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# SUFFICIENCY OF DISCLOSURE AND AI-RELATED INVENTIONS

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Sufficiency of disclosure in patent law serves as a threshold requirement, linking private reward to public benefit. This article argues that AI-related inventions expose a structural tension within sufficiency doctrine, particularly where formal legal enablement diverges from practical reproducibility and knowledge dissemination. While existing doctrines of enablement, plausibility, and possession remain conceptually coherent, their application to data-dependent and opaque AI technologies may validate disclosures that are legally sufficient but practically irreproducible.

Building on a distinction between Core AI and Applied AI, this article shows that disclosure challenges arise most acutely in Applied AI, where technical effects depend on training data, training methods, model configuration, or trained model states. Through a comparative analysis of the UK, EU, US, Singapore, and China, it develops a context-sensitive, reproducibility-oriented approach to sufficiency without requiring AI-specific legal tests.

## I. Introduction

The patent system promotes innovation by granting inventors exclusive rights in exchange for public disclosure of their inventions.[1] This exchange is operationalised through the requirement of sufficient disclosure, which obliges the patent applicant to describe the invention in terms that enable a person skilled in the art to reproduce it without undue experimentation.[2] Sufficiency thus functions as a threshold condition for patent validity, conditioning entitlement to private reward on the provision of public benefit through disclosure. The skilled person, while a legal fiction, is normatively understood as an ordinary skilled person with common general knowledge in the relevant technical field, with the level of expertise, resources, and equipment varying according to the nature of the invention.[3] In this way, sufficiency is designed

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1 Lionel Bently *et al*, *Intellectual Property Law*, 6th ed (Oxford: Oxford University Press, 2022) [Bently *et al*] ch 14 at 409.

2 Patents Act 1977 (UK), ss 14(3), 14(5); *European Patent Convention* [*EPC*] art 83; 35 USC § 112 (a); Patents Act 1994 (Singapore), ss 25(4), 25(5); Patent Law of the People's Republic of China (2020 Amendment), art 26.

3 *General Tire & Rubber Co v Firestone Tyre & Rubber Co Ltd*, [1972] RPC 457 at 466; [1995] OJ EPO 275 at 283 (Enlarged Board of Appeal-G 2/93); *Panduit Co v. Dennison Mfg Co.*, 810 F 2d 1561 (Fed Cir 1987) at [40] ("how the skilled would employ 'engineering principles' and 'common experience'"); *Ng Kok Cheng v Chua Say Tiong* [2001] SGHC 143 [*Ng Kok Cheng* (2001)]; The Supreme People's

to secure not merely formal enablement, but a socially meaningful transfer of technical knowledge.

The emergence of artificial intelligence-related ("AI-related") inventions places this doctrinal settlement under strain. In this article, AI-related inventions contain two main types, which are inventions on core AI technology itself ("Core AI") and inventions in which AI is part of the inventive concept ("Applied AI").[4] In this article, references to AI-related inventions are descriptive rather than definitional, encompassing patent claims whose technical contribution depends materially on algorithmic decision-making, training processes, or data-dependent optimisation. Two features of AI are particularly disruptive. First, many AI systems exhibit a "black box" character as their internal decision-making processes are opaque even to their designers,[5] complicating the articulation of how claimed technical effects are achieved. Secondly, AI-related inventions frequently depend on training datasets that are proprietary, inaccessible, or impractical to disclose in full.[6] Where the technical contribution of an invention lies not in a novel algorithmic architecture but in model training, data selection, or optimisation, the absence of meaningful disclosure of datasets raises acute questions about whether enablement can be satisfied in any substantive sense.[7]

These developments expose a deeper structural tension within patent law. While sufficiency continues to be assessed doctrinally as a formal inquiry into enablement without undue experimentation,[8] AI-related inventions reveal a widening gap between theoretical enablement and practical reproducibility. It is increasingly possible for a patent to satisfy the legal test of sufficiency as enablement, while nevertheless failing to equip others to replicate, verify, or meaningfully build upon

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Court (PRC), *Interpretation (II) of the Supreme People's Court on Several Issues concerning the Application of Law in the Trial of Patent Infringement Dispute Cases (2020 Amendment)*, art 4.

4 World Intellectual Property Organization ("WIPO"), *WIPO Conversation IP and Frontier Technologies: AI Inventions* (2023) <https://www.wipo.int/documents/d/frontier-technologies/docs-en-pdf-wipo-ai-inventions-factsheet.pdf> [*WIPO Frontier Technologies*]. This article refers to WIPO's definitions of AI inventions. Even though the way of naming AI-related inventions is different, the substantive meanings are the same. In addition, the terms "Core AI" and "Applied AI" are also used by the UK Intellectual Property Office ("UKIPO"), see UKIPO, *Guidelines for Examining Patent Applications Relating to Artificial Intelligence (AI)* (30 January 2025) <https://www.gov.uk/government/publications/examining-patent-applications-relating-to-artificial-intelligence-ai-inventions/guidelines-for-examining-patent-applications-relating-to-artificial-intelligence-ai--2#sufficiency> [*UKIPO Patent Application Guidelines*] at [3.6]–[3.7]. (Even though the guidance was withdrawn on 11 February 2026, following the judgment of the UK Supreme Court in *Emotional Perception AI Ltd v Comptroller General of Patents, Designs and Trade Marks* [2026] UKSC 3, the way that the UKIPO categorised and defined these two categories of AI-related inventions is of reference value.)

5 Riccardo Guidotti *et al*, "A survey of methods for explaining black box models" (2018) 51:5 ACM Comput Surv (CSUR) 1 [Guidotti *et al*]; Mateo Aboy *et al*, "The Sufficiency of Disclosure of AI Inventions" (2024) 19:11 JIPLP 834 [Aboy *et al*].

6 Hanchen Wang *et al*, "Scientific discovery in the age of artificial intelligence" (2023) 620 Nature 47; Aboy *et al*, *supra* note 5.

7 Aboy *et al*, *supra* note 5.

8 Aboy *et al*, *supra* note 5; Mateo Aboy *et al*, "The Sufficiency of Disclosure of Medical Artificial Intelligence Patents" (2024) 42 Nature Biotechnology 839 [Aboy, *Medical AI*]; Shahrokh Falati, "A Singular Disclosure Requirement Is Necessary for Patent Law" (2022) 24 Colum Sci & Tech L Rev 249; Mark T. Roundtree, "In Support of Industry-Conscious Disclosure Standards for Pharmaceutical and Biotechnology Patents" (2023) 11 Tex A&M L Rev Arguendo 35.

the claimed invention in practice. The result is not merely doctrinal strain, but a weakening of the patent bargain itself, as exclusive rights may be granted without a commensurate contribution to the public domain.

This article argues that AI-related inventions expose a structural mismatch between sufficiency assessed as formal enablement and sufficiency understood as a functional mechanism for reproducibility and knowledge dissemination. To address this tension, sufficiency must be reconceived not merely as enablement without undue experimentation, but as a context-sensitive obligation calibrated to reproducibility, informational spillovers, and the prevention of speculative monopolies.

This article adopts a comparative analysis across five jurisdictions: the United Kingdom ("UK"), the European Union ("EU"), the United States ("US"), Singapore, and China. These jurisdictions are selected to capture distinct institutional approaches to the sufficiency of disclosure and to reflect variation in how patent systems perform their gatekeeping and informational functions in the context of AI-related inventions.

The UK and the EU serve as primary doctrinal reference points, given their sustained emphasis on sufficiency as a constraint on claim scope, articulated through enablement and plausibility, and developed through judicial decisions and the jurisprudence of the Boards of Appeal of the European Patent Office ("EPO"). The US provides a contrasting model in which sufficiency is structured through a separation between the enablement requirement and "written description" requirement,[9] with particular emphasis on possession and the relationship between disclosure and the economic justification of patent rights.[10] Singapore and China illustrate policy-oriented systems in which sufficiency is shaped through administrative calibration and innovation-driven governance, offering insight into how disclosure standards operate under conditions of technological ambition and institutional experimentation.[11] The comparative analysis examines how sufficiency is articulated and applied across these systems, before drawing out the implications of doctrinal variation for reproducibility and knowledge dissemination in AI-related inventions.

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[9] US Patent and Trademark Office ("USPTO"), "2164 The Enablement Requirement [R-11.2013]" in *Manual of Patent Examining Procedure* ("*MPEP*") <https://www.uspto.gov/web/offices/pac/mpep/s2164.html> at ch 2100, § 2164 "the enablement requirement of 35 U.S.C. 112(a), first paragraph, is separate and distinct from the written description requirement."

[10] USPTO, "Guidelines for the Examination of Patent Applications Under the 35 U.S.C. 112(a) or Pre-AIA 35 U.S.C. 112, first paragraph, 'Written Description' Requirement [R-01.2024]" in *MPEP* <https://www.uspto.gov/web/offices/pac/mpep/s2163.html> at ch 2100, § 2163.

[11] Intellectual Property Office of Singapore (IPOS), *Examination Guidelines for Patent Applications* (26 May 2022) <https://isomer-user-content.by.gov.sg/61/d159c40c-f15d-49d6-97de-feb33bca527f/examination-guidelines-for-patent-applications.pdf>; *Supplemental Guidance for the Examination of AI-Related Patent Applications* (11 October 2024) <https://isomer-user-content.by.gov.sg/61/1889bce0-bd7f-4946-8879-4583d3a933a5/supplemental-guidance-for-the-examination-of-ai-related-patent-applications.pdf>; China National Intellectual Property Administration ("CNIPA"), *Patent Examination Guidelines* (2023 version) [CNIPA Patent Examination Guidelines]; *Guidelines for Patent Applications for AI-Related Inventions (Trial Implementation)* [CNIPA AI Guidelines]. For a related discussion of doctrinal recalibration in response to technological and social transformation in Chinese private law, see Lei Chen & Jia Wang, "The Tort Law Reform under the Chinese Civil Code" (2025) 33(1) Eur R Priv L 217.

This article adopts a conceptual and normative approach, informed primarily by utilitarian and economic justifications of patent law. Rather than displacing existing doctrine, these perspectives explain why and when heightened disclosure obligations are normatively warranted in AI contexts. By situating sufficiency within the broader functioning of innovation ecosystems, this analysis shows that disclosure matters not only for legal validity but also for sustaining cumulative innovation, mitigating information asymmetries, and constraining exclusive rights grounded in unverifiable technical claims. Framed this way, the challenge posed by AI-related inventions is not simply one of doctrinal adaptation, but of preserving the integrity of the patent bargain in the face of technologies that destabilise traditional assumptions about knowledge production and transfer.[12]

This article is structured into seven sections. Following this Introduction, Section II explains what AI-related inventions are with examples that may raise issues of insufficient disclosure, and examines the challenges they pose to sufficiency, focusing on issues of opacity and data dependence. Section III outlines the requirement of sufficiency of disclosure in patent law, clarifying its core standards and terminology. Section IV undertakes a comparative analysis of how different patent systems operationalise sufficiency in assessing AI-related inventions. Section V analyses the normative justifications for assessing sufficiency in this context, with particular emphasis on utilitarian and economic frameworks. Section VI develops a context-sensitive account of sufficiency and considers institutional mechanisms for recalibrating disclosure obligations. Section VII concludes by drawing together the doctrinal and normative implications of the analysis.

