the constraint experienced is not the simple permission or prevention of other elements of knowledge being incorporated into the network. It shows that *Spirochaeta pallida* and *Spirochaeta pertenuis* could have been taken to be the same pathogen, just so long as yaws and syphilis are taken to be the same disease. This was an option, even if Castellani did not see it as such. What adding new elements to the network does is *limit the options* available to researchers, rather than precisely dictating what they can and cannot do. If yaws and syphilis are distinct diseases, then the spirochaetes must be different species, given the configuration of the rest of the network. For the spirochaetes to be the same species, then yaws and syphilis must be the same disease. Making decisions about which active elements to accept into the network limits the freedom researchers have to accept other active elements, without making adjustments to how the rest of the network is configured.

As we constrain ourselves, we lose degrees of freedom

Adding more active elements to the network further constrains researchers. Adding the view that each species of pathogen has a specific antibody (element 1), which is only produced in patients immunized against or infected with that pathogen, logically entails that the presence of that antibody indicates an immune reaction to that pathogen. As each species of pathogen (element 3) is connected to its corresponding species of disease (element 2), this logically entails that the presence of that antibody indicates the presence of that species of disease, so long as the patient had not recovered from the disease or had been vaccinated against it. These three elements together constrain researchers enough to suggest the basis of a serological test for the disease but does not constrain them enough to determine exactly how the test should be carried out, or how to interpret the results. Adding further elements regarding test procedures and controls (element 6) allows researchers to specify what it is to carry out a serological test for a disease such as syphilis. Researchers eventually feel tightly constrained in a coherent and robust network. The constraint felt by researchers gradually increases as they decided to accept more and more active elements of knowledge into the network.

Of course, I do not use decision here to mean a deliberate, conscious decision made by the group. Rather, decision is used in the sense of an encultured choice described above. As the active element of knowledge is in this sense *chosen* by the researchers, it is completely determined by their *will*. If something is accepted as an active element

of knowledge, then it is according to the will of researchers. Another way of saying this is that nothing in the active element of knowledge *resists the will* of researchers, everything is as they want it to be. Consequently, the loss of freedom researchers feel from *the active element of knowledge is a self-imposed constraint*.

All this should not trouble the most pernicious of relativists. If the only constraint felt by researchers is self-imposed, then knowledge is reduced to whatever researchers willingly accept as such. They are limited only by their imagination and their respect for logic, which is itself within their gift. If this was the only form of constraint experienced following the adoption of the active element of knowledge, there is no difference between fact and fantasy. Thankfully, as Fleck says, it is not.

> "These last statements must not, however, be taken to mean that the Wassermann reaction can be reconstructed in its objective entirety simply from historical factors along with those of individual and collective psychology. Something inevitable, steadfast, and inexplicable by historical development is always left out of such attempts" (Fleck, 1979, p. 79).

It is important to understand this inevitable and steadfast something is not the mind and culture independent world. This something is not independent of the culturally adopted active elements that give rise to it. It is a different form of constraint. Fleck's effulgent insight is that the self-imposed constraint of the active element of knowledge gives rise to another kind of constraint that resists the will of researchers—the "passive element of knowledge" (Fleck, 1979: 83). He paints a beautiful epistemic picture for us. None of us can know how the real world is in itself. We are confronted with a world that is beyond our meager cognitive abilities—a "complex confusion and chaos". As do gods in a creation myth, we bring some order to this chaos, by adopting active elements of knowledge, which respond to our will. We grope around in the chaos like this, often unsuccessfully, until we manage to find something that resists our will:

"The work of the research scientist means that in the complex confusion and chaos which he faces, he must distinguish that which obeys his will from that which arises spontaneously and opposes it. This is the firm ground that he, as representative of the thought collective, continuously seeks. These are the passive connections, as we have called them" (Fleck, 1979, p. 95).
"The research worker gropes but everything recedes, and nowhere is there a firm support. Everything seems to be an artificial effect inspired by his own personal will. Every formulation melts away at the next test. He looks for that resistance and thought constraint in the face of which he could feel passive" (Fleck, 1979, p. 94).

