

Why do researchers change their research directions? Evidence from biomedical scientists

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Changes in the direction of research are commonly acknowledged, but little is known about their nature and why they happen. Therefore, we present evidence from interviews with biomedical scientists whose research grant on a particular disease led to publications in other areas. A range of contributing factors is offered for these changes in direction, both planned and unplanned. Researchers can change directions in response to serendipitous discoveries and dead ends emerging in their work. They can also reorient their work to take advantage of new tools or methods, or aspects of the research context including research funding and collaborations. Shifts in research directions during projects are common, systemic, and vary by disease. These findings suggest that efforts to target research towards addressing societal needs require complementary support for unexpected discoveries.

Keywords: research direction change; scientific uncertainty; researcher perspectives; project funding; serendipity; research funding.

1. Introduction

There is increasing concern about the direction of scientific research, prompted by several important developments in the way science is organized: limited growth of science budgets (Ziman 1994; Whitley 2010); higher levels of accountability and management (Guston and Keniston 1994; Morris and Rip 2006); and the identification of misalignments between R&D efforts (supply) and societal needs (demand) (Sarewitz and Pielke 2007; Yegros et al. 2020). One response to these pressures has been a move by funding agencies towards more project-based funding, directed towards research priorities that are more closely related to public policy goals and societal needs (Whitley 2010).

Project funding is increasingly seen as a potentially important policy instrument for influencing which areas of research are undertaken and for responding to societal priorities more broadly (Franssen et al. 2018; Whitley et al. 2018). For example, allocating project funding for neglected diseases could trigger a substantial re-orientation of researchers' work (Röttingen et al. 2013; von Philipsborn et al. 2015; Coburn et al. 2023). At the same time, scientific research is uncertain and frequently changes direction in terms of research topic, research approach, and/or research activities, including during research projects (Bush 1945; Knorr-Cetina 1999; Gläser et al. 2014; Sigl 2016).

These features of science highlight inherent tensions between curiosity-driven research and research targeted towards specific policy goals, between academic freedom and scientific management, and between funding basic and applied research (Sarewitz 1996; Mowery et al. 2010; Sampat 2012). Tensions can be seen in research policy debates about the balance between investing in basic and applied research, and 'the extent to which it may be feasible and desirable

to direct research investments in general towards particular outputs, outcomes, and social challenges' (Yaqub et al. 2022). For health research funders, like the US National Institutes of Health or the UK Medical Research Council, there is a dual emphasis on fulfilling science and health missions (Sampat 2012).

For medical research, diseases are important organizing categories for policy and practice, and 'advocacy groups, research funding, and entire research institutes are often assembled around the notion of a disease' (Yaqub et al. 2022, p. 947). Yet, we also know that biomedical research often crosses disease areas, with different patterns for different diseases (Sampat 2015; Azoulay et al. 2019; Coburn et al. 2024; Yaqub et al. 2024). The nature of the associated changes in research direction is little examined in the literature (Coburn 2024).

This article extends this prior research in several ways. Taking the perspective of projects as a common organizing structure of research, the contribution of this article is to better understand *why research changes direction during projects*, defined as a shift in focus between project funding (inputs) and publication of results (outputs), *as viewed by researchers themselves*, including *variations by disease and multiple influences and how they interact*. In this article, we examine biomedical researchers' own perspectives on what influences changes in their research direction, and how these influences interact by asking: Why do individual biomedical researchers change their research directions?

Understanding researchers' views on changes in their research directions is important because it may suggest ways for policymakers, funders, and research organizations to balance concerns about encouraging more research that addresses societal needs with the need to maintain scientific freedom and autonomy, to better manage researcher careers

in the context of uncertainty and scientific change, and to help researchers to foster serendipity and cope with failures in research.

We also show that researchers identify with their work in different ways, and that a variety of factors can affect whether researchers consider their present work as having shifted direction. In some cases, this ambiguity offers a vehicle for researchers to re-orient their work whilst simultaneously remaining committed to their pre-existing lines of work (Gieryn 1983; Bowker and Star 2000; Gläser 2019).

In Section 2, we review the literature related to the factors that influence changes in research direction. Section 3 describes our method for examining these influences in greater depth and identifying novel elements. We present our findings in Section 4, and we discuss these findings and draw conclusions, including in relation to science policy, in Section 5.

2. Influences on changes in research direction

Research can change direction in response to influences at the individual level (e.g. Fujimura 1987), and at the contextual level (e.g. Whitley et al. 2018), and this varies by disease (e.g. Coburn et al. 2024). We define changes in research direction during projects as involving different research topics, research approaches, and/or research activities (Gläser et al. 2014), as manifested in differences between grant funding proposals and research publications, and as defined by researchers themselves.

