A BRIEF GUIDE TO PATENTS FOR ACADEMIC SCIENTISTS

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ABSTRACT

While the established infrastructure of academia promotes ventures into unknown intellectual territory, translating technologies from the enclaves of esoteric journals to the lives of everyone remains a challenge. Patents play a crucial role in the world beyond the university setting by disseminating academic work to those who can use it while financially protecting them. We discuss the reasons why an academic scientist would or would not patent, review the basics of patents relevant to a university setting, walk through the steps of filing patents at a university, and provide a more holistic analysis of the role of patents in various industries. We hope that you know enough about patents by the conclusion of this document to informedly decide whether you want to care about them, and that you have the basic vocabulary to dive into the details with experts should you decide you do.

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1 THE BIG PICTURE

1.1 What are patents?

The purpose of patents is to spur innovation by giving inventors assurance that they own, and can thus capitalize on, their inventions. Without such assurance, inventors may not be incentivized to invest time, money, and energy to develop useful technologies, e.g. highly efficient and massive chemical processing plants and life-saving drugs. Under the authority of a patent-granting institution[1], a patent holder is granted the sole right bar those to make, use, sell, or import the invention for some number of years. In exchange for these legal rights, patent holders publicly disclose everything there is to know about the invention so that others can build on said invention or copy it with lower costs once the patent's lifespan ends. The motivations of a patent authority are thus twofold—incentivize innovation both on an individual level by offering protections, and on a global level by disseminating details of novel innovations. Of course, the devil is in the details. What counts as a patentable invention? Can an academic scientist build the invention on their own just to test it out? What goes into a public disclosure of the invention? How does patenting work at a university? Are the norms for, say, the quantum technologies industry different than the pharmaceuticals industry? This guide will cover all these questions and more, but first...

1.2 As an academic scientist, why should I care about patents?

At some point, we all made the conscious decision to devote our best years to serving as an academic scientist, typically for some combination of

1. satiating our curiosity,
2. credentializing carefully disguised hubris,
3. making a positive impact on the world at large, and
4. building a financially secure future for ourselves and our communities.

The infrastructure of the academic world does an excellent job supporting the first reason: venturing into the vast swaths of unknown knowledge. Consider science journals with the stringent requirements of peer review to ensure valid science is disseminated; competitive, federally-funded grants that support (and punish) ideas, not people; and the preponderance of conferences encouraging open discussion and collaboration. And the invention of the h-index [1] gave us a quantifiable way to satisfy the second. Such amenities are less commonly available in the private sector.

The latter two reasons for becoming an academic scientist are generally better supported in the private sector: translating research into society-wide positive impact and putting food on the table. Universities and public research laboratories were not. For evidence of the former, note that just half of academic papers are read only by their authors and journal editor [2], and the average journal article is read in its entirety by only 10 people [3].[2]

Forty years ago, the US Patent and Trademark Office (USPTO), recognizing the importance of brisk technological development and the lethargic pace of translating academic research to usable technologies, turned to the patent system that had been successfully spurring innovation for hundreds of years.[3] It needed a way to

1 In this article, we focus on the United States Patent and Trademark Office (USPTO). As a start to understand how to extend US patent protections internationally, Google "Patent Cooperation Treaty of 1970".

2 For evidence of the latter, note our empty fridges.

3 Patents have been around since 1474. The US's Founding Fathers understood the importance of protecting intellectual property and passed the first patent statute in the US, the Patent Act, just a year after the Constitution was ratified.

incentivize academic scientists to patent their work. This way, companies could license these patents and pull ahead in the never-ending war for better technology,[4] resulting in the Bayh-Dole Act of 1980 [5]. The Bayh–Dole Act changed the rules of patent ownership so that universities could retain ownership of inventions funded by federal grants, as opposed to giving ownership to the federal government.[5] Universities became incentivized to license their patents out to companies,[6] and academic scientists became incentivized to file patents for universities to get a cut of any royalties made from licensing their patents, as well as other potential benefits, such as priority rights if an inventor wanted to, say, spin out a company based on the technology.[7] This approach has succeeded: "from less than 1 percent in 1975, the share of US patents applied for by universities grew to almost 2.5 percent in 1990" [8], and the total contribution of academic licensors to industry gross output ranges from $723 billion to $1.7 trillion, in 2012 U.S. dollars [9].

In summary, academic patents play an important role in a greater ecosystem beyond the university setting. If you are looking for mechanisms to augment the impact of your work from breaking ground in your field to breaking ground in this greater ecosystem via starting your own company or giving existing companies access, it is important to at least become aware of another mode of disseminating your work beyond the silo of scientific journal articles.