Fleck described the active element of knowledge as preconditions to produce the passive element of knowledge. "The preconditions correspond to active linkages and constitute that portion of cognition belonging to the collective. The constrained results correspond to the passive linkages and constitute that which is experienced as objective reality" (Fleck, 1979, p. 40). The active element of knowledge is a necessary precondition for the passive element to emerge. Without making decisions about whether diseases exist, how they relate to causative agents, how specific diseases are defined, about what is happening during immune reactions, about how to control serological reactions, and others, facts about how accurate the Wassermann reaction is cannot be

generated. “Not a single statement can be formulated from passive links alone. Active links, usually inappropriately called "subjective," are always involved” (Fleck, 1979, p. 49). Furthermore, the passive element of knowledge cannot exist at all without the active preconditions being in place. The relationship between the culturally conditioned active element and the steadfast passive element is not like that of the social decisions to build an object like a bridge and the bridge itself. Although a bridge would not exist without those decisions, once it has been made it enjoys an autonomous existence. If people decide it was a bad idea to build the bridge, the bridge still exists independently of those decisions. Passive resistance is more like the resistance of a trampoline. When someone jumps on a trampoline (the active element), it resists their weight (the passive element). How they jump on the trampoline changes how the trampoline resists them. But when they get off the trampoline, it does not resist them anymore. Without the continuous cultural acceptance of active elements, there would be no passive elements at all.

To see how the network generates passive resistance, it is best to attend to Fleck’s case study. Fleck described Wassermann groping towards this passive resistance (Fleck, 1979, p. 94). Fleck saw that Wassermann’s team had a definite plan for how to explore the potential of the reaction as a diagnostic tool, but also that there were so many uncontrolled variables that their results would be difficult to decipher (Fleck, 1979, p. 85). The network was not yet sufficiently dense to tightly constrain researchers, allowing them more latitude in interpreting their observations. However, this apparent freedom is a double-edged sword, as it means that the objects formed in the network are indeterminate. Freedom of interpretation comes with the price of not knowing what is observed. For example, even though the reaction eventually became a test for antibodies in patient serum, early results indicated that it would be a promising test for the syphilitic antigen in patient blood. To test for syphilitic antigen, Wassermann needed a supply of syphilis antibodies for use in the test. Wassermann used immunized monkeys to produce immune serum containing the antibodies to test for syphilitic antigen. However, pure cultures of *Spirochaeta pallida* could not be produced at the time, so he inoculated these monkeys with syphilitic material from human patients. This left open the possibility that the monkey serum would contain antibodies for human tissue, in addition to syphilitic antibodies. Immune complexes might form between these antibodies and human tissue in the antigen extract from patient samples, fixing the complement and producing a positive reaction.

This, and other concerns, weighed on Wassermann’s mind (Fleck, 1979, p. 85). According to Fleck, Wassermann was aware of many factors that could disturb his experiments for which he had not controlled. These factors allowed a considerable degree of freedom with which to interpret his results. Therefore, Wasserman and his team could not determine with certainty whether his early results showed that the reaction was working properly. However, they did provide an early, incomplete, tentative signal that they were on the right path—the *widerstandsaviso* (Borck, 2004, p. 457, 2006, p. 454). The widerstandsaviso is not the autonomous influence of the material world, and it need not oppose the expectations of researchers (although it may). It is simply the earliest hint that a network is generating passive resistance.

Fleck used the metaphor of radio operators casting around for a signal to illustrate the process by which the widerstandsaviso turns into full blown passive resistance

(Fleck, 1979, p. 86). At first, all they hear is white noise. Then, in the noise, some researchers can make out the faintest hint of a signal. This is initially not clear enough to discern what the signal is exactly, but it is enough to indicate there is something worth pursuing, that the game is afoot. They continued to work on the reaction, learning about how it should be carried out and controlled. They learned that certain negative controls could return positive results and modified their procedures to cope with this problem. They learned how to carry out their procedures at the correct speed, to reduce the variability of results. They stopped sourcing their immune serum from monkeys to test patients for syphilitic antigen, instead focusing on testing patient serum for antibodies to syphilitic antigen. They added these elements to their network, tightening it, reducing the degree of freedom they had to interpret their results in different ways, until no one would deny the reaction's value as a diagnostic test for syphilis. At this point, the objects of the syphilis disease entity and the Wassermann reaction became firm and distinct, and the fact of the relationship between these objects became established.