## II. AI-Related Inventions and Challenges of Insufficient Disclosure

### A. *Scope and Examples of AI-Related Inventions*

In this article, the term "AI-related inventions" is used in accordance with the classifications adopted by the World Intellectual Property Organization and national patent offices. Following WIPO, AI-related inventions are understood to comprise two broad categories: inventions directed to artificial intelligence technology itself ("Core AI"), and inventions in which AI forms part of the inventive concept ("Applied AI").[13] Although different terminology is sometimes used in national guidance, the substantive distinction between these categories is widely shared. The UK Intellectual Property Office, for example, similarly distinguishes between Core AI inventions and those that apply AI techniques as part of a wider technical solution.[14]

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[12] "Patent bargain" is a metaphorical notion referring to the grant of exclusive rights in return for patent disclosure. This also underscores the principle of *quid pro quo* in the UK Supreme Court and the US Supreme Court, see *Warner-Lambert Co LLC v Generics (UK) Ltd* [2018] UKSC 56 [*Generics* (UKSC)] at [98]; *Eldred v. Ashcroft*, 537 US 186 (2003) at 216.

[13] *WIPO Frontier Technologies*, *supra* note 4.

[14] *UKIPO Patent Application Guidelines*, *supra* note 4 at [3.6]–[3.7].

While the analysis adopts this broad institutional classification, the disclosure challenges examined in this article arise most sharply in relation to Applied AI, where AI systems form part of the claimed technical solution and reproducibility depends on data-dependent and often opaque processes.[15] The analysis does not seek to introduce additional taxonomies, but to examine how existing sufficiency standards function when applied to AI-related inventions falling within these established categories. For the purposes of illustration, this article distinguishes between "Core AI" and "Applied AI" inventions by reference to whether the claimed technical effect is confined to the development or improvement of computational or algorithmic processes themselves, or whether it is realised through interaction with a specific technical application beyond the internal operation of the AI system.[16]

Disclosure of Core AI technologies, such as computer-implemented methods for auto-tuning machine learning and deep learning models, focuses on how training datasets affect model performance and enable the claimed technical effects.[17] The description of datasets remains at a functional or abstract level without further details. Although the availability of training data is a necessary precondition, the technical effect lies primarily in the deep neural network ("DNN") architecture and its training method.[18] The same technical effect can, in principle, be achieved across different tasks, provided that the dataset structure remains comparable.[19]

Whereas the disclosure of Applied AI technologies focuses on how parameters derived from datasets are extracted and used as inputs for model training. For example, an invention claims a method that transforms information about a driver's behaviour into a target function for a machine-learning model.[20] Although the specification suggests that the model may be trained using training images as inputs and corresponding content information as outputs, it fails to provide any substantive description of the characteristics of the training datasets intended to capture drivers' behaviour in aggregate.[21] Similarly, an invention concerns computer-implemented techniques for cell localisation and classification.[22] The specification explicitly describes using images of biological samples as inputs for training machine learning models; however, it only specifies general features of the input data rather than the overall characteristics of the dataset.[23] Although more concrete than disclosures in applications involving Core AI, disclosures of Applied AI remain at a general level and do not provide detailed characteristics of the dataset itself.[24] The relatively concrete disclosure focuses on how pieces of information as data are collected from

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15 "Applied AI", *ibid* at [3.6].

16 Examples of Core AI inventions: EP2953066B1, EP3568811B1, EP3459017B1; examples of Applied AI inventions: EP4287091B1, EP4210019B1, EP3750765B1, EP4196889B1. Data source: Espacenet <https://worldwide.espacenet.com/>.

17 See *UKIPO Patent Application Guidelines, supra* note 4 at [7]–[7.17].

18 See EP3459017B1.

19 See EP2953066B1.

20 See EP3750765B1.

21 *Ibid.*

22 See EP4196889B1.

23 *Ibid.*

24 See EP2953066B1, EP3568811B1, EP3459017B1, EP4287091B1, EP4210019B1, EP3750765B1, EP4196889B1.

various sources, rather than on datasets *per se*,[25] which have been compiled and developed specifically for training AI models.

### B. *Challenges to the Sufficiency Requirement*

The sufficiency requirement is designed to uphold the patent bargain by conditioning exclusive rights on the disclosure of technical knowledge that others can use.[26] In doctrinal terms, sufficiency is satisfied where the invention can be enabled without undue experimentation.[27] In functional terms, it supports the dissemination of knowledge and the accumulation of innovation over time.[28] AI-related inventions place these two functions under strain. The distinctive features of AI systems expose a widening gap between formal enablement and practical reproducibility, calling into question whether existing sufficiency standards can continue to perform their intended role.

Two features of AI-related inventions are particularly significant. The first is opacity.[29] Many AI systems operate as "black boxes" in the sense that their internal decision-making processes cannot be readily explained or traced, even by their designers.[30] This opacity affects how AI-related inventions are described in patent specifications. Rather than setting out a clear technical pathway to the claimed result, disclosures may rely on functional descriptions or high-level architectural claims that obscure the basis of the technical contribution.[31] While such descriptions may satisfy formal enablement requirements, they often provide limited guidance to a skilled person seeking to reproduce the invention in practice. The second feature is dependence on training data. For many AI-related inventions, performance depends not only on model architecture or algorithmic design but on the selection, composition, and treatment of training datasets.[32] These datasets are frequently proprietary, commercially valuable, or subject to legal constraints such as data protection and contractual obligations.[33] As a result, applicants have strong incentives to withhold meaningful information about training data, even where such information is central

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[25] *Ibid.*

[26] See *supra* note 12.

[27] Bently *et al*, *supra* note 1 ch 20 at 609.

[28] Jeanne C Fromer, "Patent Disclosure" (2008) 94 Iowa L Rev 539 [Fromer].

[29] Stefan Larsson & Fredrik Heintz, "Transparency in artificial intelligence" (2020) 9 Internet Pol'y Rev 1.

[30] Guidotti *et al*, *supra* note 5.

[31] See Applied AI examples: EP4287091B1, EP4210019B1, EP3750765B1, EP4196889B1; Core AI examples: EP2953066B1, EP3568811B1, EP3459017B1.

[32] Ning Ding *et al*, "Parameter-Efficient Fine-Tuning of Large-Scale Pre-Trained Language Models" (2023) 5 Nature Machine Intelligence 220.

[33] Organisation for Economic Co-operation and Development, *Mapping Relevant Data Collection Mechanisms for AI Training* (2025) <https://www.oecd.org/content/dam/oecd/en/publications/reports/2025/10/mapping-relevant-data-collection-mechanisms-for-ai-training_62921889/3264cd4c-en.pdf?utm_source=chatgpt.com>; OpenAI, *OpenAI Data Partnerships* (9 November 2023) <https://openai.com/index/data-partnerships/>.

to the functioning of the invention.[34] This creates a further disjunction between what is disclosed and what is required to reproduce the claimed technical effect.

The implications of the challenges posed by insufficient disclosure in AI-related inventions can be further understood along three dimensions. Firstly, where patents are granted without adequate disclosure, exclusive rights persist without a corresponding contribution to the public domain.[35] Knowledge that should enter the public sphere upon grant, or at least upon expiry, remains inaccessible, weakening the disclosure function that underpins the patent bargain.[36] This raises a structural question about how private control over AI technologies should be calibrated against the public interest in access to technical knowledge.

Secondly, the widening gap between theoretical enablement and practical reproducibility undermines the effectiveness of the sufficiency requirement. Even where formal enablement standards are met, disclosures that do not allow a skilled person to reproduce or verify the claimed invention in practice diminish the capacity of patent law to promote knowledge dissemination and cumulative innovation.[37] In this respect, insufficiency in AI patents risks hollowing out sufficiency as a functional safeguard, calling into question its role in advancing societal welfare through innovation.

Finally, the combination of patent protection with the strategic concealment of key technical information distorts the allocation of knowledge within innovation markets.[38] Where AI inventors withhold essential details, whether to preserve competitive advantage or to monetise complementary assets, patents may operate less as instruments of disclosure and more as tools of exclusion.[39] This dynamic can constrain lawful design-around activity and follow-on innovation, particularly in fields characterised by cumulative technological development.[40]

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34 Alexander Wan *et al*, "The 2025 Foundation Model Transparency Index", *arXiv cs.AI* (11 December 2025) <https://arxiv.org/abs/2512.10169>; Katherine J Strandburg, "Users as innovators: Implications for patent doctrine" (2008) 79 U Colo L Rev 467 at 521.

35 Katherine J Strandburg, "What Does the Public Get-Experimental Use and the Patent Bargain" (2004) Wis L Rev 81 at 106 [Strandburg].

36 Fromer, *supra* note 28 at 547–554.

37 *Ibid.*

38 There is a possibility that inventors file patents for obtaining exclusive rights while withholding key details about how to reproduce AI-related inventions, which can be exemplified by many cases, such as *Chemcast Corp v. Arco Industries Corp.*, 913 F 2d 923 (Fed Cir 1990) and the requirement for "best mode" under the 35 USC § 112(a). The requirement for best mode, separate from the enablement requirement, under the US patent law was designed to require the inventor display the best approach to reproduce the invention, so "helps fill the gap between enablement's minimum disclosure and the inventor's own knowledge about the preferred implementation of the invention." See also Brian J Love & Christopher B Seaman, "Best Mode Trade Secrets" (2012) 15 Yale JL & Tech 1 at 5 –7. Overall, both the judicial case and the statutory requirement work out to present that some patent agents and their clients employ strategic approaches to obtain patent grants and also conceal key information on how to better reproduce the claimed invention as much as they can. However, this does not argue that inventors cannot enjoy their rights to hold trade secrets, this aims to suggest that inventors should not be prevented from concealing key information of the claimed technical effect of AI-related inventions when they are filing patents.

39 Andrew Beckerman-Rodau, "The choice between patent protection and trade secret protection: a legal and business decision" (2002) 84 J Pat & Trademark Off Soc'y 371.