1.3 To patent or not to patent?

We end the previous section by advising you to *consider* patenting, not thoughtlessly hurtle toward your university's on-campus patent experts in the technology transfer office every time you have a half-baked idea. As patent attorney Hanne Bonge-Hansen remarks, "That would be a colossal waste of time and money. What could, on the other hand, be very beneficial, is to sometimes consider it—and even better, to have some sort of strategy or plan related to intellectual property." The purpose of this section is to discuss the oft-cited reasons not to patent, so that you can more

4 You might wonder why companies would want to spend money on licensing patents when they could just take the same information from papers that academic scientists would have publicly published anyway. In the most idealistic and simplistic view of economics, the greater your monopolies, the more profit you can squeeze out of your business. Owning the sole means of producing a product by owning the information contained in a patent is an easy way to do this. If no one "owns" the information, then any company could produce the product, making for a more efficient market and driving down profits. Furthermore, from an engineer's perspective, the information contained in papers is often insufficient or unreliable compared to that of a patent, which undergoes examination by the US Patent Office to ensure all necessary information to reproduce the invention is disclosed (although in practice, this may not be the case). In our personal experience working as materials scientists for several technology-based companies, we rarely referred to papers. Much of the required knowledge acquired was through either internal expertise, external engineering consultants, internally-conducted experiments, or patents. As further anecdotal evidence of the value companies place on patents, when the life sciences company Verily had just spun off from GoogleX, Verily so wanted to stake intellectual property claims that they paid engineers hundreds or thousands of dollars per patentable idea—on the weekends, engineers would (metaphorically) drive in a Toyota Camry to the office to spitball ideas and drive out with a Mustang. The government itself has been known to engage in similar patent-hungry behavior as well. In his famous autobiography [4], Richard Feynman tells a story of how when he was on the Manhattan project, military officers encouraged him to patent every possible idea relating to nuclear technology he could think of, leading to some unexpected calls some years later, when a company wanted to license one of these throwaway patents.

5 The government knew it wasn't very good at licensing patents to spur technological innovation: it held 28,000 patents but licensed just 5% of them prior to the enactment of the Bayh-Dole Act [5].

6 Stanford University, for example, made $336 million when it liquidated its ownership of Google [6].

7 While academic scientists are now more incentivized to file patents, doing so doesn't necessarily pay off. As Dennis Crouch notes, relying on patents as income is like playing the lottery: the probability of winning is negligibly low, but those who do win, win big [7]. We can look to Stanford's Office of Technology Licensing's 2019 year-end review as an example: "In FY2019, Stanford received $49.3M in gross royalty revenue from 875 technologies, with royalties ranging from $10 dollars to $16.5M dollars. 49 of the 875 technologies generated $100,000 or more in royalties. Only five inventions received $1M or more. The long tail of inventions that bring in less than $100,000 in royalties is the steady royalty base for Stanford."

informedly balance these reasons *not to* against the reasons *to* patent discussed in the previous section.

1.3.1 I want to stay in academia. Patents do not carry as much weight as papers do on CV for getting post-docs, faculty positions, or tenure.

It depends.[8] In some institutions, it is definitely the case that patents hold no weight against papers. Only 25 of the top 200 national research universities include patents and commercialization in tenure decisions. Even the staunchest supporters of the inclusion of faculty patenting and commercializing activities into tenure and career advancement decisions agree that these activities should not replace scholarly pursuits, such as teaching and mentoring students and publishing research.

In other institutions, however, patent-supportive language is explicitly included in their tenure criteria. These institutions include Virginia Polytechnic Institute and State University, Texas A&M, University System of Maryland, University of North Carolina–Greensboro, University of Minnesota, University of Nebraska Medical Center, Arizona State University, The University of Arizona, North Dakota State University, The Ohio State University, and the New Jersey Institute of Technology. Other institutions, such as Stanford, MIT, Caltech, Cornell, and Georgia Tech, have an innovation-driven academic culture that has already made global impact through its start-ups and technology transfer, and for such institutions, formal changes in tenure and career advancement criteria may not be necessary. Some universities are exploring the use of the sabbatical leave process to encourage faculty to invest time into transitioning their technology to start up a company, too: half of the universities surveyed in a National Council of Entrepreneurial Tech Transfer Survey indicated that faculty are permitted to use sabbatical leave for this purpose.

There are signs that times are a-changin' in favor of universally putting patents on similar footing as papers, too. There is broad support for increasing entrepreneurial efforts, and thus patenting, among groups that shape academic research policies. For instance, the Advancing Research in Science and Engineering (ARISE) 2 report from the AAAS advocates as one of their two broad goals "the creation of an environment that allows flexible interactions among the academic, government, and private sectors throughout the discovery and development process." A recent report from the American Association of University Professors recognizes that "collaborations between industry and the academy present tremendous opportunities for advancing knowledge applying it to real-world problems, and bringing about various social benefits. Cooperative research involving both university and industry scientists has proven critical to the development of numerous powerful methods, products, and technologies."

Professors themselves are in favor of ascribing higher value to patents.[9] A 1994 national survey of 1,000 university professors from nine academic disciplines across 115 universities found that 72% of the respondents approved of faculty engaging in use-oriented research and 71% agreed to treating patentable inventions as refereed articles. A more recent 2013 survey confirmed this trend.

Overall, change in academia can be glacial, so don't expect every university everywhere to value patents. If, however, you value them, then there certainly are institutions whose values align with yours.

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8 Most of this section has been shamelessly copied from "Changing the academic culture: Valuing patents and commercialization toward tenure and career advancement" in PNAS [10].