The network became sufficiently tight so that researchers knew what syphilis was. It was also sufficiently tight so that they knew how the Wassermann reaction was carried out, and how to read the results. With these active elements in place, they could now ask the questions 'do patients with syphilis return positive results?' and 'do patients without syphilis return negative results?' It is crucial to recognize that the answers to these questions were not fixed by the active elements of knowledge already adopted. Answering yes or no to either question, or both, would not have contradicted any of the logical consequences of adopting the active elements of knowledge in the network. All combinations of answers were logically possible. Patients with syphilis might have tested positive, or they might not. Patients without syphilis might have tested negative, or they might not. And yet, the researchers *were not free* to answer these questions in any way they please. Whether or not the Wassermann reaction accurately detects syphilis *was not up to them*. As it happened, the Wassermann reaction was found to be accurate. When they carried out the Wassermann reaction, to look and see whether it accurately detected syphilis, researchers were constrained by their results, and not simply by the active elements of knowledge.[8] This constraint is not self-imposed. It is *in addition to* the self-imposed constraint provided by the active element of knowledge. This additional loss of freedom, over and above the loss bargained for by accepting the active element of knowledge, is the passive element of knowledge.

As we constrain ourselves, we lose a greater degree of freedom than we bargained for

The passive element of knowledge resists the will of researchers. As it turns out, this resistance can also conflict with active elements that gave rise to it. This is exactly what happened with the Wassermann reaction (Fleck, 1979, pp. 73–74). During the process of increasing the density of the network, something truly surprising was observed by serological researchers. Instead of trying to detect antigen in patients' blood using

[8] Ilana Löwy (2004b) describes how researchers later came to find that the Wassermann reaction was not an accurate test for syphilis. Even so, there was a fact of the matter to be determined, making my point.

antibodies produced in the laboratory, they had come to focus more on detecting antibodies in patient serum, using syphilitic antigen extracted in the laboratory. Within two years of Wassermann's first publication, several teams of researchers had shown that the Wassermann test would still distinguish syphilitic from non-syphilitic patients *even if syphilitic antigen extracts were not used in the test*. Extracts made from healthy tissue, and even tissue from non-human animals such as beef heart, could be used in place of the syphilitic antigen. As there was no syphilitic antigen present in the reacting mixtures, the immunological reaction taking place could not be immunologically specific for the syphilis pathogen. As discussed, an active element of knowledge within the serological thought style was that antibody/antigen interactions were immunologically specific (element 1). The Wassermann reaction was conceived of and developed assuming that this was true. Wassermann's whole project, of developing a complement fixation test for syphilis, made no sense at all unless this was true. And yet, it was not.

Despite the theoretical confusion this result caused, serologists continued developing the Wassermann reaction, as it could distinguish between cases with and without syphilis, even if how it did this was not understood. Even so, Fleck argued that the observation that the Wassermann reaction was not immunologically specific contradicts Wassermann's belief that the test worked by exploiting the immunological specificity of antibody/antigen reactions. "The belief of Wassermann and his coworkers 'that a spirochaete antigen and spirochaete amboceptor, that is, a specific antigen–antibody reaction, had been demonstrated' was therefore completely mistaken" (Fleck, 1979, p. 74). Fleck argued that there was something *wrong* about Wasserman's early beliefs and about the serologists' thought style.

This finding resisted the will of the researchers. No matter how unexpected it was, no matter how much they would have preferred to believe something else, it was a fact that the Wassermann reaction was not immunologically specific. Even though this fact was generated by the serologists' thought style, and could not exist without it, it still undermined the very tenets that had brought it into existence. The serologists' thought style suffered the same fate as Victor Frankenstein—each being destroyed by what they created.