40 Strandburg, *supra* note 35 at 113.

Together, opacity and data dependence give rise to a structural mismatch within sufficiency doctrine. An AI invention can satisfy the legal test of enablement while remaining practically irreproducible without access to undisclosed information.[41] In such cases, the patent system risks granting exclusive rights over technical knowledge that has not been meaningfully shared.[42] This shifts the balance of the patent bargain in favour of exclusivity, at the expense of the public domain, and weakens the role of disclosure as a mechanism for knowledge dissemination.

However, the challenges identified in this section do not imply that AI-related inventions should be excluded from patent protection, nor that sufficiency standards must be uniformly raised. Rather, they suggest that existing disclosure doctrines may not fully capture the functional demands that AI-driven innovation places on sufficiency. Hence, it becomes necessary to assess how different patent systems apply the sufficiency doctrine to AI-related inventions, and whether current approaches can reconcile formal enablement with practical reproducibility.

## III. Patent Disclosure, Sufficiency Requirements, and Enablement Doctrine

Patent law requires inventions to be disclosed through a specification accompanied by claims. The specification contains a description of the invention, setting out the technical subject matter and explaining how the invention operates, while the claims define the legal scope of the exclusive rights conferred. This disclosure structure reflects a core feature of the patent bargain: exclusive rights are granted only when the invention is disclosed with sufficient clarity to inform others what they specifically cannot do during the term of the patent in the absence of a licence, and hence what they can do after the patent expires.[43] At the international level, art 29 of the Agreement on Trade-Related Aspects of Intellectual Property Rights ("TRIPS Agreement") requires Member States to ensure that inventions are disclosed "in a manner sufficiently clear and complete for the invention to be carried out by a person skilled in the art".[44] Consistent with this obligation, all of the jurisdictions examined in this article treat sufficiency of disclosure as a mandatory condition of patentability.[45]

In practice, sufficiency is assessed through the doctrine of enablement. This doctrine asks whether the patent specification equips the person skilled in the

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41 Jacob S Sherkow, "Patent Law's Reproducibility Paradox" (2016) 66 Duke LJ 845.

42 The concern is evidenced by empirical research, which entails that the grant of patents does not equate to demonstrating that the disclosed information actually enables reproduction. Sixty-two per cent of interviewees claim that they may need supplemental information if they try to reproduce the invention. See Lisa Larrimore Ouellette, "Do Patents Disclose Useful Information" (2011) 25 Harv JL & Tech 545 [Ouellette].

43 See note 12; Strandburg, *supra* note 35 at 112.

44 World Trade Organization *Agreement on Trade-Related Aspects of Intellectual Property Rights* [*TRIPS Agreement*], 15 April 1994, 1869 UNTS 299, (entered into force 1 January 1995), as amended on 23 January 2017, art 29.

45 Patents Act 1977 (UK), ss 14(3), 14(5); *EPC*, art 83; 35 USC § 112 (a); Patents Act 1994 (Singapore), ss 25(4), 25(5); Patent Law of the People's Republic of China (2020 Amendment), art 26.

art to perform the claimed invention without undue experimentation, taking into account the common general knowledge available at the relevant priority date. The enablement inquiry is therefore inherently context-dependent, as both the acceptable degree of experimentation and the attributes of the skilled person vary according to the nature of the invention and the technical field. Section III examines the enablement doctrine by outlining its two core components: the prohibition on undue experimentation and the normative construction of the person skilled in the art. It also considers the treatment of biological materials in biotechnology, where special disclosure mechanisms have been developed to address reproducibility and access constraints. These mechanisms provide a useful analogue for assessing how sufficiency doctrine may respond to the distinctive features of AI-related inventions.

### A. *"Undue Experimentation" and "The Person Skilled in the Art"*

The requirement that an invention be reproducible without undue experimentation lies at the core of the enablement doctrine. Although jurisdictions employ different formulations, such as "undue burden"[46] or "undue experimentation",[47] they share a common underlying inquiry. The specification must guide the person skilled in the art to perform the claimed invention without requiring excessive trial-and-error or the exercise of inventive skill beyond ordinary technical competence.[48] Undue experimentation, therefore, functions as an operational test through which sufficiency of disclosure is assessed across technological fields.

Courts and patent offices have consistently rejected purely quantitative approaches to undue experimentation, such as counting the number of experimental steps or the time required to achieve success, since experimentation is inherently field-sensitive.[49] In some technologies, iterative testing and optimisation are routine and expected, while in others even limited experimentation may be excessive.[50] The decisive question is not the amount of effort involved, but whether the disclosure

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[46] *Human Genome Sciences v Eli Lilly* [2011] UKSC 51 at 33; *PF4A receptors/GENENTECH*, T 0604/04 at [22].

[47] *In re Wands*, 858 F 2d 731 (Fed Cir 1988) [*In re Wands*]; *Amgen Inc. v. Sanofi*, 598 US 594 (2023) [*Sanofi*].

[48] *Mentor Corporation v Hollister Inc* [1993] RPC 7 at 6–7 [*Hollister*]; *Amorphous silica/INEOS*, T 1743/06 at 11-12; *In re Wands* (Fed Cir 1988), *supra* note 49; *Halliburton Energy Services Inc v Smith International (North Sea) Ltd*, [2006] RPC 2 (Singapore cited this UK court decision to explain their standard for testing undue experimentation. See IPOS, *Sufficiency of Disclosure at the Intellectual Property Office of Singapore* <https://www.wipo.int/documents/d/scp/docs-en-meetings-session-34-comments-received-singapore-3.pdf> [IPOS, *Sufficiency of Disclosure*] at [4.1]; CNIPA Patent Examination Guidelines (2023), pt II, ch 4, art 2.4.

[49] *Kirin-Amgen Inc v Hoechst Marion Roussel* [2004] UKHL 46 at [103]–[104], [109] [*Kirin-Amgen*]; *Sanofi* (2023), *supra* note 47; *Dien Ghin Electronic (S) Pte Ltd v Khek Tai Ting (trading as Soon Heng Digitax)* [2011] SGHC 36 [*Dien Ghin Electronic*].

[50] See *Halliburton Energy Services v Smith International (North Sea)*, [2006] EWCA Civ 1715 at [18] [*Halliburton*] ("The setting of a gigantic project, even if merely routine, will not do."); *Cellulose/WEYERSHAEUSER*, T 727/95 at [10] ("The reproduction of the invention depended on a 'stroke of luck'.".)

directs the skilled person to success through routine steps, rather than leaving them to solve technical problems independently.[51]

Accordingly, experimentation will not be considered undue merely because an invention is complex or requires multiple trials, provided that the specification supplies clear technical guidance leading to the claimed result. In contrast, where the disclosure offers only broad possibilities or leaves critical choices to the skilled person without instruction, the experimentation required may exceed what is permissible. This principle is illustrated in cases involving claims to synergistic combinations drawn from large lists of components, where sufficiency depends on whether the specification explains how to select effective combinations or how to identify the claimed technical effect.[52] The law does not require exhaustive disclosure of every step, but it does require that the path to success be disclosed rather than discovered.[53]

Whether experimentation is undue is inseparable from the attributes of the person conducting it. The person is commonly referred to as the skilled person in the art or the person having ordinary skill in the art ("PHOSITA").[54] It was characterised in such a way that a hypothetical construct was used to objectively assess sufficiency. This person is assumed to possess common ordinary skills and general knowledge in the relevant field at the priority date, including the ability to conduct routine experimentation and consult standard sources of information.[55] While the precise characterisation of the skilled person varies across jurisdictions, the core assumption is shared: the skilled person is competent but not inventive, and capable of following technical instructions without exercising independent ingenuity.

The construction of the skilled person is necessarily context-dependent. In assessing sufficiency, patent offices and courts calibrate the level of skill and knowledge by reference to the nature of the invention and the relevant technical field.[56] Where common general knowledge is limited or fragmented, more detailed disclosure may be required to ensure enablement. Conversely, where the skilled person is assumed to possess substantial background knowledge, the specification may rely on that knowledge without restating it. This flexibility allows the sufficiency doctrine to

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[51] *In re Colianni*, 561 F 2d 220 (CCPA 1977).

[52] IPOS, *Sufficiency of Disclosure*, *supra* note 48 at [4.1].

[53] *Hollister* (1993), *supra* note 48 at 4; *Ng Kok Cheng* (2001), *supra* note 3.

[54] Rebecca S Eisenberg, "Obvious to whom? Evaluating inventions from the perspective of PHOSITA" (2004) 19 Berkeley Tech LJ 885; Connor Romm, "Putting the Person in PHOSITA: The Human's Obvious Role in the Artificial Intelligence Era" (2021) 62 BCL Rev 1413; Dan L Burk & Mark A Lemley, "Is Patent Law Technology-Specific?" (2002) 17 Berkeley Tech LJ 1155 [Burk & Lemley] at 1185–1190. The hypothetical notion of "the skilled person in the art" is phased in statutes pertaining to the requirement for sufficiency of disclosure. The similar usage of languages between "the skilled person" for assessing sufficiency and "the skilled person" for assessing inventive step and non-obviousness of inventions may raise questions and doubts about whether the levels of skills and expertise should be the same when they can both be interpreted to have common general knowledge and ordinary skills. However, the question of whether they are slightly different is not the point that this article argues. Burk and Lamley have clarified in their research that "the PHOSITA is equally central to calibrating the legal standard for patent disclosure … indeed, the language appears to tie the enablement requirement to non-obviousness via this shared metric." See also Burk & Lemley at 1186.

[55] See *supra* note 3.

[56] *Kirin-Amgen* (2004), *supra* note 49; *Halliburton* (2006), *supra* note 50; *Sanofi* (2023), *supra* note 47; *Dien Ghin Electronic* (2011), *supra* note 49.

accommodate technological diversity, but it also places pressure on the doctrine where inventions rely on expertise or resources that extend beyond established disciplinary boundaries.

These features of the enablement doctrine are particularly significant for emerging technologies. The relational nature of undue experimentation and the variable construction of the skilled person provide doctrinal tools for adapting sufficiency standards to new forms of invention. At the same time, they raise questions about whether existing assumptions about routine experimentation and common general knowledge remain tenable in contexts where reproducibility depends on opaque processes or restricted inputs. These issues become acute in the case of AI-related inventions, which are examined in the following sections.

### B. *Availability Constraints and the Deposit Analogy*

In some areas of patent law, reproducibility is constrained not by the clarity of description in words but by the limited availability of the materials required to perform the invention.[57] This problem has arisen most prominently in biotechnology, where certain biological materials are not publicly accessible and cannot be adequately characterised through description in words alone.[58] To address this limitation, patent law has developed a deposit mechanism under the Budapest Treaty, allowing applicants to deposit biological material with a recognised depository institution so that others may access it for the purpose of reproducing the invention.[59] The relevance of the deposit regime lies not in its specific mechanics, but in its underlying rationale. It recognises that reproducibility may depend on access to constrained inputs that cannot be fully captured through description in words, while maintaining the *ex ante* integrity of the sufficiency requirement.