2.1 Individual-level influences

2.1.1 Research processes and research trails. Post-Mertonian sociology of science literature has focused on research processes, principally on how the content of research is shaped by researchers' engagement with knowledge, material objects (e.g. research technologies), and each other (Knorr-Cetina 1981; Hackett 2005). Many decisions are governed by "scientists' concern with making things "work"" (Knorr-Cetina 1981, p. 4). Researchers select research problems that are intellectually interesting and technically feasible, constructing 'do-able' problems (Fujimura 1987).

For individual researchers, the challenge of conducting scientific research has also been described as 'maintaining a core activity under conditions of turbulent environments' (Gläser 2019, p. 438), and learning to cope with the 'epistemic and social uncertainties' associated with knowledge production (Sigl 2016, p. 351). Researchers can also manage a research portfolio, allowing them to follow different lines of research as necessary, and to drop 'unfundable' lines (Gläser 2019). In the face of uncertainties, researchers may make decisions based on social security considerations instead of epistemic rationales or the desire to address societal needs (Sigl 2016). In these ways, concern for research stability can influence changes in research direction.

Individual researchers' changing specialities can be conceptualized as their 'research trails' across a cognitive landscape (Chubin and Connolly 1982; cited by Ziman 1987), also defined as 'sequences of thematically interconnected projects in which findings from earlier projects serve as input in later projects' (Gläser and Laudel 2015, p. 301). Researchers can follow multiple trails at the same time, and trails can also branch out and end (Gläser and Laudel 2015).

2.1.2 Types of change: Planned and unplanned changes. Individual changes in research direction can be planned or unplanned. Scientists may plan to transition from one scientific area to another as part of their desired career trajectory (Cañibano et al. 2019), to build on new scientific and technical opportunities (Lichtenberg 2001; Polanyi 1962), or to react to shifts in societal demands, such as disease outbreaks and crises (Gross and Sampat 2023; Yaqub et al. 2022), or they may make unplanned changes as events unfold. When unplanned changes are beneficial, they are described as serendipitous; conversely, when driven by difficulties, they are expressed in terms of failures or barriers.

Literature on serendipity includes examples of serendipitous discoveries (Shapiro 1986; Meyers 2007), an analysis of the extent to which biomedical research changes direction, framed as serendipity (Sampat 2015), and an exploration of the role of 'luck' in scientific careers (Davies and Pham 2023). Four mechanisms of serendipity have been identified: theory-led, observer-led, error-borne, and network-emergent (Yaqub 2018). Collectively, these studies suggest that serendipity in biomedical research occurs frequently and that it takes different forms.

Failure is also common in science, and it can relate to theorizing or to methodology (Guttinger and Love 2019). Indeed, it has been argued that science 'is all about ignorance and failure, and perhaps the occasional lucky accident' (Firestein 2015, p. 5), and that failures can be a source of subsequent scientific progress.

There is a substantial body of literature in the sociology of science/science and technology studies (STS) on various influences that shape knowledge production at the individual level (e.g. knowledge, tools, or methods), but few studies have focused on changes that occur during research projects in particular, and on the role of unplanned changes.

2.2 Context-level influences

2.2.1 The research environment and project funding. Science policy literature has focused, largely at the level of the research environment, on the factors that influence the direction of research at structural levels and over long timeframes (e.g. Whitley et al. 2018). Studies at the level of the research environment have examined, for example, the impact of institutional reforms (Whitley and Gläser 2014), evaluation practices (de Rijcke et al. 2016), research programmes (Shove and Correljé 2003), and multiple institutional elements (Hollingsworth 2008) on research direction.

As project-based funding becomes more common, sometimes termed 'projectification', the project has been recognized as an important site for analysing changes in the research direction of individuals (Sigl 2016; Franssen et al. 2018; Franssen and de Rijcke 2019; Gläser 2019). Project-based funding may influence researchers' opportunities to change topics or approaches in various ways. For well-resourced projects, changes in direction may be enabled by 'protected space', in which researchers have a period of autonomy over their use of resources (Gläser et al. 2014; Whitley et al. 2018). Conversely, a lack of project funding may limit researchers' ability to build the protected space needed 'to deviate from epistemic and organizational standards' (Franssen et al. 2018, p. 31).

Although less research has been done in this area, evidence suggests that the attitude of funders towards changes in

direction also exerts an influence. Comparing researchers funded by the National Institutes of Health (NIH), with those funded by the Howard Hughes Medical Institute (HHMI), HHMI investigators changed direction and increased the breadth of their research to a greater extent than NIH grantees, as measured by changes in publication keywords and citations (Azoulay et al. 2011). HHMI funds ‘people not projects’ and emphasizes freedom to experiment.

2.2.2 Collaboration and interpersonal networks. Much of research is a collective endeavour, particularly with the move towards big science. Large teams of scientists often collaborate with a wide range of specialized skills and expensive instruments (Ziman 1987). This additional strand of literature argues that interpersonal networks are an important feature of science, and they influence changes in research direction.