Fleck did not contradict himself by claiming both that all facts are the product of stylized thought constraint and that the belief in the immunological specificity of the Wassermann reaction was completely mistaken. Both claims are perfectly consistent within his epistemology. Fleck shows us how to reject scientific realism entirely whilst at the same time preventing the collapse into pernicious relativism. Facts about the accuracy of the Wassermann reaction do not correspond to the way a mind and culture independent world is, as they only come into existence once mind and culture dependent active element of knowledge is accepted. Changing what is accepted as the active element of knowledge will change how the passive element of knowledge resists the will of researchers. However, this not a pernicious form of relativism, where facts about the Wassermann reaction are whatever researchers believe them to be. The passive element of knowledge resists the will of researchers, even though it does not correspond to the way the world is in itself. For Fleck, the passive resistance generated by the network would never correspond to an absolute reality. Rather, passive resistance provides inspiration for further modifications to the network of knowledge, to endlessly generate new ways of being resisted.

5 Conclusion

Fleck's epistemology is a form of relativism that is neither pernicious nor self-contradictory. Fleck denied that *absolute* knowledge of the world-in-itself is possible. He made no appeal to what this mind and culture independent world is like in his epistemology. Nor does he refer to what is similar to it, or fits with it, or conforms to it.

The active element of knowledge responds to the will of researchers and generates the passive element of knowledge, which resists the will of researchers. This resistance to researchers' will is what licenses knowledge so produced as factual. As the passive resistance is generated within the network of active elements, and will change if different active elements are adopted, the passive element is *dependent* upon the active element for its very existence. This dependence is also a *local* dependence, as the active element of knowledge is part of researchers' culture. Nevertheless, the passive element is not fully determined by the active element. The passive element can conflict with the beliefs and expectations of researchers. The passive element can even conflict with the active element that brought it into being, showing it to be mistaken. Even though facts are relative to a thought style, they are still facts.

Fleck described how researchers may adopt different active elements of knowledge, which produce a *multiplicity* of different sets of facts, and these different sets of facts are in *conflict* with each other. The disease syphilis was a different object after the development of the Wassermann reaction compared to before, as the results of the Wassermann reaction were used to include patients with secondary, latent and tertiary syphilis in this disease category. Whole diseases might exist in one thought style that may be absent in another. One might view this as a weak form of incompatibility, as facts about the prevalence of syphilis in a given population produced in these different thought styles are in conflict because syphilis is a different object in these thought styles. As the patients have different characteristics in different thought styles, they could even be considered as different people. This would be consistent with Fleck's claim that "every discovery is actually a recreation of the whole world by a thought collective" (Fleck, 1979, p. 102). And yet, if we allow the patients in these populations to be seen as the same patients, diminishing the amount of recreation going on during a shift from one thought style to another, then there will be patients who have the same disease status in one thought style but different a disease status in another. Thus, if we diminish the amount of world creation going on when changing from one thought style to another, we increase the amount of incompatibility between the thought styles. Whether this constitutes a stronger or weaker form of relativism I do not know.

Thought styles are not *equally valid* in the universal sense: all thought styles are not *equally valid*. Researchers may claim that a thought style generates passive resistance that it does not. Such claims are mistaken, as Fleck points out. However, some thought styles are *equally valid* in the existential sense, as there are many thought styles that do generate passive resistance without corresponding to or resembling anything in a mind and culture independent world.

One may object that the requirement for producing passive resistance is an absolute criterion by which all knowledge claims must be judged, disqualifying Fleck's philosophy as form of relativism. Notice that this objection would only exclude Fleck's