All five jurisdictions examined in this article recognise the deposit system as a means of satisfying sufficiency where description in words is insufficient on its own.[60] The doctrinal rationale is not to relax the disclosure requirement, but to preserve the patent bargain where reproducibility depends on access to non-public material.[61] The deposit mechanism operates as a substitute, rather than a replacement, for disclosure. A deposit cannot cure an otherwise deficient specification, nor can a pure description in words suffice where the material itself is unavailable.[62]

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57 In this context, reproducibility serves as a standard for evaluating whether a patented invention can be replicated in practice, distinct from the legal requirement of enablement. See Ouellette, *supra* note 42.

58 Bently *et al*, *supra* note 1 ch 20 at 611–612.

59 Budapest Treaty on the International Recognition of the Deposit of Microorganisms for the Purposes of Patent Procedure, 1977 (as amended 26 September 1980) [Budapest Treaty].

60 Patents Act 1977 (UK), s 125A (inserted by Copyright, Designs and Patents Act 1988 (c 48, SIF 67A), s 295, sch 5, at [30]); *Implementing Regulations to the Convention on the Grant of European Patents* ("EPC Implementing Regulations"), pt II, ch V, r 31; 37 *CFR* §§ 1.801–1.809; *Patents Rules 2007* (Cap 221) (Singapore) R 1, sch 4, at [1]; Detailed Rules for the Implementation of the Patent Law of the People's Republic of China (2023 Rev Ed) (People's Republic of China), art 27.

61 Bently *et al*, *supra* note 1 ch 20 at 611–612.

62 UKIPO, *Manual of Patent Practice*, s 125A (last updated October 2025).

Sufficiency is satisfied only where the specification explains the invention and the deposited material enables its performance.

In determining whether a deposit is required, some patent offices follow a broadly shared analytical sequence. Examiners first consider whether the relevant biological material forms part of the common general knowledge and is publicly accessible at the priority date.[63] If it is not, they assess whether the description in words alone enables reproduction of the invention.[64] Where neither condition is met, a deposit may be necessary to satisfy sufficiency. Applicants may contest the need for a deposit, but cannot rely on assertions of functionality or effect in the absence of reproducible access. The timing of the deposit is treated strictly, reflecting the *ex ante* nature of the sufficiency inquiry. While jurisdictions differ in the precise deadline, with most requiring a deposit before the filing date and the US permitting a deposit before a grant, the underlying principle is the same: sufficiency must be satisfied at the point when exclusive rights are claimed.[65]

The relevance of this doctrinal framework to AI-related inventions lies in the structural similarity between biological materials and training datasets. In both contexts, the technical contribution may depend on access to non-public inputs that cannot be fully captured through descriptive language.[66] Biological systems may lack predictability and repeatability due to their internal complexity, just as AI systems exhibit opacity arising from model architecture, training processes, and data dependence.[67] The deposit regime, therefore, provides a useful analogue for examining how sufficiency doctrine responds when reproducibility depends on access to constrained inputs, without suggesting that AI-related inventions should be treated as biotechnology.[68]

## IV. Sufficiency as a Gatekeeping and Informational Mechanism Across Patent Systems

Across the patent systems of the jurisdictions studied in this article, sufficiency operates in at least two distinct yet related ways. First, it acts as a gatekeeping mechanism that constrains the grant of exclusive rights by excluding speculative or unreliable inventions. Secondly, it functions as an informational requirement that shapes the quality and usefulness of patent disclosures for subsequent innovators and the public. This section examines how different patent systems operationalise sufficiency's gatekeeping and informational functions in the face of technological uncertainty.

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63 *EPC Implementing Regulations*, pt II, ch V, r 31; EPO, *Guidelines for Examination*, pt F, ch III, s 6.3 ("Deposit of biological material").

64 *Ibid*.

65 Patents Rules 2007 (UK), sch 1, at [1], [3]; UKIPO, *Manual of Patent Practice*, s 125A.04 (last updated October 2025); *EPC Implementing Regulations*, pt II, ch V, r 31(a); 37 *CFR* §§ 1.801–1.809; *Patents Rules 2007* (Singapore) (Cap 221) R 1, sch 4, at [1]; *Detailed Rules for the Implementation of the Patent Law of the People's Republic of China (2023 Revision)*, art 27.

66 Aboy *et al*, *supra* note 5 at 839.

67 *Ibid*; Bently *et al*, *supra* note 1 ch 20 at 611–612.

68 *Ibid*.

These dual roles have been developed unevenly across jurisdictions. While some systems emphasise sufficiency as a negative filter to restrict the scope of claims and prevent overreach, others also require a more affirmative demonstration that the invention has been credibly realised and can be reproduced in practice. Examining how these functions are articulated and applied across jurisdictions provides insight into whether existing sufficiency doctrines are capable of responding to the disclosure challenges posed by AI-related inventions.

This section, therefore, undertakes a comparative analysis of sufficiency across five jurisdictions. It first examines how the UK and the EU employ plausibility to preclude speculative inventions and limit excessive exclusivity. It then situates this approach alongside alternative mechanisms used in the US, Singapore and China to assess possession, credibility, and predictability. The analysis does not seek uniformity but instead evaluates whether the sufficiency doctrine operates as intended in the context of emerging, data-dependent technologies.

### A. *The United Kingdom and European Union: Plausibility as a Gatekeeping Standard*

A central function of the sufficiency requirement is to constrain the scope of exclusive rights by ensuring that patent protection corresponds to a credible technical contribution.[69] In both UK and European patent law, this function is expressed through the doctrine of plausibility, which excludes speculative inventions whose asserted technical effects are not adequately supported by the disclosure.[70] Sufficiency, in this sense, serves as a test of reliability, asking whether the technology embodied in the claims can credibly be achieved across their full breadth by a person skilled in the art.[71] As a standard of proof imposed on inventors, a patent may be revoked if plausibility cannot be demonstrated.[72]

Plausibility is seen as a "relatively undemanding" standard, characterised by its flexibility in accommodating the absence of absolute proof at the patent

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[69] *Regeneron Pharmaceuticals v Genentech* [2013] EWCA Civ 93 at [100] [*Genentech*] ("It must therefore be possible to make a reasonable prediction the invention will work with substantially everything falling within the scope of the claim or … the invention will work across the scope of the claim must be plausible or credible").

[70] *Generics* (UKSC), *supra* note 12 at [21]; *Generics (UK) Ltd v Warner-Lambert Co LLC* [2016] EWCA Civ 1006 [*Generics* (EWCA)] at [46]–[47] ("Both the UK Supreme Court and the Court of Appeal expressly suggest that the test of plausibility is used for excluding 'purely speculative claims'"); *BDP1 Phosphatase/MAX-PLANCK*, T 0870/04, at [21] ("A 'vague and speculative' indication of possible objectives … is not sufficient for fulfilment of the requirement of industrial applicability"); *Hematopoietic receptor/ZYMOGENETICS*, T 0898/05 at [5] ("It would be at odds … to grant exclusive rights to prevent the commercial activities of others on the basis of a purely theoretical or speculative patent application").

[71] *Generics* (UKSC), *supra* note 12 at [22]–[23].

[72] In the UK and EU patent systems, plausibility has no explicit statutory foundation, and neither jurisdiction recognises plausibility as an independent ground of patent revocation, but instead it forms part of the sufficiency doctrine, which means that a lack of plausibility can render a patent invalid on the ground of insufficiency. See Bently *et al*, *supra* note 1 ch 20 at 618; *Generics* (UKSC), *supra* note 12 at [39]; [2023] OJ EPO A85 at [92] (Enlarged Board of Appeal-G2/21) [G2/21].

filing date.[73] In many research contexts, particularly where resources are limited, it may be impractical to generate comprehensive experimental or clinical data prior to filing.[74] The plausibility standard therefore permits claims to be supported by a range of evidentiary materials, provided that the asserted technical effect is credibly disclosed.[75] It permits reliance on alternative forms of technical reasoning or indirect evidence, at least provided that the disclosure establishes a credible basis for expecting that the claimed technical effect can be realised.[76] The limit of flexibility is defined by the standard that such alternative forms of demonstration must prove a level of credibility that is functionally equivalent to that provided by experimental data.[77] While the forms and methods of demonstration may vary, the underlying evidentiary threshold must nevertheless be satisfied. This evidentiary calibration reflects a deliberate attempt to balance the exclusion of speculative claims against the need to preserve incentives for early-stage innovation.

Plausibility is commonly understood as operating primarily as a gatekeeping mechanism within the sufficiency doctrine. The key rationale is that it prevents speculative inventions from obtaining exclusive rights over resources that are supposed to belong in the public domain, while still maintaining incentives for technological innovation.[78] Therefore, plausibility operates to strike a balance between these competing interests. Indeed, the balance exists along a spectrum rather than on a single, fixed equilibrium. The UK case law expressly interprets plausibility as a standard to differentiate mere speculations from contributions to the art, whereas the EU refrains from articulating the standard in the same way as the UK does.[79] These approaches reflect different positions along a spectrum, each internally coherent and normatively justified by the respective legal system's expectations concerning the

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[73] *Generics* (UKSC), *supra* note 12 at [36] (The majority (Lord Sumption, Reed, and Briggs) held that "the adoption of plausibility is a mitigation of the principle in favour of patentability". Lord Sumption disagrees with the Court of Appeal's statement that "the threshold was not only low but … could be satisfied by a prediction based on the 'slimmest of evidence'."); *AP-1 complex/SALK INSTITUTE*, T609/02 at 12 [T609/02] ("by not requiring an absolute proof that the compound is approved as a drug before it may be claimed as such. It is required that the patent provides some information in the form of, for example, experimental tests, to the avail that the claimed compound has a direct effect on a metabolic mechanism specifically involved in the disease.").

[74] T609/02, *supra* note 73 at 12, which was also cited in *Genentech* (2013), *supra* note 69 at [103].

[75] G2/21 (2023), *supra* note 74 at [60]. ("The Enlarged Board takes note of the decision in T 578/06, point 13 of the Reasons … no experimental proof for patentability and that considered that the disclosure of experimental data … was not always required to establish that the claimed subject matter solved the objective technical problem.").

[76] *Generics* (UKSC), *supra* note 12 at [37] ("reasonable scientific grounds were disclosed for expecting that it might well work."); *Factor-9/JOHN HOPKINS*, T 1329/04 at [11] ("There is not enough evidence in the application to make at least plausible that a solution was found to the problem which was purportedly solved.").