The structure of these networks can be elite and non-obvious (Price and Beaver 1966). Work has been done to characterize the influence of collaboration on research direction, including, for example, the interplay between spatial and structural effects in the geography of R&D collaborations (Scherngell 2013); collaboration patterns across different sectors (Rosenberg 1976); and the influence of collaboration on the direction of research impact (Hong et al. 2016; Malkov et al. 2023). Research collaboration in turn can be influenced by, for instance, ‘proximity among scientists in social, cognitive, and physical dimensions’ (Frenken 2020, p. 1007), and by research funding (Ubfal and Maffioli 2011).

Research collaborations and interpersonal networks have a strong influence on shifts in research direction during projects, especially since ideas, resources including equipment, and/or expertise are typically shared among collaborators/network members in scientific communities (Gläser 2019).

Prior science policy literature has focused on how research directions are influenced by elements of the research context, such as research funding and collaboration, but there is limited evidence on how these elements might influence changes in research direction during projects, and how they might interact with individual-level influences.

More generally, there is a need for more research linking context-level influences, traditionally the concern of science policy studies, to individual-level influences, usually the focus of the sociology of science/STS (Hollingsworth 2008; Gläser and Laudel 2016).

2.3 Disease-related variations and interactions between influences

In biomedical research, different diseases, for which research is oriented towards finding diagnoses, treatments, or cures, are often an aspect of research direction in and of itself (Yaqub et al. 2022; Coburn et al. 2024). Thus, there are likely to be disease-related variations with respect to the influences identified in the previous sections. We do know that biomedical research frequently crosses disease areas, with different patterns for different diseases that can be measured quantitatively (referred to as cross-disease spillovers or flows) (Sampat 2015; Azoulay et al. 2019; Coburn et al. 2024; Yaqub et al. 2024). However, the nature, causes, and consequences of these changes in research direction that occur during projects are poorly understood and little examined in the literature (Coburn 2024).

There may be disease-based differences in individual-level influences on changes in research directions. For instance, a researcher may purposefully migrate from working on malaria

research to HIV research because there is more funding and higher-profile opportunities available for the latter than the former. Conversely, issues related to research processes, such as a lack of available data, might be more likely in a disease-based research area that has less resources, such as neglected diseases research. In such a context, it may be more difficult to respond to unexpected events in general, both serendipitous and failure-related.

In terms of context-level influences, research into neglected diseases in low-income country (LIC) settings may be subject to narrow-remit grants, scarce resources, or a lack of capacity, limiting the ability of researchers to switch focus. In comparison, research into diseases in high-income country (HIC) settings may have greater funding, resources, and capacity, granting researchers more flexibility to be able to follow new research directions (Coburn et al. 2023).

Related to projects, for neglected diseases research, in which resources can be scarce, it may be necessary to tailor research to distinct and limited projects, whereas for diseases that receive more research funding, it may be more feasible to work over longer timeframes and to plan research that requires larger and more sustained investments.

Related to collaboration, in the African context, capacity-building efforts have traditionally meant pairing a research group in Africa with one in a developed country, in a ‘North–South’ collaboration, to enable access to resources, equipment, and expertise. However, such collaborations may not align well with African needs, so ‘South–South’ collaborations are also important (Cochrane et al. 2017; Burgess and Chataway 2021). Despite possible problems related to ‘North–South’ collaborations, Southern researchers can sometimes ‘reshape the balance of power’ and influence the content of research, particularly when they are involved in the proposal writing process (Bartroli 2023).

These examples show that different influences on changes in research directions can be related to, and interact with each other, including variations by disease, and so this is a multi-dimensional phenomenon. There have not been many efforts to analyse the multifaceted nature of changes in research direction that occur during projects.

This section has identified some under-researched areas related to changes in research direction, namely, changes that occur during projects, key factors influencing these changes at both the individual level, such as features of the research process itself or responses to unexpected events; and/or features of the research context, such as funding arrangements or research collaborations. In the case of biomedical research, there are also likely to be disease-based variations in many of these influences.

We close this review with the following overarching research question: Why do individual biomedical researchers change their research directions during projects? More specifically, we also ask:

- 1) Which factors influence changes in research directions at the individual level?
- 2) Which factors influence changes in research directions at the context level?
- 3) How do the influences of 1 and 2 interact and vary by disease?

The key concepts from the literature to be explored in the data in relation to these questions are: related to the individual level and research processes—knowledge, tools, methods, and

serendipity and failure; related to the context level—aspects of the research environment, project funding, protected space, collaboration, proximity, and expertise; and related to variations by disease—features of diseases themselves, resources, capacity, ‘North–South’ collaborations, as well as interactions with other concepts.

3. Methods

We carried out twenty-one semi-structured interviews with researchers, lasting 60–90 min. Ethical approval and interviewees’ consent were obtained. The interviews were carried out in English, and they were recorded and transcribed in full.