philosophy as a form of epistemic relativism about the standards by which knowledge is judged. Fleck's philosophy could still be a form of factual relativism, as different sets of facts are still generated in different frameworks. Even so, I don't think this objection is fair. Resistance is not one uniform thing in every framework. As discussed, resistance comes by degree, it is not present or absent. A certain degree of resistance may be adequate in one framework but not in another. Resistance also differs in kind. Researchers might prefer frameworks that generate passive facts about which patients are infectious to other people, about who has a particularly poor prognosis, or who will respond to a particular therapy. Different thought styles can perform better or worse according to these differing standards. Although I have not provided an example of these different standards being mutually unintelligible, I see no reason why they would have to be mutually intelligible. Thus, Fleck's relativism is compatible with *non-appraisal*. But these differing standards need to be adopted as part of the active element of knowledge, and do not exist as a transcendent, culture-independent standard. Rather, if we follow Fleck, they are adopted for historically contingent reasons. Going beyond Fleck, they could be selected for pragmatic purposes. Thus, there is *no neutral* set of criteria by which every knowledge claim can be judged. Even so, multiple frameworks can produce knowledge claims that are *equally valid* in the sense of having the same rank because they all produce passive resistance. However, this is 'ranking' in a diminished sense, as passive resistance only provides a necessary criterion for accepting claims as knowledge. The presence of some form of passive resistance does not provide a sufficient criterion for knowledge, which is required for a proper or complete ranking of knowledge claims. As these additional criteria are culturally specific or pragmatic, there is *no neutral* way of carrying out such a proper or complete ranking of knowledge claims. Thus, multiple frameworks can produce knowledge claims that are also *equally valid* in the sense of there being *no neutral* and complete set of criteria that can be used to rank them. I suggest Fleck's philosophy is both an epistemic and a factual relativism.

Fleck's relativism about science is reasonable because it shows how knowledge can be dependent upon the active frameworks that generate it, whilst not collapsing into silly and pernicious relativism. Knowledge is dependent upon our culturally adopted active elements without being determined by them. We do not need anything outside of the framework. Even if everything we experience only exists inside our active frameworks, we can still experience passive resistance to our will. We can still have facts. We can still have science.

Acknowledgements I am indebted to Martina Schlünder for her help hammering this article into itself on the anvil of rejection.

Funding This research was funded by the Dutch Research Council (N.W.O), as part of the project "Health and disease as practical concepts: a pragmatist approach to conceptualization of health and disease", project number 406.18.FT.002. https://www.erasmusmc-rdo.nl/project/health-and-disease-as-practical-concepts/.

Declarations

Conflict of intesers The author has no relevant financial or non-financial interests to disclose. The author has no competing interests to declare that are relevant to the content of this article.

References

Ashton, N. A. (2020). Scientific perspectives, feminist standpoints, and non-silly relativism. In A.-M. Crețu & M. Massimi (Eds.), *Knowledge from a human point of view* (pp. 71–85). Springer. https://doi.org/10.1007/978-3-030-27041-4_5

Babich, B. E. (2003). From Fleck's Denkstil to Kuhn's paradigm: Conceptual schemes and incommensurability. *International Studies in the Philosophy of Science, 17*(1), 75–92. https://doi.org/10.1080/02698590305236

Baghramian, M. (2019). I—The virtues of relativism. *Aristotelian Society Supplementary, 93*(1), 247–269. https://doi.org/10.1093/arisup/akz013

Baghramian, M., & Coliva, A. (2020). *Relativism*. Routledge.

Boghossian, P. (2006). Fear of knowledge: Against relativism and constructivism. *Oxford University Press*. https://doi.org/10.1093/acprof:oso/9780199287185.001.0001

Boorse, C. (1997). A rebuttal on health. In J. M. Humber & R. F. Almeder (Eds.), *What is disease?* (pp. 1–134). Humana Press. https://doi.org/10.1007/978-1-59259-451-1_1

Borck, C. (2004). Message in a bottle from 'the crisis of reality': On Ludwik Fleck's interventions for an open epistemology. *Studies in History and Philosophy of Science Part C: Studies in History and Philosophy of Biological and Biomedical Sciences, 35*(3), 447–464. https://doi.org/10.1016/j.shpsc.2004.06.002

Borck, C. (2006). Between local cultures and national styles: Units of analysis in the history of electroencephalography. *Comptes Rendus Biologies, 329*(5), 450–459. https://doi.org/10.1016/j.crvi.2006.03.015

Brorson, S., & Andersen, H. (2001). Stabilizing and changing phenomenal worlds: Ludwik Fleck and Thomas Kuhn on scientific literature. *Journal for General Philosophy of Science / Zeitschrift Für Allgemeine Wissenschaftstheorie, 32*(1), 109–129.

Cassirer, E. (1950). *The problem of knowledge: Philosophy, science, and history since Hegel*. Yale University Press.