9 Anecdotally, Manu Prakash, a professor of bioengineering at Stanford who's best known for inventing a microscope out of paper that costs less than $1 to help doctors in developing nations identify infections, often says something along the lines of, "I measure my productivity in patents, not papers. If you want to impress your colleagues, publish papers. If you want to change lives, file patents." We personally feel that there is a field-specific optimal balance. For commercially nascent fields where physical concepts are still being unconvered, such as the quantum technologies to be discussed in Section 4, papers obviously still matter a lot. See Section 4 for further discussion.

1.3.2 *While my invention is patentable, it is such an upstream, fundamental method for my field that if a company monopolized the technology and charged exorbitant prices to access it, the whole field would suffer.*

When Jonas Salk, the inventor of the polio vaccine, was asked if he owned the vaccine, he famously responded "There is no patent. Could you patent the sun?"[11][10]

Fear of the so-called tragedy of the anti-commons is a valid concern, especially since the university, not you, has the right to decide which company licenses your patent. Firms have wielded the power of patent law to charge the equivalent of >1,000 Taco Bell Cheesy Bean and Rice Burritos for an iPhone [12],[11] steal medicinal knowledge that has been passed down for generations within groups of indigenous peoples [13], or force developing nations to pay absurdly high prices for crucial drugs [14]. In academic settings, the conflict between patenting and open access has been exemplified by the acrimonious Crispr-Cas9 trials [15].

This abuse is generally not the case, however. According to the AAAS's project on Science and Intellectual Property in the Public Interest, "dissemination of the protected intellectual property was through publication and informal sharing for 85% of the cases. Licensing of these patented technologies was a secondary mode of dissemination for a minority of the cases." Notably, "[a]bout one-third of the respondents who did use licensing in the dissemination of their technology included a research exemption." Research exemptions will be discussed in more detail in Section 2.8, but generally, academics can formally or informally use patented technology without fear of an infringement lawsuit.

The decision to patent is ultimately yours, so consult a patent expert and experts in your field to understand the possibility of harmful competition-excluding behavior.

1.3.3 *The patenting process seems like it would take a lot of time. I don't want patenting to affect how quickly I publish papers.*

If you were to patent on your own, yes, it could take a long time to fill out the patent forms correctly. Fortunately, many universities have a technology transfer team stuffed with patent experts that will minimize the time it takes to patent an invention. Specifically, they will help you define the scope of your invention and deal with the complex legal shenanigans based on documents you send them (e.g. the paper you were going to write anyway), and negotiate licenses with companies who want to use them. And if you decide to spin out a company based on the technology yourself, university technology transfer offices are anecdotally very reasonable about licensing, often granting you restricted licenses so that you and only you have permission to use the patented technology. Our colleagues' and personal experiences with technology transfer offices at universities have been very positive. See Section 3 for more details on patenting at universities.

Even if university resources minimize the time it takes to patent, is an academic's paper publishing rate negatively impacted? One might expect that filing for patents could have an impact on the publication of scientific results, and at least on its timeliness, because fulfilling the patenting criteria requires the non-disclosure of the invention as long as a patent application has not been filed and because private funding of academic research frequently induces restrictions on the disclosure and timing of publication of the outcomes [8]. The quantitative evidence, however, speaks to the contrary. Generally, professors involved in patents publish more and higher quality papers than their colleagues with no patents, and increase their productivity after patenting [16, 17, 18]. This difference may be because patenting

10 He didn't mention, however, that lawyers from his sponsoring organization looked into patentability and decided that that prior art precluded the patent. The sentiment stands, however, and polio has almost been eradicated, so we'll give the guy a pass.

11 Read about the Apple v. Samsung patent trials concerning Samsung's attempt to charge lower prices for a copy of the iPhone, leading to Apple body-slamming Samsung back for $1b.

encourages researchers to crystallize their scientific expertise into patents before publishing [19]. Of course, the positive effect between the number of patents and publications may be more correlative than causative, but it at least seems that patenting does not exert negative effects on the rate of publishing papers.

1.3.4 *I don't want my research direction to become more applied and less fundamental in pursuit of patents.*

This concern has played out in reality, especially in the biotechnology and pharmaceutical fields, but the choice of what to study is ultimately yours. Consider a strategy of conducting research as you would and checking with a patent agent before you publish something to see if it's worth patenting.

1.3.5 *I want to keep the results of my research a secret, so that I can start a company while keeping my invention a trade secret.*

In our opinion, if the research has been publicly funded, it should be publicly disclosed at some point no matter what, regardless of whether the output is a patent, paper, or presentation. We do not think starting a company based on your publicly funded invention as a trade secret is fair, but we have no idea what the legal constraints associated with this situation are. Sounds like a great question to ask your university tech transfer office!

1.3.6 *Patenting seems like it would cost a lot.*

Filing fees can definitely start racking up on the order of a few thousand dollars, but if an inventor is patenting on behalf of an organization, the inventor is likely not personally responsible for filing fees. Most universities that we know of will pay the fees and then divert some percentage of the royalties back to the filing office to repay them. See Section 3 for further discussion.

2 PATENT BASICS

There are many, many articles online that effectively describe the basics of patents,[12] so we take a broad-strokes approach tailored to academic scientists, and defer to experts for the finer details. We'll start with the what (patentability), then the how (the patent submission process and infringement), and finish with the why (commercialization).