Potential interviewees were identified via data from four major public funders of biomedical research [NIH, UK Research and Innovation (UKRI), the European Research Council, and the Wellcome Trust], across different diseases (podoconiosis, Chagas disease, malaria, ischaemic heart disease, and breast cancer) gathered during prior scientometric analysis (Coburn et al. 2024). Interviewees were invited to discuss apparent changes in direction between their project grants and their publication outputs if the disease focus of their publication(s) was different from the disease focus of the grant that gave rise to those publications. The qualitative data gathered from semi-structured interviews provided detailed narratives about how researchers themselves defined changes in research directions during projects, including some features of the system that could not have been identified from quantitative data from grant proposals or publications alone (Coburn et al. 2024), such as variations in researcher definitions of changes in research direction, different motivations of researchers, and the influence of collaboration and networks beyond co-investigators or co-authors.

Where possible, interviewees were selected to span a range of attributes that might affect changes in research direction. Of the twenty-one researchers, fourteen were male and seven were female; eleven were full professors and ten were not full professors; eleven worked at universities and nine at university hospitals; nine were NIH-funded, eight UKRI, and four Wellcome Trust; ten were based in the UK, eight in the USA, one in Ghana, one in Portugal, and one in Uruguay; and seven focused on malaria, six on Chagas disease, four on ischaemic heart disease, three on breast cancer, and one on podoconiosis.

Researchers were asked to describe the trajectory of their research from grant proposal to outputs and outcomes in an open-ended way. Then they were asked more specific questions about the extent to which features of the research process itself, or the context within which the research was carried out influenced whether the research had changed direction, and they were also asked about their experiences of serendipity and failure.

Using NVivo software, we carried out thematic analysis of the interview transcripts, searching for semantic themes across the whole data set by iterative reading and coding of the transcripts, and by interpreting themes in relation to key concepts from existing theories highlighted at the end of Section 2 (Braun and Clarke 2006). The analysis used concepts from the literature review as a starting point for coding the data, but additional codes were added if significant patterns were repeated between interviewees (addressing prevalence), if new

sub-categories were required (adding new details and nuances to existing categories), and if an unforeseen finding seemed particularly significant in relation to one of the research questions (addressing importance).

We do not report all of the findings from the interviews here. Instead we focus specifically on findings that were particularly prevalent across the interview data, and findings that were novel and important in relation to the research questions and to making novel contributions to prior literature discussed in Section 2.

In the results (Section 4), we draw on the literature on influences on changes in research direction (Section 2) to orient the results from the qualitative interviews and thematic analysis described in this section. Section 4 is organized into key themes that we judged to be particularly prevalent, novel, and/or significant because they built on concepts from the literature, providing new insights and additional nuances, although it is important to note that all of the concepts outlined in the literature review were mentioned by at least one interviewee.

Findings and quotes from particular interviews are indicated by using square brackets around an interviewee code, e.g. [001]. For anonymity, some items appear in angle brackets, for example, <research funder> is used instead of naming a specific funder.

4. Results

4.1 Individual-level findings

4.1.1 Changes in research direction during projects are commonplace and influenced by aspects of research processes. Interviewees reported that the direction of their research often changes between grant funding and publication of results. Researchers observed that ‘it doesn’t always match up ... where I get to by the end of the grant isn’t necessarily where it started’ [003]; and ‘what actually emerges as a publication may or may not be what you were predicting, for many reasons’ [011]. Several researchers estimated what percentage of the work specified in a grant gets done, for example: ‘We are required to frame [grants] quite rigidly but there should be an understanding that things change and not everything works as written on the page. So I think if you get 50% through a proposal, covering the things you said, then you’ve probably been successful’ [005].

At the individual level, these mid-project redirections can be influenced by changes in knowledge (e.g. biological mechanisms [007], [015]), tools and technologies ([002], [006]) (e.g. a new tool for weighing cells more precisely [014]), methods (e.g. advances in genome wide association studies [010]), data (e.g. gathered from multiple research projects for the first time in a very accessible database [004]), level of analysis (e.g. adding structural and computational biology to other layers of analysis [007]), or approaches (e.g. molecular design [001]). Additionally, one researcher described how he might have to change various aspects of his research if he wanted to measure something new:

So, you try to measure something new. And it’s not always even a new method, sometimes it can be, in biology, that you have a new sample type. So, you’re used to working with a certain kind of let’s say white blood cells, and then you move to studying something like liver cells, and oh, what do you know? [With] the measurements, you have a

Failure was also highlighted as the source of redirections when problems were overcome incrementally, and research moved forwards in a better direction ([016], [020]), for example:

I think nine things out of ten someone tries in the lab, you know, doesn't necessarily result in a result that moves you forward ... they might help chip away at the problem, sometimes you chip away, and each chip you don't really see the sculpture, but nevertheless, it is a step towards the final understanding, ... but the key thing is you learn something from every experiment, and that hopefully gives you experience and knowledge to design a better experiment. [020]

This example also shows how researchers gain new knowledge and experience from overcoming failures.