Chang, H. (2016). Pragmatic realism. *Revista de Humanidades de Valparaíso, 8*, 107–122.

Cunningham, A. (2002). Identifying disease in the past: Cutting the gordian knot. *Asclepio, 54*(1), 13–34. https://doi.org/10.3989/asclepio.2002.v54.i1.133

Fehr, J. (2012). '…The art of shaping a democratic reality and being directed by it…'—Philososophy of science in turbulent times. *Studies in East European Thought, 64*(1/2), 81–89.

Fleck, L. (1979). *Genesis and development of a scientific fact*. University of Chicago Press.

Gagné-Julien, A.-M. (2021). Towards a socially constructed and objective concept of mental disorder. *Synthese, 198*(10), 9401–9426. https://doi.org/10.1007/s11229-020-02647-7

Giere, R. N. (2006). *Scientific perspectivism*. University of Chicago Press.

Ginev, D. (2015). Ways and dynamics of reception of Ludwik Fleck's work in the social sciences. *Social Science Information, 54*(2), 192–210. https://doi.org/10.1177/0539018414566422

Harré, R., & Krausz, M. (1996). *Varieties of relativism*. Blackwell.

Harwood, J. (1986). Ludwik Fleck and the sociology of knowledge. *Social Studies of Science, 16*(1), 173–187. https://doi.org/10.1177/030631286016001009
Hedfors, E. (2006). The reading of Ludwik Fleck: Questions of sources and impetus. *Social Epistemology, 20*(2), 131–161. https://doi.org/10.1080/02691720600784477
Jasanoff, S. (2012). Genealogies of STS. *Social Studies of Science, 42*(3), 435–441. https://doi.org/10.1177/0306312712440174
Kienhues, D., Jucks, R., & Bromme, R. (2020). Sealing the gateways for post-truthism: Reestablishing the epistemic authority of science. *Educational Psychologist, 55*(3), 144–154. https://doi.org/10.1080/00461520.2020.1784012
Koterski, A. (2002). Affinities between Fleck and Neurath. In M. Heidelberger & F. Stadler (Eds.), *History of philosophy of science: New trends and perspectives* (pp. 299–306). Springer. https://doi.org/10.1007/978-94-017-1785-4_23
Kulyk, O. (2019). Chaos in Heinrich Rickert's philosophy. *Granì, 22*(8), 37–46.
Kusch, M. (Ed.). (2019). *The Routledge handbook of philosophy of relativism*. Routledge.
Kusch, M. (2019a). Introduction: A primer on relativism. In M. Kusch (Ed.), *The Routledge handbook of philosophy of relativism* (pp. 1–8). Routledge.
Kusch, M. (2019b). II—Relativist stances, virtues and vices. *Aristotelian Society Supplementary, 93*(1), 271–291. https://doi.org/10.1093/arisup/akz007
Kusch, M. (2020a). Relativism in the sociology of scientific knowledge revisited. In N. A. Ashton, M. Kusch, R. McKenna, & K. A. Sodoma (Eds.), *Social epistemology and relativism* (pp. 184–203). Routledge.
Kusch, M. (2020b). *Relativism in the philosophy of science*. Cambridge University Press.
Kusch, M., Steizinger, J., Kinzel, K., & Wildschut, N. J. (Eds.). (2019). *The emergence of relativism: German thought from the enlightenment to national socialism*. Routledge.
Latour, B. (2007). A textbook case revisited. Knowledge as mode of existence. In E. J. Hackett, M. Lynch, J. Wajcman, & O. Amsterdamska (Eds.), *The handbook of science and technology studies* (3rd ed., pp. 83–112). The MIT Press. https://hal-sciencespo.archives-ouvertes.fr/hal-00972922
Longino, H. E. (2002). *The fate of knowledge*. Princeton University Press.
Löwy, I. (1993). Testing for a sexually transmissible disease, 1907–1970: The history of the Wassermann reaction. *AIDS and Contemporary History* (pp. 74–92). Cambridge University Press.
Löwy, I. (2004a). Introduction: Ludwik Fleck's epistemology of medicine and biomedical sciences. *Studies in History and Philosophy of Science Part C: Studies in History and Philosophy of Biological and Biomedical Sciences, 35*(3), 437–445. https://doi.org/10.1016/j.shpsc.2004.06.005
Löwy, I. (2004b). 'A river that is cutting its own bed': The serology of syphilis between laboratory, society and the law. *Studies in History and Philosophy of Science Part C: Studies in History and Philosophy of Biological and Biomedical Sciences, 35*(3), 509–524. https://doi.org/10.1016/j.shpsc.2004.06.006
Mazumdar, P. M. H. (1995). *Species and specificity: An interpretation of the history of immunology*. Cambridge University Press.
Mulinari, S. (2014). The specificity triad: Notions of disease and therapeutic specificity in biomedical reasoning. *Philosophy, Ethics, and Humanities in Medicine, 9*(1), 14. https://doi.org/10.1186/1747-5341-9-14
Neurath, O. (1931). Soziologie im physikalismus. *Erkenntnis, 2*, 393–431.
Omodeo, P. D. (2020). The struggle for objectivity: Gramsci's historical-political vistas on science against the background of Lenin's epistemology. *HoST—Journal of History of Science and Technology, 14*(2), 13–49. https://doi.org/10.2478/host-2020-0013
Poincaré, H. (1905). *Science and hypothesis*. The Walter Scott Publishing Company.
Rickert, H. (1986). *The limits of concept formation in natural science: A logical introduction to the historical sciences* (Abridged). Cambridge University Press.
Schnelle, T. (1986). Microbiology and philosophy of science, Lwów and the German Holocaust: Stations of a life—Ludwik Fleck 1896–1961. In R. S. Cohen & T. Schnelle (Eds.), *Cognition and fact: Materials on Ludwik Fleck* (pp. 3–36). Springer. https://doi.org/10.1007/978-94-009-4498-5_1
Smith, B. H. (2006). *Scandalous knowledge: Science*. Edinburgh University Press.
Steizinger, J. (2019). National socialism and the problem of relativism. In M. Kusch, J. Steizinger, K. Kinzel, & N. J. Wildschut (Eds.), *The emergence of relativism* (pp. 233–251). Routledge.
Strong, T. B. (2019). Truth, facts, alternates and persons: Or, whatever has happened to post-modernism? In A. Condello & T. Andina (Eds.), *Post-truth, philosophy and law* (pp. 136–154). Routledge.