2.1 What's patentable?

The textbook criteria for patentability include [20]:

- *Utility*. Your invention must be useful. This requirement focuses on the difference between a "discovery" and an "invention." You can't patent fundamental physical mechanisms, but you could patent a device that takes advantage of this effect to do something. Here are some examples: It is a discovery to realize that hydrogen gas is generated when an electric current is passed through water, and it becomes a patentable invention when that discovery is harnessed in a method of the production and collection of hydrogen gas from water. It is a discovery to observe and characterize a tissue response to a subcutaneous implant, and it is an invention to include in the implant a substance which favorably influences such a tissue response to affect drug release from the

12 See, for instance, Mark Bucker's blog posts on patenting and `http://softlib.rice.edu/ques.html`.

implant. The Purcell effect is a discovery, and a microcavity design that increases the efficiency of a solar cell is an invention. In practice, it's pretty easy to argue that anything is somehow useful, so the Utility criterion does not preclude many patents.

- *Novelty*. Your invention must be different from that which already is publicly known or available, including printed literature (e.g. papers) and patents (collectively referred to as "prior art"). You can't have publicly disclosed your invention prior to filing the patent, either. See Section 2.2 for more information on what is considered public disclosure.

- *Nonobviousness*. Your invention must not have been, at the time of the invention, obvious to a person of "ordinary skill" in your field. A person of ordinary skill is likely not a first-year graduate student, but also not likely the famous professor in your field. The requirement of "nonobviousness" is anything but straightforward.

Notably, the invention doesn't need to be built or demonstrated—it just has to be physically reasonable.[13] Demonstrating that the invention is physically reasonable may require data on your behalf, in effect requiring you to build it.

Evidently, the criteria for patentability come in many shades of gray.[14] In practice, what is patentable is constantly shifting and industry-dependent. These differences manifest as secondary factors that patent offices consider when deciding on a patent application's eligibility, including but not limited to:

- *Abstractness.* Inventions that are too upstream in the research process may be rejected to prevent stifling of downstream innovation. Think fundamental gene sequencing techniques for biotechnology.

- *Experimental use.* Ordinarily, if an invention was on sale or in public use for more than a year, but if the product requires interaction with the public to iteratively improve, e.g. a software beta, then an exception to this rule may be granted.

- *Level of skill in the art.* If a field is more developed with many practitioners, then the nonobviousness threshold is higher.

- *Contextual nonobviousness.* Can the invention be commercially successfully? Have many others failed to make it? Perhaps the invention is obvious or straightforward to produce, but has there been long-felt need?

- *Written description.* The degree to which a patent applicant must understand what she is claiming depends on the industry.

- *Reasonable interchangeability.* Substituting, say, steel A for steel B might not be a big deal in a patent for a dinner table, but it might make a difference in a patent for the landing gear of a plane.

- *Pioneering patents.* If inventions are seminal, they may be entitled to a broader range of protection.

Because there are so many unspoken industry-dependent norms on patentability, as we incessantly advise, seek help from your institution's licensing office. We further discuss how we can expect the patentability of a specific industry, quantum technologies, to evolve by comparing this nascent field to more mature ones in Section 4.4.

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13 This restriction means no perpetual motion machines and no meetings on Monday mornings, but Friday afternoon meetings are OK as long as someone brings food.

14 50? We'll give you novelty, but nonobviousness is a hard sell.

2.2 What's considered "public disclosure"?

Public disclosure is when the invention has been described in printed literature, in public use, on sale, or made known to the public in any way. Remember, public disclosure precludes a patent. Because what is considered public disclosure is well-documented,[15] we focus on academia-specific situations.

- *Governmental grant proposals.* If funded, they become available in the public domain. Either describe the invention in general enough terms that it cannot be reproduced from the descriptions, or ask the grant giver if certain pages can be labelled as confidential. If unfunded, there should be no issue with public disclosure.
- *Conversations with industrial or academic collaborators at different institutions.* This counts as disclosure, unless you agree to confidentiality terms.
- *Talks.* If everyone present is not part of the "public," e.g. in the same research group, department, or university, then a talk typically does not count as public disclosure. If you are giving, say, a departmental seminar and a guest takes detailed notes, then you have publicly disclosed your invention.
- *Abstract submissions.* Often, abstracts have to be submitted many months before a conference occurs and perhaps before an idea has crystallized enough to patent. If the conference organizers guarantee confidentiality of abstract submissions, then you are in the clear. Not all conferences do so, however, so check if you are concerned.

2.3 What goes into a patent?

A patent applicant must describe:

- *The invention (the specification).* This section is effectively a general summary of the following disclosure sections.
- *How to make it (enablement).* Striking the correct balance of too detailed and too general is tough but important. Describing in too much detail makes the patent vulnerable to infringement by simply substituting, adding, or removing a step, while describing too generally increases the probability that the patent office will reject or, worse, declare it invalid after being re-examined for a court case.
- *How to use it (best mode or preferred embodiment).* The patent does not cover the same device or object being used for another purpose. This section and the preceding one often include drawings and figures that you can provide to your patent agent to accelerate the filing process.
- *The claims.* This section is the meat of the patent. Here the applicant outlines exactly what this patent covers: components, manufacturing steps, functionalities, materials, and applications. Each claim must be novel. Claims are where patent lawyers really earn their bread.