Borrowing from prior work in industry, one researcher described how his 'fail fast' mindset allowed the project team to work on multiple pathogens at the same time:

My mindset, which I apply to our projects, is deeply unpopular among academics, ... but if you're doing drug discovery, which is inherently risky and expensive, and you have resources to work on project (a), and project (a) fails, and those resources are still around, it's better to redirect it to something that's going to work. So, it's in that sort of mindset that ... we decided to work on multiple pathogens at the same time, because we wanted to have as many shots on goal with the resource that we have, as opposed to just banging your head against the wall ... [for] that first pathogen. [004]

This example also shows that a change in direction/pursuing multiple directions in terms of disease-focus might be driven by maximizing the use of project resources, which we discuss in more detail in Section 4.3.

4.2 Context-level findings

4.2.1 Research funding influences the extent to which new research directions can be pursued. Whilst the literature (see Section 2) recognizes that the research environment can influence changes in research direction, our interviewees discuss here the extent to which these changes can be pursued and offer additional insights on how these dynamics can come about. In line with previous research, for example, researchers highlighted the research field within which they worked, their research institute, academic publishing, and research evaluation as influencing changes in their research direction ([011], [013], [020]).

Research funding was also identified as an important influence on the extent to which changes in research direction could be pursued, not just the availability of funding but also the attitude of the funder towards change, and the flexibility of the type of funding. To describe funders, one researcher used an analogy of trains *versus* jeeps, with trains only able to reach the desired destination, and jeeps able to explore the landscape and reach different locations [008]. She viewed some sources of funding as being less flexible, like a train, and other sources as being more flexible, like a jeep, and she preferred the latter because 'it makes us feel more empowered ... to go in different directions without being afraid' [008].

Another researcher observed that:

... at the call for applications level, [funders] send out a message of being linear and non-serendipitous, but they

don't actually enforce that or follow up on that. So, they kind of make a dialogue of that and try to be accountable, but they know that science is not like that, and they want innovation and creativity, so there's never any scolding if you don't do it. But ... everybody is just getting the message that you should propose something and do it and deliver on it. [001]

These examples show that the attitude of the funder towards unexpected changes in research direction during projects exerts an influence on researchers' attitudes towards pursuing new directions; and that there is sometimes a tension between the message that a funder conveys to their own sponsors and to the public about their expectations in the name of accountability, and the way science actually works in practice with its inherent uncertainties. The latter dynamic requires researchers to read between the lines to assess the extent to which they can pursue unexpected new directions in their research.

Many researchers highlighted that the flexibility of the type of funding they received enabled them to pursue new directions when the opportunity arose. Flexible funding mechanisms included 'new innovator' type grants [001], capacity-building grants ([005], [019]), 'fund the person, not the project' type grants [008], grants for travel money to enable collaboration and networking [013], fellowships with intended flexibility [014], PhD grants in which the supervisor 'protected' the student from external pressures [018], and permanent academic positions [013].

When faced with the need to change her PhD quite radically from what had been planned, one researcher reflected that: 'I mean it didn't necessarily always feel safe at the time, but having had a mentor, a supervisor, who a) had the experience and, b) just, he could deal with it for sure, no matter what happened' [018].

In another example, a researcher had been the recipient of a fellowship, which had a positive impact on the feasibility of finishing the research for a specific publication:

That paper actually would have been hugely delayed ... if I did not have the flexibility, because ... there was a big gap when no one actually had a lab, and I was able to do some basic things here. So it might have been a year's delay or more ... but because the funding had the flexibility, I was able to do the missing final pieces needed. [014]

One researcher with a permanent academic position explained that 'I have the luxury to listen to people and pick up on interesting problems, as and when they present themselves, but that's fairly uncommon I think' [013].

Some researchers reported that their funding was like a repayment plan, with funding for one project enabling them to do the innovative research to generate the preliminary data needed to apply for the next project ([003], [004], [014]): 'So, you basically cram so much preliminary data into the <research funder> grant, unfunded preliminary data, that a certain amount of that money that arises from <research funder> is essentially backfilling the effort that you had done before' [004]. In this case, evidence of changes in direction will be found between one project and another, not between grant funding and publishing results, even though some of

An additional reason for research to change direction during a project in relation to funding is that there can be a long time lag in between writing a grant proposal and starting a project, and in that time the field may have moved on:

Most researchers emphasized the importance of research collaboration and the networks of people within which they were embedded, including mentors such as the principal investigator [018], colleagues ([000], [008], [014]), other researchers worldwide in scientific communities ([000], [004], [005], [007], [010], [013], [015], [016], [018], [019]), patients ([000], [006], [009], [018]), clinicians [020], and people working in industry ([004], [005], [006], [009], [020]) in influencing changes in the direction of their research. To emphasize its significance, one researcher explained that collaboration is ‘where a lot of the magic happens’ [018].