[77] *Generics* (UKSC), *supra* note 12 at [37] ("Although the disclosure needs not definitely prove the assertion that the product works for the designated purpose, there must be something that would cause the skilled person to think that there was a reasonable prospect that the assertion would prove to be true. The effect on the disease process need not necessarily be demonstrated by experimental data. It can be demonstrated by a priori reasoning."); T609/02, *supra* note 73 at 12.

[78] See *supra* note 72.

[79] *Generics* (UKSC), *supra* note 12 at [37]; Markus Ackermann, "No Need for 'Plausibility' in German Patent Law" (2021) 70:1 GRUR International 3 at 6.

nature and degree of evidentiary support required for patentable subject matter.[80] Accordingly, in the assessment of sufficient disclosure of AI-related inventions, plausibility does not impose a uniform threshold. Instead, it functions as a flexible tool that asks whether the disclosed information, such as model parameters and characteristics of training datasets, provides the skilled person with a reliable prospect of achieving the claimed technical effect. This offers enquiries whose outcomes may legitimately vary across jurisdictions.

Nonetheless, the plausibility test still falls short in clarifying the degree of credibility that must be demonstrated. In other words, it remains inadequate to resolve the structural problem that is the gap between the statutory requirement for enablement and the functional need for reproducibility in any case. Because the assessment ultimately rests on the perspective of the person skilled in the art, its application depends on assumptions about common general knowledge and routine experimentation that may vary across technological contexts. Where AI performance is sensitive to training choices or data configurations that are not evident from the specification, a disclosure may satisfy the plausibility test while still leaving practical reproducibility uncertain.[81] Plausibility performs an important but limited gatekeeping function within the sufficiency doctrine, constraining speculative claims without guaranteeing that disclosed inventions can be reproduced in practice. It constrains speculative claiming by requiring a credible basis for the asserted technical effect, but it does not, by itself, ensure that the disclosure equips the skilled person to reproduce or interrogate the invention in practice, particularly where performance depends on opaque or data-dependent processes.

### B. *The United States: Possession, Physicalism, and Limits of Disclosure*

Plausibility primarily functions to exclude speculative inventions by ensuring that the claimed technical effects have a credible basis. In doing so, sufficiency operates largely in a negative or gatekeeping capacity, constraining claim scope and preventing the issuance of low-quality patents. However, this function alone does not exhaust the role of sufficiency within the patent system. Beyond excluding speculative claims, sufficiency may also be understood as a positive mechanism that ensures an invention has been made, in a concrete sense, by the time patent protection is sought.

This more demanding conception of sufficiency is most clearly articulated in US patent law. The US approach emphasises whether the inventor was in possession of the claimed invention at the filing date.[82] This emphasis reflects a relatively

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[80] Patents Act 1977 (UK), s 1; *EPC,* art 52; Bently *et al*, *supra* note 1 ch 17 at 471, 482–483 (“‘technical contribution’ is currently applied in the UK. It is similar to the approach that was used at the EPO until (around) 2000 … the Technical Boards of Appeal rejected the contribution approach … the Board focused on the character of the invention.”).

[81] Janet Freilich, “The replicability crisis in patent law” (2020) 95 Ind LJ 431; Aboy*, Medical AI*, *supra* note 8.

[82] *Capon v. Eshhar*, 418 F 3d 1349 (Fed Cir 2005) at 1357, 76 USPQ2d 1078 at 1084.

physicalist orientation, under which an invention must have a tangible or otherwise concrete manifestation that demonstrates the inventor's technical understanding and enables others to reproduce the invention without relying on further inventive effort.[83] Physical embodiment, in this sense, improves reproducibility by ensuring that the disclosure reflects an invention that has been realised, rather than merely conceived in abstract or aspirational terms.[84]

The doctrinal foundation of this approach lies in the "written description" requirement under US patent law.[85] Distinct from enablement, a written description requires applicants to demonstrate that they have actually invented and possessed the claimed subject matter, rather than merely articulating a plan or research objective.[86] US courts have consistently insisted on "something more" than functional claiming or high-level description, particularly where the technology is complex or unpredictable.[87] Reliance on literal language alone is often insufficient, as it may obscure the absence of genuine technical possession. The evolution of the "written description" doctrine illustrates the enduring tension within US patent law between encouraging early disclosure and preventing the grant of rights over inventions that have not yet been fully realised.

The physicalist orientation of the US sufficiency doctrine reflects the system's utilitarian foundation.[88] By requiring inventors to demonstrate possession, the law seeks to ensure that exclusive rights are granted only where the disclosed contribution is concrete and reproducible. This approach is particularly relevant to AI-related inventions, where the opacity of algorithmic systems and the dependence on training processes complicate assessments of whether an invention has in fact been made. In the absence of AI-specific examination guidelines, the "written description" requirement provides a doctrinal tool for addressing these challenges by demanding disclosure that evidences technical understanding and implementation. In this way, physicalism operates not merely as a constraint on speculative claims but also as a mechanism to enhance the informational value of patent disclosures and to support knowledge diffusion in technologically complex fields.

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83 Christopher A Cotropia, "Physicalism and Patent Theory" (2016) 69 Vand L Rev 1543 [Cotropia].

84 Cotropia, *supra* note 83 "working requirement"; Jeffrey A Lefstin, "The Formal Structure of Patent Law and the Limits of Enablement" (2008) 23 Berkeley Tech LJ 1141.

85 35 USC § 112.

86 35 USC § 112; see *Moba, B.V. v. Diamond Automation, Inc.*, 325 F 3d 1306 (Fed Cir 2003) at 1319, 66 USPQ2d 1429 at 1438; *Ariad Pharm Inc. v. Eli Lilly & Co.*, 598 F 3d 1336 (Fed Cir 2010) at 1340.

87 See *In re Wilder*, 736 F 2d 1516 (Fed Cir 1984) at 1521, 222 USPQ 369 at 372–373 (affirming rejection because the specification does "little more than outline goals appellants hope the claimed invention achieves and the problems the invention will hopefully ameliorate."); see also USPTO, *2163 Guidelines for the Examination of Patent Applications Under 35 U.S.C. § 112(a)* ("More evidence is required to show possession. For example, disclosure of only a method of making the invention and the function may not be sufficient to support a product claim other than a product-by-process claim.").

88 Early US patent law (Patent Act of 1836, ch 357, 5 stat 117 (enacted 4 July 1836)) required inventors to submit a physical prototype of their invention in situations where a description in words alone might fail to disclose how the invention could be made. Later, these requirements for "physicalism" have been abolished. See Cotropia, *supra* note 83 at 1561.

### C. *Singapore and China's Articulation of Sufficiency*

Singapore and China adopt their own approaches to utilising the sufficiency requirement to exclude speculative inventions. While the terms differ from "plausibility" as used in the UK and EU, their substantive meanings and intended functions are identical. In Singapore, sufficiency of disclosure is assessed primarily through enablement, without recognition of plausibility as a distinct doctrinal requirement.[89] Concerns analogous to plausibility are instead addressed through the assessment of inventive step, particularly via the notion of reasonable prediction. This approach asks whether the claimed invention can credibly be expected to work based on the disclosure and common general knowledge. Although framed differently, it performs a comparable gatekeeping function by limiting patent protection to inventions whose technical contribution is credibly established.

Singapore is analytically significant not merely as a recipient of transplanted doctrine, but as a system in which sufficiency operates at the intersection of common law reasoning and explicit innovation policy, making visible the trade-offs between doctrinal clarity, examination flexibility, and the informational function of disclosure.[90] In practice, where an AI-related invention operates in an unpredictable technical field, concerns analogous to plausibility are addressed through the interaction between sufficiency and inventive step, with the latter functioning as a complementary screening mechanism that asks whether the claimed technical effect can reasonably be expected to be achieved on the basis of the disclosure and common general knowledge.[91] Enablement is accordingly calibrated conservatively to prevent speculative claiming without developing a separate plausibility doctrine.[92]

In China, the sufficiency doctrine similarly relies on the concept of predictability in the relevant art to assess whether enablement can be achieved without undue experimentation.[93] Rather than articulating plausibility as a separate standard, Chinese courts and examiners consider whether the technology underlying the claims is sufficiently predictable to support the asserted effects across their scope.[94] Where the art is unpredictable, greater disclosure may be required, with enablement

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89 *Ng Kok Cheng* (2001), *supra* note 3. Under Article 14(3) of the UK Patents Act 1977, the patent specification must disclose the invention in a manner which is "clear enough and complete enough" for the invention to be performed by a person skilled in the art. In contrast, Article 25(4) of the Singapore Patents Act 1994 contains the same requirement but deletes the word "enough." From a legislative standpoint, in the absence of the term "enough", the requirement for sufficiency in Singapore patent law can be interpreted as stricter than that in the UK. The interpretation does not pertain to a minimum standard, which means that the requirement for sufficiency is met as long as the disclosure enables the skilled person to reproduce the invention, but rather to a demand for absolute clarity and completeness.

90 Wee Loon Ng-Loy, *Law of Intellectual Property of Singapore*, 2d ed (Singapore: Sweet & Maxwell, 2014) at 449–451 (historical origins); Andrew Phang, "The Singapore Legal System — History, Theory and Practice" (2000) 21 Sing L Rev 23; Yihan Goh & Paul Tan, "An Empirical Study on the Development of Singapore Law" (2011) 23 SAcLJ 176.

91 Ng-Loy, *supra* note 90 at 487–490.

92 *Ibid.*

93 CNIPA, *Patent Examination Guidelines* (2023 version), pt II, ch 2, s 3.2.1.

94 CNIPA, "Guidelines for Patent Applications for AI-Related Inventions (Trial Implementation)" (31 December 2024) <https://www.cnipa.gov.cn/art/2024/12/31/art_66_196988.html> [CNIPA AI Guidelines]; (2022) 最高法知行终361号 [Supreme People's Court of China, Intellectual Property Court, Civil Division, Final Judgment]; (2021) 最高法知行终1071号.

calibrated through examination practice rather than rigid doctrinal thresholds.[95] This assessment is primarily shaped by administrative examination practice rather than judicial elaboration, allowing disclosure expectations to be adjusted in line with industrial policy priorities and the perceived maturity of the relevant AI technology.[96] This approach reflects the close alignment between patent examination and industrial policy, allowing sufficiency requirements to be adjusted pragmatically in response to technological uncertainty.

Singapore and China approximate possession without relying on physicalism, since they do not require patent applicants to demonstrate possession of the invention through a distinct physicalist standard. In these jurisdictions, sufficiency of disclosure remains anchored primarily in enablement, with the central inquiry being whether the specification enables a person skilled in the art to perform the invention without undue experimentation. This approach does not demand proof that the invention has been realised in a concrete form at the filing date. Instead, it functions to exclude inventions whose implementation would require excessive trial and error or inventive effort beyond the skilled person's ordinary competence. Read together, the Singaporean and Chinese approaches illustrate how policy-oriented patent systems respond pragmatically to AI-related uncertainty while leaving the normative foundations of disclosure largely implicit, highlighting the need for doctrinal articulation rather than wholesale reform.