How detailed the disclosure must be is field-dependent. For instance, mechanical and electrical devices are expected to be described in great detail because the US patent office believes the underlying mechanisms to be well-understood and the industry to be rather mature. Meanwhile, in biotechnology, given the general newness of the field and uncertainty of the science, claims can be much more general and broader.

Finally, note that an applicant cannot conceal any knowledge, e.g. a secret post-treatment of HF to a microfabricated device that drastically enhances functionality, or the patent may be invalidated.

15 See, for instance, "Patent Disclosure" on UpCounsel.

2.4 When should I file for a patent?

Generally as soon as possible. This was not always the case in the US. Before, the US patent system operated under first-to-invent rules, meaning that if someone else patented your idea before you, but you could demonstrate that you had the idea before them (perhaps with a nicely documented lab notebook), then the other person's patent would be invalidated. Nowadays, however, the system has converted to first-to-file rules, so proving that you had the idea earlier but didn't act on it is not a valid defense anymore.

2.5 What does the patent application process look like?

In contrast with the full patent (also called a *utility patent*), you can start off the patent submission process with a *provisional patent*, which details the invention but does not include claims. The USPTO does not review the provisional, but instead allows you to secure an earlier priority date before you've been able to formulate all the claims (and allows you to call your invention "Patent Pending"). You must submit a full application within 12 months of submitting the provisional. Note that this gives you flexibility in what you include in the full patent as opposed the provisional; you'll have to ask a patent lawyer what this flexibility entails.

Once you formulate claims and submit the full patent application, it will be subject to review by the USPTO, during which patent examiners will conduct their own searches of prior art and evaluate your patent against the criteria above. You (by which we mean, your patent lawyers) will undergo *patent prosecution* with the USPTO, which entails negotiation on what can and can't be claimed and the scope of the patent. This can take up to three years, and your patent application is automatically published after 18 months. All told, expect the process from initial provisional submission to final granting of the patent to take three to five years. In some cases, it may be expedient to "fast track" your application, where you pay an extra fee to expedite the prosecution process and bring the overall time down to around two years.

2.6 Does my patent guarantee my ability to make, sell, or use my invention?

In a word, no. This is because there is an important distinction between what is patentable and what infringes. Fundamentally, a patent does not give you the right to user your invention; instead, it gives you the right to *prevent others from using your invention*. Infringement means that something that you make, sell, import, or use contains *all* of the features of at least one claim in another valid patent—it has nothing to do with the novelty/nonobviousness of your patent. You can imagine that this leads to paradoxical situations where there exist patents where if the invention is contained within, mutually infringe on one another; a simple Google search will yield many examples of inventions which are both patentable and infringe.[16] This is one of those areas where expert advice is really important. Early on in the patenting process, you and the tech transfer team will search through prior art in two ways:

1. *Patentability search* to evaluate the novelty and nonobviousness criteria. This will focus mainly on patent specifications in prior art.

2. *Freedom to operate search* to evaluate if there exist any claims that your invention infringes upon. This will focus mainly on claims in the prior art.

As with everything in IP law, there's flexibility. If you find that your invention as you envision it infringes upon an extant claim, you're often able to design your

16 See, for example, http://www.patenttrademarkblog.com/patentability-vs-infringement/.

claims or modify your invention around the problematic extant claim. We defer to the experts for details here, however.

2.7 How does a patent holder exclude others from infringing the patent?

One could send a letter nicely asking the infringer to stop, request court-backed injunctive relief (forcing the infringer to stop), or sue to get damages. An academic scientist will most likely not be involved with these actions. We defer the details to the experts.

2.8 What happens if I infringe someone's patent?

As discussed in Section 2.7, a patent holder has several options to attack to a perceived infringer. If you believe you are not infringing the patent or that the patent is invalid, you could request re-examination of the patent or counter-sue.

More realistically, none of these options will come to pass, as you are an academic scientist. Academic researchers have historically been protected by a research exemption from patent laws. In more straightforward terms, if the purpose of your research was not to commercialize the invention, but to understand it and improve upon it, then you were in the clear. As universities have become more prominent engines of technological commercialization, however, the research exemption is not so protective anymore.[17] For now, it seems that academic researchers have a *de facto* exemption because suing you is probably not worth the company's legal expenses (although "several trends suggest that the issue might intensify in the coming years" [21]). We recommend being cautious, but not paranoid. Perhaps you could do a quick patent survey in case while doing literature review for new projects. Doing so is beneficial not only to confirm whether you have freedom to operate, but also to see what companies have already achieved in the field, since they may not publish in the scientific journals you typically read.

2.9 How does a patent holder commercialize the patent?

In Section 1.1, we briefly mention that one of the rights ascribed to patent owners[18] is the freedom to commercialize their invention. What does it actually mean to commercialize an invention?[19] Here are a few options:

- License out the patent: This means letting a company use the patent in exchange for some fixed cost, royalties, and/or other benefits. The patent owner can decide to grant exclusive or non-exclusive licenses, meaning that there can be just one or many licensees, respectively.[20]

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17 See Madey v. Duke University in 2002, which tightened the research exemption clause.