In one example, collaboration with a colleague based on not only proximity but also on diversity, led to a side project that followed a completely different direction to the researcher's primary research, and as a consequence she argued that:

Collaboration can happen both during projects and over longer periods of time, and as part of both planned and accidental changes. Several researchers were inspired to change direction by a chance encounter, such as attending a particular conference or meeting ([003], [008], [011], [012], [020]), or socializing outside work ([011], [012]).

For instance, one researcher gave a talk on a particular topic, and then 10 years later an opportunity arose to collaborate with someone who came to the talk, because they had complementary data at that particular point in time:

This example illustrates both the importance of timing in relation to collaboration, and how collaboration can be related to serendipity.

Many changes in research direction were influenced by collaborator expertise, data, or other resources that were complementary to those of the researcher ([000], [001], [002], [004], [011], [013], [012], [019]). For example, a researcher might have the right expertise, but need collaborators to provide appropriate data ([002], [012]) or resources ([004], [019]), or a researcher might be approached by potential collaborators because of their complementary expertise ([001], [013], [017]):

So, I was kind of a person who a lot of researchers would come to when they needed this new kind of skill ... [and] the collaborator was one of many who ended up at my doorstep, and many projects took on from there. So, it is serendipity in the sense that, out of many of those requests for assistance, this one had some fortunate timing and data and things like that, to make it advance relatively quickly. [001]

In these ways, issues relating to collaboration interact with individual-level, research process related issues.

Finally, shifts in direction during projects related to collaboration were sometimes influenced by the funding mechanism, for example, *via* grants for travel money to encourage networking [013] or capacity-building grants [005].

Some influences on changes in research direction are specific to particular types of diseases and the countries in which they are more prevalent. Interestingly, in our data, we found more evidence for the latter than for the former. For example, in HICs, the materials and capacity needed for experiments are more likely to be available than in some LICs. In LICs, there are instances in which researchers are forced to change direction to pursue cheaper lines of research because of a lack of funding and/or resources. One researcher explained that in some LICs, capacity issues, and the availability of reagents limit the extent to which (and the speed with which) research can change direction:

Well, [one] thing is obviously capacity - there are some things we generally cannot do here. We pretend that we can do everything here. We don't have the capacity to do everything we wanted to do, so we have to basically work within the limitations of our capacity. So, we do experiments based on what we can do here. When there are critical experiments we need to do, that we can't do here, then we try to do with collaborators in other countries, but for the most part we try to work within our capacity, and that has some restrictions, of course, in terms of what

we can dream of. The other thing is reagents - it takes us a very long time to get reagents, so that affects the way you plan experiments, and the phase at which you can do experiments, because sometimes you're stuck without your reagents for months, because, you know, unlike the US, where I could order in and the next day I get them, here it's unpredictable - you don't know when you'll get it. So you have to always plan your experiments many, many months ahead of time, and ... it takes a lot more planning than I had to do when I was in the US, where I just needed 24 hours to get whatever I needed. [019]

On the other hand, some capacity-building grants in LICs have inbuilt flexibility, which allows researchers to 'follow the story':

When we find something interesting, we pursue it and see where it leads ... We're trying to discover new targets for vaccine, so we follow the story, and sometimes we find clues in immune responses, and sometimes we find clues in the parasite behaviour, so yeah, I'll say that we are open and looking ... Because it's capacity-building funding, we have the discretion to decide what kind of research to do with it, as long as it's in the broad area of pathogen biology and human genetics and host-pathogen interaction. So, because we have that flexibility, we're able to follow the story wherever it leads us, and we're not boxed in by grant requirements, ... although we have other grants that are project specific, which we're able to do that with, but with the core funding we have for capacity building, for training students and postdocs, there's room to basically explore. [019]

Additionally, researchers are also sometimes influenced by public health priorities, as happened during the COVID pandemic, for example:

We also look at, what are the challenges around us? For example, since Covid came, we had to redirect a lot of our efforts to doing Covid work. We have sequencing capacity that we're building to do malaria parasite sequencing, but since Covid came, we've done very little parasite sequencing, we've done more Covid genome sequencing ... [because] that's what everybody's worried about, and that's what the public health policymakers need information about, so we have to provide early information about new variants that are coming in, ... So basically, the environment also is very important. We have to be responsive to the needs of the community [and] what is the topmost public health issue at the moment. [019];

and:

When Covid happened, my old PI reached out and said - would you mind coming back to help out with Covid work? - [and] while we were doing all that Covid support work, we found that all the data that we were getting from a number of lower and middle income countries wasn't that reliable, and that's spawned a few other different projects on quantifying underreported Covid mortality, ... and those all really came about from just having to interact with that initial project and seeing where the issues arose, and

there are a number of outputs from that specific 6 month period that were definitely not what was described, which was very much just producing tools for health. [012]

Some researchers used methods that could be applied to multiple diseases ([001], [004]) and the disease focus changed during their research, while other aspects remained the same. For example, for one researcher, the research topic changed from malaria to HIV during a project, but there was little change in the methodological approach (designing molecules to be drug candidates) [001]. Additionally, a change in disease focus may in fact represent the judicious use of an existing resources, techniques or skill to cover more ground than was originally envisaged, because, for example, many biochemistry procedures apply across a range of diseases [004].