### D. *Comparative Perspectives: Jurisdictional Responses to AI-Related Inventions*

Across the five jurisdictions examined, sufficiency of disclosure operates as a legal threshold that performs, to varying degrees, both gatekeeping and informational functions. In practice, however, the information disclosed under this standard typically satisfies only minimum legal requirements and often falls short of securing reproducibility or meaningful knowledge transfer, particularly in the context of AI-related inventions. Rather than reforming sufficiency doctrine itself, jurisdictions have generally responded to the challenges posed by AI through adjustments in examination practice and administrative guidance. These responses reflect institutional compromises shaped by doctrinal traditions, examination structures, and competitive pressures associated with AI development.

In the UK and the EU, administrative guidance has extended plausibility-based analysis to AI-related inventions. Where the performance of an AI system depends materially on training data, applicants may be required to disclose relevant characteristics of those datasets, unless reproducibility can reasonably be achieved without

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[95] Ning Lizhi & Yang Yingying [宁立志 & 杨莹莹], "The Institutional Mechanism and Implementation Path of Patent Protection for Artificial Intelligence Algorithms" [人工智能算法专利保护的制度机理与实现进路" (2025) 11 知识产权24; 李雨峰, "论专利公开与排他利益的动态平衡] (2019) 9 Intellectual Property [知识产权] 3.

[96] CNIPA AI Guidelines, *supra* note 94.

such information.[97] This conditional approach seeks to mitigate the risk of speculative claiming while avoiding a categorical obligation to disclose datasets in all cases. Plausibility thus continues to function as a gatekeeping mechanism, with informational demands addressed pragmatically through examination rather than doctrinal elaboration.

A broadly comparable approach is observable in Singapore. The assessment focuses on whether disclosure of training data, or of its relevant characteristics, is necessary to enable the reproducibility of the claimed invention. Intellectual Property Office of Singapore ("IPOS") guidance emphasises whether the specification enables the skilled person to achieve the claimed technical effect and, where appropriate, whether information concerning training data characteristics is required for that purpose.[98] While these expectations closely track those applied in the UK and EU, they are articulated through administrative practice rather than judicial doctrine. As a result, the normative basis for requiring additional disclosure remains implicit, even where examination outcomes are substantively aligned.

By contrast, neither the US nor China has adopted AI training dataset-specific sufficiency guidelines comparable to those issued in the UK, EU or Singapore. In the US, questions concerning disclosure of training data are addressed indirectly through general enablement and written description doctrines, reflecting an institutional preference for *ex post* judicial assessment and market-based allocation of informational risk.[99] In China, sufficiency is applied more flexibly through administrative calibration, with disclosure expectations adjusted according to the type of AI invention and the technical effects claimed.[100] This approach reflects the close alignment between patent examination and industrial policy, allowing examiners to respond to technological uncertainty without imposing rigid disclosure mandates. In both systems, disclosure requirements are framed as pragmatic tools of examination rather than as expressions of an articulated doctrinal principle concerning reproducibility.

A shared limitation of these guideline-based approaches is the absence of an explicit normative account of when additional disclosure is required. The difficulty lies not in the flexibility of administrative guidance, but in its doctrinal opacity. Where disclosure expectations are articulated primarily at the level of examination practice, it becomes harder to explain, in adjudicative terms, why certain patents should fail for insufficiency despite satisfying formal enablement requirements. This weakens the capacity of sufficiency to function as a principled constraint on exclusive rights and leaves the informational dimension of disclosure underspecified.

The comparative analysis shows that patent systems converge in treating sufficiency as a gatekeeping doctrine aimed at excluding speculative claims, yet diverge

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97 *UKIPO Patent Application Guidelines*, *supra* note 4 at [10.4]; EPO*, Guidelines for Examination*, pt F, ch III, s 3.

98 IPOS, *Supplemental Guidance for the Examination of AI-Related Patent Applications* (11 October 2024) <https://isomer-user-content.by.gov.sg/61/1889bce0-bd7f-4946-8879-4583d3a933a5/supplemental-guidance-for-the-examination-of-ai-related-patent-applications.pdf> at [15].

99 USTPO, "The Enablement Requirement [R-11.2013]", *MPEP* <https://www.uspto.gov/web/offices/pac/mpep/s2164.html> at ch 2100 § 2164.

100 CNIPA, "Guidelines for Patent Applications for AI-Related Inventions (Trial Implementation)" (31 December 2024) <https://www.cnipa.gov.cn/art/2024/12/31/art_66_196988.html>.

in how they articulate and operationalise the informational demands of disclosure in AI-related inventions. Jurisdictions that rely heavily on administrative guidance risk under-specifying the normative basis of disclosure obligations, while those that emphasise market-oriented enforcement may tolerate informational gaps that undermine reproducibility. Other systems strengthen reproducibility indirectly through possession-based requirements, albeit at the cost of higher evidentiary demands. These differences do not reflect doctrinal incoherence, but distinct institutional strategies for managing uncertainty, incentive design, and knowledge diffusion in technologically complex fields.

This divergence indicates why AI-related disclosure challenges cannot be resolved through uniform sufficiency standards. What is needed instead is a context-sensitive account of sufficiency that preserves its core gatekeeping function while allowing disclosure requirements to respond to technological complexity. Such an approach need not impose uniform obligations across all technologies. Rather, it would justify more concrete disclosure where necessary to sustain the patent system's informational function, by clarifying the relationship between enablement, reproducibility, and possession in AI-driven innovation, while remaining attentive to differences in institutional design and innovation policy.

## V. Justifying Context-Sensitive Sufficiency in AI-Related Inventions

As discussed in the preceding sections, the difficulties posed by AI-related inventions do not arise from the absence of the sufficiency doctrine, but from the pressure placed on its established functions. In particular, existing sufficiency standards may be less effective in supporting knowledge dissemination across different technological sectors. This section examines the normative justifications for sufficiency, focusing on its role in facilitating the diffusion of technical knowledge. It prioritises utilitarian and efficiency-based justifications in the context of rapid development cycles, high investment costs, and the reduced practical value of post-expiry access to AI-related inventions. Utilitarian and economic frameworks offer a useful basis for assessing whether current disclosure obligations continue to support the core functions of the patent system.

### A. *The Patent Bargain and the Limits of Formal Reciprocity*

Patent law has long been justified by reference to a reciprocal exchange between inventors and the public.[101] Under the social contract and labour-based accounts,[102] exclusive rights are legitimate only insofar as inventors disclose their inventions in a manner that contributes to the collective stock of technical knowledge.[103] The grant

[101] Bently *et al*, *supra* note 1 ch 14 at 409.

[102] John Locke, *Second Treatise of Government*, edited by CB McPherson (Indianapolis: Hackett Publishing Company, 1980) [*Locke*].

[103] Peter Drahos, *A Philosophy of Intellectual Property*, 1st ed (London: Routledge, 1996).

of exclusivity is conditioned on the transfer of knowledge being disclosed so that others may later use, verify, and build upon it.[104]

Within this framework, sufficiency of disclosure operates as a gatekeeping mechanism that ensures reciprocity.[105] An invention that cannot be reproduced by a person skilled in the art does not fully deliver the knowledge promised in exchange for exclusive rights. From this perspective, the requirement of enablement reflects a baseline commitment to fairness, ensuring that patentees do not appropriate legal control over technical subject matter without providing a commensurate contribution to the public domain.[106]

However, these justificatory accounts are limited in their ability to resolve the disclosure challenges posed by AI-related inventions. Social contract and labour theories explain why disclosure matters, but they do not specify how sufficiency should be assessed where technical contributions depend on opaque processes or inaccessible inputs.[107] In such cases, formal compliance with enablement standards may satisfy the appearance of reciprocity while failing to secure its substance. This limitation suggests that appeals to fairness alone are insufficient to determine whether existing sufficiency standards remain normatively adequate for AI-related inventions.

For this reason, while social contract and labour-based justifications provide an important normative backdrop, they cannot by themselves guide the recalibration of sufficiency doctrine. A fuller account requires engagement with utilitarian and economic considerations that address how disclosure functions within innovation systems, and how failures of reproducibility affect knowledge dissemination and cumulative technological development.

### B. *Utilitarian Justifications: Disclosure, Reproducibility, and Knowledge Spillovers*

Utilitarian accounts of patent law justify exclusive rights on the basis that they promote innovation and, ultimately, social welfare.[108] Within this framework, disclosure serves an instrumental role.[109] It is expected to facilitate the dissemination of technical knowledge, enable verification and cumulative innovation, and generate informational spillovers that benefit actors beyond the patentee.[110] Hence, sufficiency of disclosure is not merely a formal validity requirement, but a mechanism

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[104] Locke, *supra* note 102; Adam D Moore, "A Lockean theory of intellectual property revisited" (2012) 49 San Diego L Rev 1069 at 1096–1098.

[105] Justin Hughes, "The Philosophy of Intellectual Property" (1988) 77 Geo LJ 287.

[106] Bently *et al*, *supra* note 1 ch 20 at 608.

[107] Shubha Ghosh, "Patents and the Regulatory State: Rethinking the Patent Bargain Metaphor After Eldred" (2004) 19 Berkeley Tech LJ 1315 at 1319–1349. The author critiques the metaphor of "patent bargain" as a broad criticism of social contract theory.

[108] Bently *et al*, *supra* note 1 ch 1 at 6.

[109] *Ibid*.

[110] Fromer, *supra* note 28; Brett M Frischmann & Mark A Lemley, "Spillovers" (2007) 107 Colum L Rev 257 [Frischmann & Lemley].

through which patent law seeks to align private incentives with broader social gains.[111]

AI-related inventions reveal the limits of this alignment. As shown in Section II, disclosures that satisfy formal enablement standards may nonetheless fail to support practical reproducibility. Where patents provide only high-level functional descriptions or omit information central to performance, such as training data characteristics or model specialisation, their informational value is reduced. In utilitarian terms, this weakens the link between exclusive rights and the production of socially valuable knowledge.[112] The patent continues to restrict use and follow-on activity, but the expected benefits of disclosure, in the form of learning, verification, and spillovers, are diminished.[113]

From a welfare perspective, this gap matters because patents that are irreproducible in practice do not merely fall short as disclosure documents. They can also distort the innovation process by shifting effort away from cumulative development and towards strategic control of information.[114] Where key technical knowledge remains inaccessible, other innovators are less able to assess feasibility, explore alternative solutions, or build upon prior work.[115] The result is a reduction in the spillover effects that justify the grant of exclusivity in the first place.[116]

Utilitarian reasoning, therefore, supports a context-sensitive understanding of sufficiency. The appropriate level of disclosure should be assessed in light of the contribution that disclosure is expected to make to social welfare in a given technological context. In fields where reproducibility depends on access to non-obvious inputs or processes, sufficiency standards that focus narrowly on formal enablement risk underperform their instrumental function. This does not imply that patents must disclose all information necessary for immediate commercial deployment, but it does require that disclosures enable meaningful engagement with the claimed invention by others operating in the field.[117]

Applied to AI-related inventions, this perspective suggests that sufficiency must be evaluated with greater attention to whether the disclosed information allows

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[111] Strandburg, *supra* note 35 at 111–118.