18 To clarify, the patent owner is not necessarily the inventor listed on the patent. At Harvard and most universities, you, the academic researcher, would be listed as the inventor, but you do not own the patent. The institution at which you conducted the research does.

19 This section has been largely adapted from "Academic Patenting" by the World Intellectual Property Organization (WIPO).

20 From "Academic Patenting" by the World Intellectual Property Organization: Licensees often require exclusive licenses as they offer more protection for the necessary development to be conducted before a university-provided invention can become a marketed product. The issue is particularly crucial for start-ups which have few assets other than their IP. [While exclusivity protects start-ups as they develop technologies,] exclusive licenses limit the diffusion of technologies. The OECD report has found that the mix of exclusive and non-exclusive licenses granted by public research organizations is fairly balanced, and that exclusivity is often granted with restrictions on the licensee side. Research institutions often include clauses in license agreements to protect public interests and access to the IP for future research and discovery. Licensing agreements in many institutions include a commitment to exploit the invention on the part of the licensee, particularly if the license is exclusive, and to agree on milestones in order to assure that commercialization will take place. Such safeguards can be used to ensure that technology is transferred and that licensed patents are not used simply to block competitors.

- Use the patent, typically meaning that the patent holder forms a company to make and sell the invention.
- Sell the patent.
- Sue others for violating the patent: Holding a patent for the express purpose of suing others for violating it is what so-called patent trolls do—not cool.[21]

We won't discuss these latter two straightforward options further, but of the former two options, which is better? If the patent holder's goal is solely to ensure that the technology sees the light of day, then a better question to consider is, Which is the best channel for transferring the technology to the marketplace? As the World Intellectual Property Organization (WIPO) concludes, "the answer in fact depends on the technology in question, the market for such a technology, the skills set of the staff and researchers involved the invention, access to venture capital, and finally the mission of the institution. Certain 'platform' technologies with a wide range of applications may be commercialized via a start-up company, for example, while others may be licensed to larger firms with the business capacity to develop the invention further and integrate it into its R&D and business strategy." Overall, the best path is situation-dependent, so again, consult experts.

2.10 How do I get a global patent?

There is no such thing as a global patent—the country you send the patent application to must approve the application for you to own patent rights in that country. Fortunately, to minimize effort duplication, there are global agreements in place that allow you to submit the same patent application to many countries at once. Most large international corporations will pursue the multinational route every time, whereas smaller organizations may not.

2.11 How do inventorship on a patent and authorship on a paper differ?

From "All About Invention Disclosures" by Mark Buckley: While authorship on papers is generally given to people who have made important contributions when building prototypes, performing testing, and writing text for the paper, inventorship is legally different. Patent law defines an inventor of a patentable invention as someone who conceives of an original, useful, and non-obvious idea. This can but does not necessarily include students, professors, your boss, your employees, and other collaborators. Use your best judgement and ask all collaborators who you believe may have contributed to the idea to be considered in the invention disclosure. Only after everyone agrees will the inventor list be settled. Keep in mind that who gets to claim inventorship should not be based on charity, flattery, or spite. Patents can and have been invalidated for an incorrect list of inventors."

Generally, inventor lists are shorter than author lists.

2.12 What are some resources to learn more about the basics of patent law?

The online lectures of a patent law course at the Harvard Law School are available at `http://182.fab.mwp.accessdomain.com/patentx`. A rather detailed but readable text is *Intellectual Property in Academia: A Practical Guide for Scientists and Engineers* by Nadya Reingand. We also recommend reading the cited sources. They are quite readable.

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21 While patent trolling may not be cool, it can be a very profitable endeavour. Apple, for instance, was ordered to pay $500m to patent troll firm VirnetX.

3 FILING AT A UNIVERSITY

Here, we will lay out some general steps in interfacing with your university's tech transfer office. We'll often refer to Harvard's policies for concrete examples, though your institution may have slightly different practices.

3.1 How do I file for a patent?

Before you submit your manuscript to a journal or give a public presentation, contact your university's technology transfer office, discuss your idea with them, and hand over any necessary documents.

3.2 Who owns the patent?

Typically, when you signed your contract to work at nearly any university (or company), you gave your employer the rights to patents on which you are the inventor. If you didn't sign a document like this, then the grant supporting you likely has some language ascribing ownership rights to the institution hosting the grant. If neither of these clauses exist, then your patent probably still belongs to your university if any of the following criteria are met:[22]

- Under or subject to an agreement between your university and a third party; or
- With use of direct or indirect financial support from your university, including support or funding from any outside source awarded to or administered by your university; or
- With use (other than incidental use) of space, facilities, materials or other resources provided by or through your university.

3.3 Who gets paid if my university licenses out a patent on which I'm an inventor?

Terms can differ, but generally, both the university and the inventor(s) get cuts of the royalties, although the university often won't pay them until filing fees are covered first. For a concrete example of further details, see the Harvard Office of Technology Development "Statement of Policy in Regard to Intellectual Property."