For others, the disease focus remained the same, but they altered other features of the research, such as their research approach ([016], [018]) or measurement technique [014]. In this case, research may appear to stay on target according to a disease-based classification, such as malaria, but other features of the research may change, for instance, the specific research questions [002] and/or research approach [018].

Sometimes the differences between basic research and more applied, disease-related research were not clear-cut. One researcher explained that: 'I'm a basic researcher, I don't care about any specific disease' [014]. Talking about a project that was related to breast cancer, he elaborated that:

It's related to breast cancer, most importantly, it's related to a cancer drug that is used in breast cancer, understanding what that drug does, when cells are exposed to that drug, what actually is that drug influencing? Which proteins in the cell? ... It had a lot of novelty to it, partly because of the new technology, and a lot of interest, partly because of the breast cancer drug aspect ... [but] it's more about basic research. [014]

In the same vein, another researcher described how, although his department does basic research, researchers try to frame their grants to relate to health and diseases because (a) the department is in a medical school, and (b) funding agencies have a preference for research that might have applications:

I'm in a school of medicine, so, [in] my department, biochemistry, it is almost a survival art to be able ... to show that the biochemistry that we do can have some applications and some destiny in terms of the health and disease process. So I would say that when we write a grant, even if the grant is very basic, we try to show that there is a connection with human biology and human pathology and medicine. I would say that our projects are basic and then eventually they will become translational, but we always try to keep an eye to the fact that at the end of the day, we want to have some connection with a better understanding of health and disease, ... because the funding agencies see that there is a possibility that this will translate into applications, so we always try to touch that in all our grants. [007]

Thus, apparent shifts in direction between grant funding proposals and publication of results may occasionally not be changes at all, but may relate to how grant proposals and

Some researchers were methodology researchers, and so their research naturally spanned different diseases and research areas, both during projects and over longer periods of time. On being a methodology researcher:

[013]

Thus, research directions are multidimensional, and can change according to one classification system, but not necessarily according to another, with examples of relevant classification systems being diseases, approaches, methods, and even molecular mechanisms within a disease that was previously categorized according to physical symptoms. These changes in direction may happen for any one or combination of reasons cited earlier in this discussion. [Table 1](#) synthesizes concepts from the literature and novel findings into one framework for classifying influences on changes in research direction that happen during projects.

Building on sociology of science/STS literature focusing on the factors that influence the construction of scientific knowledge on the one hand (Knorr-Cetina 1981; Hackett 2005), and on science policy literature focusing on influences on the direction of research at structural levels and over long timeframes on the other hand (Hollingsworth 2008; Whitley et al. 2018), this article offers a novel contribution on what constitutes a change in research direction during a research project according to biomedical researchers themselves. It puts their reasons and motivations at the forefront, highlighting hitherto under-researched causes and complexities in researcher decision-making about changes in research direction.

Researchers regard changes of direction as commonplace, to be expected, and indeed essential to the spirit of enquiry. The ability to modify research direction is considered desirable for many different reasons: for example, there may be unexpected obstacles to original lines of enquiry, new data or methods may emerge in fast-moving fields, and fairly ubiquitously, there may be serendipity of various kinds.

At the context level, features of the research environment also influence aspects of mid-project changes. For instance, institutions may demand sudden changes in focus requiring a rapid response, such as the redeployment of malaria researchers into COVID research mentioned by several researchers. Conversely, many of the researchers who had changed the direction of their research were able to do so because of some sort of ‘protected space’ afforded by their research funding (Gläser et al. 2014; Whitley et al. 2018).

Prior literature on the influence of research funding in shaping research direction has largely focused on the extent to which it shapes the research agendas of scientists (Whitley et al. 2018). This research contributes to the smaller number of studies (Azoulay et al. 2011; Franssen et al. 2018; Whitley et al. 2018) that find that changes in research direction during projects are not only influenced by the availability and ‘projectification’ of funding but also by the attitude of the funder towards change (e.g. trains versus jeeps, linearity versus serendipity) and the flexibility of the type of grant. To this literature, we add the contribution that this flexibility comes in different forms including project grants either implicitly allowing or explicitly encouraging changes in research direction (new innovators), fellowships (funding individuals), PhD grants (where the supervisor protects the student from pressures they may otherwise feel), large capacity-building grants (funding the training of cohorts), and block funding or tenured positions (where there are no predetermined deliverables). Research funding for projects was also described by researchers as a repayment plan for preliminary research carried out during prior projects.