[112] Mark A Lemley, "The Myth of the Sole Inventor" (2012) 110 Mich L Rev 709 at 745 [Lemley, *Myth*].

[113] *Ibid*; Frischmann & Lemley, *supra* note 110.

[114] Douglas Lichtman, Scott Baker & Kate Kraus, "Strategic Disclosure in the Patent System" (2000) 53 Vand L Rev 2175.

[115] Bently *et al*, *supra* note 1 ch 20 at 608 (without a "fair basis"); Lemley, *supra* note 112 at 745 "inventors don't learn their science from patents. The problem is … that the Federal Circuit has permitted a number of vague general disclosures that don't actually communicate very much to anyone, and patent lawyers often have incentives to write such vague disclosures." See also Alan Devlin, "The Misunderstood Function of Disclosure in Patent Law" (2009) 23 Harv JL & Tech 401.

[116] Frischmann & Lemley, *supra* note 110.

[117] See Lemley, *Myth*, *supra* note 112 at 747, "patent does not so much communicate valuable technical information itself as induce the communication of that information by other means … is that patents encourage public disclosure of information that would otherwise be kept secret." Lemley characterises the minimal function of patent disclosure theory as ensuring that information which would otherwise remain secret is disclosed. Similarly, Fromer also mentions this point, see Fromer, *supra* note 28 at 595–597, "either because information can be retained secretly or because the patent system accepts minimal disclosure". Yet, Fromer also argues that "where if all patentees coordinated to effectuate better disclosure, everyone would be better off … invigorated disclosure would increasingly stimulate competitors and other inventors to build on and learn from the patent disclosure."

others to understand, test, and adapt the technical contribution. Where disclosure fails to support these functions, the utilitarian case for maintaining existing sufficiency thresholds is weakened. Recalibrating sufficiency in such contexts is therefore justified, not as an expansion of patent obligations in the abstract, but as a means of restoring the alignment between exclusivity and the welfare-enhancing role of disclosure.

### C. *Economic Efficiency, Design-Around, and Follow-On Innovation*

Economic accounts of patent law emphasise the efficient allocation of resources and the calibration of incentives over time.[118] From this perspective, disclosure plays a critical role in shaping not only the initial decision to innovate but also the pattern of subsequent research and development. Patents that disclose technical knowledge in a usable form can facilitate lawful design-around activity and follow-on innovation, thereby supporting cumulative technological progress while preserving incentives for the original inventor.[119]

Insufficient disclosure undermines this function of disclosure. Where AI patents rely on opaque descriptions or withhold information essential to performance, they may foreclose design-around efforts in practice, even where such activity remains legally permissible.[120] Although patent law allows competitors to develop alternative solutions that avoid infringement, the feasibility of doing so depends on access to meaningful technical information.[121] Thin or abstract disclosure can expand the effective scope of exclusivity beyond the claims, not through legal doctrine, but through informational asymmetry.[122]

This asymmetric effect is particularly pronounced in cumulative and data-driven fields. Follow-on innovation depends on the ability of later innovators to assess, test, and adapt prior technical contributions.[123] When key inputs or processes are inaccessible, subsequent innovators may be deterred from engaging in research that builds upon existing patents, leading to inefficient concentration of knowledge and reduced diversity of innovation pathways.[124] The original patentee, meanwhile, may lack the capacity or incentive to pursue all potential applications of the invention, resulting in under-exploitation of socially valuable knowledge.[125]

From an efficiency standpoint, these dynamics undermine the justification for maintaining sufficiency standards that tolerate practical irreproducibility.[126] Accordingly, economic efficiency considerations reinforce the case for a

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[118] Kenneth W Dam, "The Economic Underpinnings of Patent Law" (1994) 23:1 J Leg Stud 247.

[119] Leonid Hurwicz, "The design of mechanisms for resource allocation" (1973) 63:2 Am Econ Rev 1.

[120] See Fromer, *supra* note 28 at 596.

[121] Christopher A Cotropia & Mark A Lemley, "Copying in Patent Law" (2008) 87 NCL Rev 1421 at 1434 (design-around theory).

[122] Jeanne C Fromer, "Dynamic patent disclosure" (2016) 69 Vand L Rev 1715.

[123] Julian Boulanger, "Patents and Follow-On Innovation: Evidence From Patent Renewal Decisions", *SSRN Preprints* (11 February 2019) <https://ssrn.com/abstract=3347134>.

[124] See Fromer, *supra* note 28 at 595–597.

[125] *Ibid*.

[126] Strandburg, *supra* note 35.

context-sensitive approach to sufficiency in AI-related inventions. Where disclosure fails to provide a reliable basis for lawful competition and cumulative development, the costs of exclusivity increase while its dynamic benefits diminish. Adjusting sufficiency thresholds in response to these conditions is consistent with the patent system's efficiency objectives and its role in sustaining long-term technological progress.

These normative considerations support a recalibration of sufficiency that is sensitive to the functional demands placed on disclosure by AI-driven innovation. They explain why formal enablement, when detached from practical reproducibility, risks undermining both the legitimacy and the effectiveness of patent protection. The question that follows is not whether sufficiency should be abandoned or uniformly raised, but how existing patent doctrines have responded to these pressures in practice.

## VI. Recalibrating Sufficiency for AI-Related Inventions

This section develops a more concrete account of how the sufficiency doctrine can be applied to AI-related inventions within existing legal frameworks. Building on the definition and categorisation set out in Section II, it proceeds from the premise that disclosure challenges do not arise uniformly across all AI-related inventions. Rather, they arise most acutely in relation to Applied AI, where the claimed technical contribution is realised through interaction with a specific technical field and depends on data-dependent, trained, or otherwise opaque processes.[127] By contrast, Core AI inventions raise more conventional enablement questions centred on algorithmic specificity.[128] Recognising this distinction allows sufficiency to be recalibrated in a principled and operational manner, without introducing technology-specific legal tests.

### A. *Context-Sensitive Sufficiency and the Relevance of AI Categories*

As discussed in Section II, AI-related inventions fall broadly into two categories. Core AI inventions are directed to advances in computational or algorithmic techniques, such as training methods, optimisation strategies, or model architectures.[129] Applied AI inventions, by contrast, embed AI systems within a broader technical application, such as medical diagnosis, image recognition, predictive maintenance, or autonomous control.[130] In these cases, the claimed technical effect is typically achieved not by algorithmic structure alone, but through the interaction of trained models, data inputs, and implementation choices within a specific technical context.

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[127] See *UKIPO Patent Application Guidelines*, *supra* note 4 at [5]–[6.22] Applied AI: performing processes or solving problems lying outside the computer" Applied AI: making computers work better".

[128] See *UKIPO Patent Application Guidelines*, *supra* note 4 at [7]–[7.17] Core AI.

[129] See *supra* note 128.

[130] See *supra* note 127.

This distinction has direct implications for sufficiency. Core AI inventions can often be assessed using familiar enablement criteria, focusing on whether the algorithmic steps, inputs, and outputs are disclosed with sufficient clarity to allow the skilled person to implement the invention.[131] Applied AI inventions, however, frequently depend on training processes, datasets, and model states that are not readily inferable from the specification or from common general knowledge.[132] It is in this category that the risk of formally sufficient but functionally thin disclosure arises most clearly. A context-sensitive application of sufficiency, therefore, requires differentiated disclosure expectations that reflect these structural differences.

### B. *Applied AI and Reproducibility-Oriented Disclosure Benchmarks*

For Applied AI inventions, sufficiency should be assessed with explicit regard to reproducibility, understood as the ability of the skilled person to implement the claimed invention and achieve the asserted technical effect across the scope of the claims without undue experimentation. Reproducibility does not operate as an independent legal requirement, but as an internal benchmark informing the application of enablement, claim breadth, and undue experimentation within the existing sufficiency doctrine.

In this context, sufficiency turns on whether the specification discloses the performance-critical elements of the invention. These are the elements that materially determine whether the claimed technical effect can be achieved in practice and that cannot reasonably be inferred from common general knowledge or routine experimentation. In Applied AI, such elements commonly include the following.

First, training data. Where the claimed technical effect depends on the nature or composition of the training data, sufficiency normally requires disclosure beyond a generic reference to data sources. At a minimum, the specification should identify the provenance of the data, the criteria for inclusion and exclusion, and the manner in which the data are structured, labelled, or pre-processed. Where performance claims depend on particular distributions, classes, or correlations within the data, those features must be disclosed in a way that allows the skilled person to recreate a functionally equivalent dataset. Mere assertions that "appropriate training data" are used will not suffice where the choice of data is central to the claimed effect.

Secondly, training methods and optimisation choices. Where the invention relies on machine learning or statistical training, the disclosure should specify the training objective, optimisation approach, and key parameters that materially affect performance, such as learning rate schedules, stopping criteria, or regularisation techniques. High-level descriptions of "training a model" or "optimising performance" are insufficient where the claimed effect depends on particular training regimes that cannot be replicated without further information.

Thirdly, model structure and configuration. Where performance is tied to architectural or structural choices, such as the use of particular feature pipelines, layers,

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[131] See Core AI examples: EP2953066B1, EP3568811B1, EP3459017B1.

[132] See Applied AI examples: EP4287091B1, EP4210019B1, EP3750765B1, EP4196889B1.

or processing stages, those choices must be disclosed with sufficient specificity to allow implementation. This does not require exhaustive disclosure of every design choice, but it does require disclosure of those elements that are said to underpin the technical contribution.

Fourthly, trained model state, including model weights, where relevant. In some Applied AI inventions, the claimed technical contribution lies not in the training process as such, but in the trained model itself.[133] Where the performance achieved is inseparable from a particular trained state, reproducibility may not be achievable through textual description alone.[134] In such cases, sufficiency may require access to the trained model weights or an equivalent mechanism that allows the skilled person to obtain a functionally identical model. Where such access is not provided, and the skilled person cannot reasonably recreate the trained state from the disclosure, the claim risks insufficiency.