Stump, D. J. (1988). The role of skill in experimentation: Reading Ludwik Fleck's study of the Wasserman reaction as an example of Ian Hacking's experimental realism. *PSA: Proceedings of the Biennial Meeting of the Philosophy of Science Association, 1988*(1), 302–308. https://doi.org/10.1086/psaprocbienmeetp.1988.1.192997

Stump, D. J. (2022). Fallibilism versus relativism in the philosophy of science. *Journal for General Philosophy of Science, 53*(2), 187–199. https://doi.org/10.1007/s10838-021-09579-x

van den Belt, H. (2011). The collective construction of a scientific fact: A re-examination of the early period of the Wassermann reaction (1906–1912). *Social Epistemology, 25*(4), 311–339. https://doi.org/10.1080/02691728.2011.604446

van den Belt, H., & Gremmen, B. (1990). Specificity in the era of Koch and Ehrlich: A generalized interpretation of Ludwik Fleck's 'serological' thought style. *Studies in History and Philosophy of Science Part A, 21*(3), 463–479. https://doi.org/10.1016/0039-3681(90)90005-S

Veigl, S. J. (2021). Notes on a complicated relationship: Scientific pluralism, epistemic relativism, and stances. *Synthese, 199*(1–2), 3485–3503. https://doi.org/10.1007/s11229-020-02943-2

Zittel, C. (2014). The politics of cognition: Genesis and development of Ludwik Fleck's 'Comparative Epistemology.' In M. Epple & C. Zittel (Eds.), *Science as cultural practice: Vol. I: Cultures and politics of research from the early modern period to the age of extremes* (pp. 183–200). De Gruyter. https://doi.org/10.1524/9783050087092.183