3.4 What if my university doesn't want to file a patent on my work?

Assuming you are not barred by other legal agreements,[23] you could go to an external patent law firm to file it anyway. Be aware, however, that the university won't release the patent to you for free. Harvard, for instance and among other conditions, requests that you "reimburse the University for all out-of-pocket legal expenses and fees incurred by the University if and when the Inventor(s) receive income from the Invention, share with the University 20% of the net income (income remaining from gross income after repayment of University expenses above and the Inventor(s)' legal and licensing expenses) received by the Inventors from the Invention, to grant back to Harvard an irrevocable, perpetual, royalty-free, nonexclusive, worldwide

22 We specifically use language from the "Statement of Policy in Regard to Intellectual Property" by the Office of Technology Development, although similar clauses exist at other universities.

23 For instance, at a technology-based company, one of the co-authors designed a novel test for a materials property. We were interested in patenting the invention, but the company wanted to keep the test a trade secret, so they did not pursue a patent on the technology. Even if we wanted to apply for a patent without the company's assistance, we would be restrained from public disclosing it by the non-disclosure agreements we signed.

right and license to use the Invention for its research, education and clinical care purposes and a right to grant the same rights to other non-profit institutions" [22].

4 CASE STUDY: QUANTUM TECHNOLOGIES

In order to situate all the information thus far, we discuss what to look out for in patent trends and how they differ from industry to industry. For concreteness, we focus on quantum technologies[24,25] in Section 4.1-4.3 and discuss how we can expect them to evolve in Section 4.4 based on similarities of and differences between the categories of quantum technologies and more established industries. We divide quantum technologies into three general categories:

- Qubits, including the materials comprising them and their manufacture,
- Hardware, including the circuitry and gates for quantum devices, some of which are specific to certain types of qubits, and
- Applications for quantum technologies, such as computation, sensing, and cryptography.

We relate them to the chemistry/pharmaceuticals, semiconductors, and software industries, respectively.

4.1 Historically, what have inventors been patenting in quantum technologies?

Perhaps surprisingly, given that there is currently more commercial interest in quantum technologies than there ever has been, quantum computing patents go back 30+ years[26] and can be divided into ~4 eras. The first era of the 1980s didn't make much progress with regard to practical application, so not much, if anything, was patented around then. The second era of the 1990s saw the rise and patenting of quantum algorithms, and the third era of the 2000s saw the realization of experimental demonstrations and, thus, some hardware patents. The fourth and current era starting in 2014 or so has seen the most patents yet: From 50-100 patents per year between 2003-2014, there were over 400 projected for 2017. Nowadays, patents are roughly equally divided between qubits, hardware, and applications, driven by superconducting qubits, circuit-level hardware, and cryptography and annealing applications, respectively.

4.2 Which countries are leading the intellectual property race in quantum technologies?

China has driven a surge in global quantum patents since 2014—China has had three times as many patent applications in the last five years as the US. Chinese and other Asian organizations are particularly interested in cryptology and communication, while quantum computer manufacturers tend to be based in North America.

24 Nearly all of these trends and much of the language come from "U.S. Leads World in Quantum Computing Patent Filings with IBM Leading the Charge" on IP Watchdog, which is based on a patent landscape report, "Quantum Computing Report" by PatInformatics. Though we typically don't find the opinionated projections of such industry reports to be reliable or sophisticated, they do a good job of collecting data.

25 We don't expect our predictive prattle to be any more useful than the industry report's, so we intentionally minimize speculative discussion of the implications of trends. Take what you will from them.

26 Some have already expired. See "Compiler for a quantum computer" by Robert Tucci.

4.3 What organizations are leading the intellectual property race in quantum technologies?

Among companies, Canada's D-Wave Systems has the largest portfolio of patent families directed at quantum computing with 170 patents. D-Wave is particularly interested in in qubits with 100 patent families in quantum annealing, which comprises 33% of D-Wave patent portfolio. D-Wave was an early developer in quantum computing with 34 patents between 2003 and 2005. The highest projection for 2017 patent family publications, however, belongs to NY-based tech giant IBM with around 60 patent families this year, particularly in circuit technologies. Rounding out the top five companies by total number of patent families are Microsoft (which is the sole leader in logic gates), Japan-based Nippon Telegraph and Telephone, and defense firm Northrop Grumman. A prominent emerging company is Somerville, MA-based MagiQ founded in 1999 that has invested in encryption applications, photon generation and processor hardware, as well as some qubit technologies. Some other emerging companies include Australian firm Qucor and Irish firm Element Six, which are more narrowly focused on qubit tech, especially within super-conducting loops and diamond vacancies. Other smaller companies include Quantum Circuits (start-up by the Yale folk), Qucor, Rigetti, and 1QB Information Technologies. Rising Chinese firms include Qasky, QuantumCTek, and Shenzhou Quantum.

Universities began patenting consistently in quantum technologies in 2014, with MIT, Harvard, Zhejiang, Tsinghua, Beijing University of Technology, and the University of Science & Technology of China leading the charge. Each has filed 5-10 patents per year. Chinese institutions, much like many Chinese companies, are not interested so much in hardware inventions as applications, especially cryptography. Approximately 72% of the academic patent families published in quantum technologies since 2012 have been from Chinese universities, and US universities are a distant second with 12%.