Research collaborations and interpersonal networks have a strong influence on changes in research direction (Ziman 1987; Ubfal and Maffioli 2011), described by one researcher as ‘where a lot of the magic happens’. We contribute to this literature, showing that this category includes chance encounters (overlapping with unplanned factors); novel combinations of expertise, data, or other resources belonging to researchers working on complementary topics (overlapping with research processes); and the use of within-project resources specifically earmarked for collaborative activities, such as travel or capacity-building (overlapping with types of research funding). Additionally, networking occurs at different levels in research systems, from professional societies and conferences,

them in the context of other competing demands' (Morris and Rip 2006, p. 255).

In relation to research careers, policies could aim to provide researchers with longer term stability for their research endeavours to reduce the likelihood of scientists' social security considerations taking precedence over epistemic rationales or the desire to address societal needs (Sigl 2016). Improving the stability of research careers and/or providing some other kind of 'protected space' (Gläser et al. 2014; Whitley et al. 2018) could also contribute to fostering serendipity. However, different policy and strategy approaches may be required to support different types of serendipity due to its heterogeneous nature. For instance, the prevalence of 'network-emergent' serendipity found in our data highlights the benefits of funding research collaboration (Yaqub 2018). Tolerating some level of failure is also important, given the relationship between failure and subsequent serendipity and scientific progress (Firestein 2015).

In these ways, these findings on why research changes direction should be taken into account in the design of policies and strategies for shaping research towards addressing societal needs; better managing researcher careers in the context of uncertainty and scientific change; and fostering serendipity in research.

Shifting our focus to broader policy issues, there are a number of governance dilemmas that are central concerns of research policy, to which this research also contributes. There is an ongoing debate about the extent to which we should fund basic research, aiming to better understand the world and advance knowledge and assuming that impacts will follow (Bush 1945; Polanyi 1962; Ziman 1994; Godin 2006), or applied research, with the aim of addressing particular challenges or achieving specified missions, with the notion of impact built in to the research itself (Bernal 1939; Sarewitz 1996, 2016; Bozeman 2020), also associated with a shift from Mode 1 to Mode 2 knowledge production and from theory development to practical applications (Gibbons et al. 1994). Following years of research policy predominantly focused on scientific productivity and excellence, there has been increasing interest in the direction of research and a move towards targeting research towards addressing societal needs, sometimes framed as excellence versus relevance (Sarewitz 1996; Stirling 2009; Kuhlmann and Rip 2019). This shift has fuelled debates about the need to balance scientific freedom and autonomy with efforts to manage, control, and steer science (Morris and Rip 2006).

Until recently, there has been a relative lack of attention paid to targeting diseases with research in particular (Rettig 1977, 1978; Crow 2011; Best 2012), and even less to the specificities of neglected diseases (Røttingen et al. 2013; Viergever 2013; von Philipsborn et al. 2015; Yegros et al. 2020). In biomedicine, the shift towards targeted research has predominantly meant targeting diseases with research (Clinton and Sridhar 2017), and this has led to misalignments between biomedical research and societal needs, with some diseases receiving more research funding than others relative to their global burden of disease (Gross et al. 1999; Røttingen et al. 2013; Viergever 2013; Evans et al. 2014; Yegros et al. 2020).

In this article, we have shown that changes in research direction during projects are common, systemic, diverse in nature and multidimensional. This finding has implications for these enduring research policy issues. First, our findings add nuance to the policy debate regarding the value of investing in basic

or applied research. They suggest that the distinction between targeted and basic research is not necessarily an important one for researchers themselves, who may, for example, be more focused on a particular problem or method, regardless of whether the funding they received was targeted towards a disease or for basic research. Scientists may also frame their basic research as being more strongly related to applications to strengthen their research funding proposals in a context in which having an impact and addressing societal needs is highly valued by funders.

Second, shifts in research directions that happen during projects also call into question the ability to control or steer science with precision, the feasibility of targeting research to address particular diseases in isolation, and they complicate the measurement of misalignments between research funding and disease burdens. One implication of mid-project changes in research directions is that more investment in underfunded areas of research such as neglected diseases is necessary, but may not be sufficient to improve the alignment between research funding and health needs because it is common for research targeted towards a particular disease to contribute to research on other disease areas (and non-disease areas). Therefore, there is a need for a strengthened awareness of the pivotal role played by changes in research direction in research priority setting and evaluation policies, and a need to find ways to value unexpected outputs and outcomes, and nonlinear research careers, as well as predicted outputs and linear careers.

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Author contributions

Josie Coburn (Conceptualization, Data curation, Investigation, Methodology, Writing—original draft, Writing—review & editing)

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Data availability

The full data underlying this article cannot be shared publicly to respect the privacy of individuals that participated in the study. However, a modified version of the data will be shared upon reasonable request to the corresponding author.

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