Finally, evaluation and evidence. Where claims assert improvements in accuracy, robustness, or efficiency, the disclosure should explain how those claims were assessed, including the metrics used, the evaluation protocol, and the baseline against which performance is measured. This is not to require proof of commercial readiness, but to ensure that the asserted effect is credibly supported and reproducible in principle.

Where these performance-critical elements are absent, and where the skilled person would be unable to reproduce the claimed effect without access to undisclosed information central to the invention's operation, the claim should fail for insufficiency. Conversely, where the disclosure enables the skilled person to implement the invention using common general knowledge and routine experimentation, sufficiency should not be denied merely because some inputs are not exhaustively specified.

### C. *Core AI and Algorithmic Enablement*

Core AI inventions raise a different sufficiency problem. Because the claimed contribution lies in algorithmic or computational advances, reproducibility is typically achieved through clear disclosure of the algorithmic steps, inputs, outputs, and technical rationale underlying the improvement.[135] In such cases, sufficiency is primarily concerned with whether the specification enables the skilled person to implement the algorithm and understand how the claimed effect is achieved.

While training data may still be relevant in some Core AI inventions, particularly where training forms part of the claimed advance, the disclosure burden will often be lighter than in Applied AI. Provided that the algorithmic method can be implemented and tested using routine datasets or simulated inputs, sufficiency does not

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[133] See *supra* note 127.

[134] The problem of reproducibility might arise in the case of lacking biological materials. See Bently *et al*, *supra* note 1 ch 20 at 611–612.

[135] See *supra* note 128.

ordinarily require disclosure of specific training datasets or trained model states.[136] The key distinction is whether the claimed technical effect depends on features external to the algorithmic logic itself. Where it does not, conventional enablement analysis remains adequate.

### D. *Complementary Mechanisms and the Practical Delivery of Disclosure*

The disclosure benchmarks outlined above identify circumstances in which sufficiency, properly applied, requires access to performance-critical information in order to support reproducibility. In practice, however, certain forms of information central to Applied AI inventions, such as large-scale training datasets or trained model states, may be difficult to disclose fully through the patent specification alone.[137] Where this is the case, the question is not whether disclosure is required, but through which mechanisms disclosure may be delivered in a manner consistent with the *ex ante* logic of the patent bargain.

Patent law already recognises that, in some technological fields, reproducibility cannot be achieved through textual description alone.[138] The deposit regime in biotechnology provides a well-established example.[139] Where an invention depends on access to biological material that is not publicly available, patent systems permit the deposit of that material at the filing stage as a means of supporting enablement.[140] Crucially, the deposit mechanism does not relax the sufficiency requirement itself.[141] A deposit cannot cure speculative claims or compensate for an otherwise deficient disclosure. Rather, it operates as a complementary mechanism, ensuring that others can reproduce the invention where access to material inputs is the limiting factor.

This logic is instructive in the context of Applied AI inventions. Where the claimed technical effect depends on a particular trained model state or dataset that is performance-critical and cannot reasonably be reconstructed from the specification and common general knowledge, access to that material may be necessary to support reproducibility. In such cases, deposit or controlled-access mechanisms may serve to operationalise disclosure, provided that they are available at the filing date and remain clearly subordinate to doctrinal sufficiency assessment. As with biological deposits, these mechanisms should be understood as facilitating reproducibility, not as justifying the grant of exclusive rights in the absence of adequate disclosure of the invention's technical contribution.

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136 *UKIPO Patent Application Guidelines*, *supra* note 4 at [10]–[10.5]; EPO*, Guidelines for Examination*, pt F, ch III, s 3 "Insufficient disclosure".

137 Aboy *et al*, *supra* note 5.

138 *Ibid* at 839.

139 Budapest Treaty, *supra* note 59.

140 Patents Act 1977 (UK), s 125A (inserted by Copyright, Designs and Patents Act 1988 (c. 48, SIF 67A), s 295, sch 5, at [30]); *EPC Implementing Regulations*, pt II, ch V, r 31; 37 *CFR* §§ 1.801–1.809; Patents Rules 2007 (Cap 221) (Singapore) R 1, sch 4, at [1]; Detailed Rules for the Implementation of the Patent Law of the People's Republic of China (2023 Revision), art 27.

141 Bently *et al*, *supra* note 1 ch 20 at 611–612.

At the same time, the use of such mechanisms must be subject to proportionality constraints. Full public disclosure of datasets or model weights will not be feasible or appropriate in all cases, particularly where scale, confidentiality, or third-party rights are involved.[142] Alternative modes of disclosure, such as controlled repositories, representative subsets accompanied by detailed statistical characterisation, or other access arrangements, may therefore be acceptable where they provide the skilled person with a workable basis for reproducing the claimed effect. However, where reliance is placed on restricted access or confidentiality, the claim scope must be calibrated accordingly. Broad claims should not be sustained where reproducibility depends on information that remains effectively inaccessible to others.[143]

Voluntary licensing mechanisms, including open licences and patent pledges, may further facilitate access to AI-related inventions once sufficiency has been satisfied.[144] Such mechanisms can reduce downstream barriers to use and support cumulative innovation in data-intensive fields.[145] However, their role is necessarily *ex post*.[146] Licensing arrangements cannot substitute for disclosure at the filing stage and cannot remedy insufficiency where the specification fails to support reproducibility. Their relevance in this context lies in mitigating the practical consequences of limited informational value in post-grant or post-expiry access, rather than in determining whether exclusive rights should be granted in the first place.

Taken together, these complementary mechanisms illustrate how patent systems can address the practical constraints associated with AI-related disclosure without displacing the sufficiency doctrine or transforming it into a vehicle for broader data governance objectives. Properly confined, they support the delivery of disclosure where doctrinal sufficiency has already identified a need for access

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[142] Tabrez Y Ebrahim, "Artificial Intelligence Inventions & Patent Disclosure" (2020) 125 Penn St L Rev 147.

[143] See Bently *et al*, *supra* note 1 ch 20 at 610–611; see *supra* note 28, DSM NV's Patent [2001] RPC (35) 675 at 712–716 ("cloning, sequencing, and recombinant expression of the gene for phytase from fungus held to be extremely broad and unworkable, because the skilled person would have had to depart from the patent and to experiment over what may have been a long period of time to achieve the desired goal.").

[144] Patent Law of the People's Republic of China (2020 Amendment), art 50 (China's open licence regime, under which patentees can voluntarily make their inventions available for exploitation by any entity or individual); *Moderna v Pfizer/BioNTech* [2024] EWHC 1648 (Pat) at [30]–[62]; see also OpenAI, "Our Approach to Patents" (4 February 2025) <https://openai.com/en-GB/approach-to-patents/>; Tesla, "Patent Pledge" (12 June 2014) <https://www.tesla.com/en_gb/legal/additional-resources#patent-pledge> (the UK, the EU, and the US rely on private ordering mechanisms, most notably patent pledges, which operate through market forces and multi-party negotiation).

[145] See CNIPA, *China National Intellectual Property Administration 2023 Annual Report*, at 2, 43 (3 September 2024) <https://www.cnipa.gov.cn/col/col3430/index.html>; Jorge L Contreras & Meredith Jacob (eds), *Patent Pledges: Global Perspectives on Patent Law's Private Ordering Frontier* (Cheltenham: Edward Elgar Publishing, 2017) at 2 ("Patent pledges represent a middle ground between full exploitation of exclusive rights and release of a patent into the public domain"); Gabriela Lenarczyk & Mateo Aboy, "OpenAI's Patent Pledge: a Post-Moderna Analysis" (2025) 20:6 JIPLP 392.

[146] See Jorge L Contreras, "Patent Pledges" (2015) 47 Ariz St LJ 543; Catharina Maracke & Axel Metzger, "Playing Nice with Patients: Do Voluntary Non-Aggression Pledges Provide a Sound Basis for Innovation" (2015) 17 NCJL & Tech 483.

to performance-critical information, while preserving the principle that entitlement to exclusive rights must be justified by disclosure at the point of filing. In this way, complementary mechanisms reinforce, rather than undermine, the role of sufficiency as both a gatekeeping and informational constraint in the patent system.

## IV. Conclusion

This article has argued that AI-related inventions expose a structural mismatch between sufficiency assessed as formal enablement and sufficiency understood as a functional mechanism for reproducibility and knowledge dissemination. While the doctrines of enablement, plausibility, and possession remain conceptually coherent, their application to AI-related inventions, particularly applied uses of AI in specific technical fields, reveals limits in ensuring that claimed technical effects can be reproduced and meaningfully understood by others. The difficulty lies not in the absence of doctrinal tools, but in their application to inventions whose performance depends on trained models, data-dependent processes, and implementation choices that are often only thinly disclosed.

By distinguishing between Core AI and Applied AI, this article has shown that disclosure challenges are not uniform across AI-related inventions. Core AI inventions typically raise conventional enablement questions centred on algorithmic specificity and can often be assessed within existing doctrinal frameworks. Applied AI inventions, by contrast, more frequently place strain on the sufficiency doctrine because reproducibility depends on access to performance-critical elements such as training data, training methods, model configuration, or trained model states that may not be inferable from common general knowledge. In these cases, the risk of formally sufficient yet functionally thin disclosure is most acute.

The comparative analysis of five patent systems demonstrates convergence in the exclusion of speculative claims, alongside divergence in doctrinal articulation and institutional emphasis. Building on this shared concern, this article has articulated a context-sensitive and category-aware understanding of sufficiency grounded in existing doctrine. It shows how sufficiency can be applied in a more reproducibility-oriented and exclusion-focused manner, denying protection where the disclosure does not provide a workable basis for reproducing the claimed technical effect across the scope of the claims, without introducing new legal tests or technology-specific disclosure mandates.

The analysis further demonstrates that, where performance-critical information cannot feasibly be disclosed through the specification alone, complementary mechanisms such as deposits or controlled access arrangements may support the practical delivery of disclosure. Properly confined, these mechanisms do not relax sufficiency requirements or justify speculative claiming, but operate as subordinate tools for operationalising disclosure where access to material inputs is the limiting factor. Voluntary licensing arrangements may facilitate downstream access and cumulative innovation, but remain *ex post* mechanisms that cannot substitute for disclosure at the point of filing.

The foregoing analysis demonstrates how the sufficiency doctrine can be recalibrated through interpretation and application within existing legal frameworks. By differentiating between types of AI-related inventions, identifying performance-critical disclosure elements in applied contexts, and preserving the hierarchical relationship between doctrinal assessment and complementary mechanisms, sufficiency can continue to function as both a gatekeeping and informational constraint. This approach aligns the grant of exclusive rights more closely with the public interest in reproducibility, knowledge dissemination, and cumulative innovation, while preserving doctrinal continuity in the face of increasingly data-dependent and opaque technological change.