4.4 How can we expect patent norms to differ between quantum technologies and other industries?

As discussed in Section 2.1, what is considered patentable, i.e. passes the bar for utility, novelty, and nonobviousness, is highly industry-dependent.[27] Some experts, including Chris Monroe, University of Maryland professor of physics and chief scientist at IonQ, contend it is too early for the industry to have standardization. A brief survey of current patents[28] in quantum technologies confirms this analysis.[29]

For qubits, see, for instance,

- "Quantum imaging, sensing and diamond component for information processing device" by Element 6,
- "Method for production and identification of Weyl semimetal" by Princeton, and
- "High colour diamond" by Element 6.

For hardware, see, for instance,

- "Parametrically activated quantum logic gates" by Rigetti,

27 Theoretically, as upheld in the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS) signed by most nations, different industries should not be treated differently. In practice, however, this is not the case.

28 Google's patent website is excellent for looking up patents.

29 Also note how "fundamental" many of these inventions are—most could have appeared in scientific journals at the time, suggesting that patents can serve as useful supplements for literature reviews and as useful output for researchers.

- “Device for achieving multi-photon interference from nitrogen-vacancy defects in diamond material" by the Dutch government and Element 6,
- “Operating a multi-dimensional array of qubit devices" by Rigetti,
- “Compilation, memory management, and fault localization with ancillas in an unknown state" by Microsoft, and
- “Frequency allocation in multi-qubit circuits" by IBM.

For applications, see, for instance,

- “Gyroscopes based on nitrogen-vacancy centers in diamond" by the University of California,
- “Encoding and error suppression for superconducting quantum computers" by D-Wave, and
- “Hybrid classical-quantum computer architecture for molecular modeling" by D-Wave.

Some of these patents, e.g. “Software-defined quantum computer" and “Method for production and identification of Weyl semimetal", seem far too general. Others seem presently physically unrealizable and uncommercializable, e.g. “Gyroscopes based on nitrogen-vacancy centers in diamond" is based on a theoretical proposal with no experimental demonstration. Some don’t even seem have an explicit utility, e.g. “High colour diamond". We can see that there is currently not much consensus on what quantum technologies can be patented.

Based on patent norms of analogous industries, we can get a sense for where patent norms for the qubit, hardware, and applications arms of quantum technologies are heading.

The qubit industry may be treated similarly as the chemistry and pharmaceutical industries where 1) the goal is to find whatever type of matter does a specific function the best and 2) R&D is high-risk and high-reward. Because structure is less important to the invention, we can expect fewer and broader patents that strongly cover functions but not specific structures. For example, perhaps defect centers will be more likely to be grouped under the same patent rather than separate ones.

The hardware arm of quantum technologies maps onto the semiconductor industry well, where the overarching goal is to make processes faster, smaller, and more efficient. Because every firm in the semiconductor industry attempts to achieve the same goal through whatever design necessary, historically there have been too many patents, resulting in a patent thicket where everyone is infringing someone else’s patent.[30] In this case, patents can actually hinder progress rather than encourage it. Patent offices have responded by increasing the nonobviousness bar, so we can expect the same of hardware patents for quantum technologies as the industry evolves.

Innovation in applications of quantum technologies are likely to be iterative, e.g. company A improves upon company B’s software by making the algorithm a little faster and the use cases a little broader. Should this improvement be patentable? Given the similarity with the present software industry, we can expect patents to be treated similarly as software patents, that is the nonobviousness bar will be rather high and patents with narrow scopes should be given to encourage subsequent incremental improvements. Although current disclosure norms for software do not require sharing of code, they probably should to permit reverse engineering to make improvements, so perhaps the norm of disclosing code will be encouraged for applications of quantum technologies.

30 While semiconductors companies could have sued the living cheese out of each other, they didn’t. The rapid growth of Silicon Valley can be attributed to this pro-competition behavior, in addition to others like not requiring employees to sign non-compete agreements that allowed employees to hop between companies and share knowledge.

5 CONCLUSION

We hope that you know enough about patents by this point to informedly decide whether you want to care about them and that you have the basic vocabulary to chat with experts.

6 ACKNOWLEDGEMENTS

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7 DISCLAIMERS

Nothing in this document should be interpreted as official legal advice.[31] We cite where possible, so if there is no citation on a given statement, it is certainly subjective conjecture based on observations, anecdotes, and conversations—we are happy to discuss further and re-write sections if convinced otherwise. As this guide is not meant to be a formal academic document, but merely a compendium of potentially useful information, we downright copy, paste, and cite when the source material is already well-worded and sufficient. Because the details of some anecdotes are mostly bound by non-disclosure agreements, we anonymize. Finally, if you would like to ask us further detailed questions, we frankly do not know much more beyond what is written here, so we would not recommend it. What we do recommend is for the reader not to dive too deep into the minutiae of patent law. When in doubt, one should just ask a (university-paid) lawyer.

31 D.S.W has only taken a 3 week long patent law course that he dropped the day of the final, and while V.V.J.V managed to complete a 10 week course, the extra 7 weeks do not make him significantly more qualified by any reliable metric.

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