Frontiers:
One Science – Life at the
interface

Evidence Synthesis
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One Science – Life at the Interface brought together leading scientists, technologists, industrialists and innovators to explore whether and how the Wellcome Trust could actively do more to support interdisciplinary research and tackle its challenges. The primary aim of the meeting, in September 2015, was to brainstorm possible suggestions to the Wellcome Trust for how it might overcome these challenges, provide better support and help create a culture in which interdisciplinary research can happen more readily.

This document draws together some overarching themes to summarise the main messages and advice that emerged from the meeting.

## What is interdisciplinarity, and whose problem is it?

- Interdisciplinarity is not an end in itself; it is, rather, one of the means to achieve certain scientific or technological goals. Asking the right questions and choosing the most appropriate methods to address them fosters the best collaborations.
- Interdisciplinary research (IR) should happen organically. Top-down prescriptive approaches by funders often fail.
- Interdisciplinarity can be considered both as an outlook of individual researchers and as the result of collaborations between teams of disciplinary experts.
- IR is a valuable asset in its potential to produce fresh thinking about a problem, because of the different methods and perspectives involved.
- IR requires various different personalities and expertise ranging from the "top-tier" scientists to the matchmakers, coordinators and administrators who can create and assist collaborations.

Many of the problems discussed at the meeting are not specific to IR but are more keenly felt by it – for example, the inherent conservatism of traditional peer review, conservatism of funders, appropriate credit and recognition for the different contributions and outputs of research, the increasing pressures on early-career researchers and the gender implications of those pressures. IR is further hindered by the invidious effects of a perceived hierarchy of sciences alongside differences in communication and motivation across different disciplines.

Existing attitudes and structures cannot be changed overnight. But Wellcome is in a unique position and could afford to take risks, unencumbered by the usual constraints of academic structures, institutions and financial resources.

Lessons learnt
- Support for IR should be predicated on the notion that it is becoming a necessary norm to address many scientific and technological challenges of the 21st century.
- Support for IR should place an emphasis on assisting with the identification of the best people with the best vision. It should be left to the right people to determine the necessary expertise needed to solve a problem.
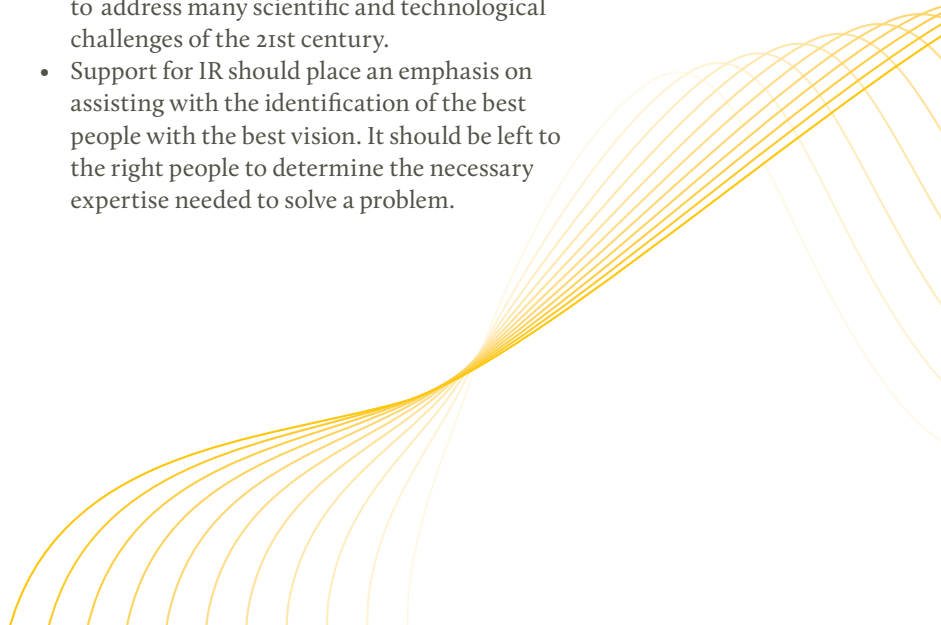
What makes a successful interdisciplinary environment?

Throughout the meeting a number of different approaches and models for interdisciplinary working were presented from academics, institutes and industry. Bell Labs, the IBM research laboratories, HHMI/Janelia and the new Francis Crick Institute were amongst the physical interdisciplinary institutes discussed, with industry models presented by Siemens, BP, GE, the UK's Defence Science and Technology Laboratory, and the Stevenage Bioscience Catalyst campus. A number of common principles and shared conclusions for successful collaboration could be drawn from these discussions:

- Interdisciplinary projects work best when all involved have trust and commitment in a particular vision, with well-defined common goals from the outset.
- A fundamental component to successful collaboration is the right culture, which should foster:
  - trust
  - creative thinking
  - curiosity
  - mutual respect across disciplines
  - a willingness to debate
  - an openness to fail honourably
- Good leadership is crucial to the success of any IR venture. Leaders become most effective not by imposing their own research priorities but by:
  - facilitating a sense of purpose
  - promoting the right culture
  - facilitating interactions
  - fostering and recruiting the right skill sets
- Centres of productive cross-disciplinary fertilisation seem to coalesce when people are hired not to fill a perceived need for a particular expertise or to fulfil a specific research objective, but because they are productive and creative.
- Success relies on finding the right people. There is little to be gained by designing the "perfect system/environment" if it isn't populated by productive, creative and collaborative people.

In academia, interdisciplinary research can generally be classified according to the following three models:

- Individual projects, perhaps spearheaded by a particular research group or principal investigator (PI), that require or benefit from interdisciplinary collaboration – often coordinated in a relatively informal manner through peer networks.
- Formal interdisciplinary programmes or collaborative awards that link people from separate academic or industrial departments, creating a pool of expertise brought together around a common goal or vision.
- Interdisciplinary institutes established for a defined scientific or technological purpose.

Given the success of the interdisciplinary institutes discussed, one of the key debates concerned the merits of co-locating different disciplines in the same physical space and whether or not this nurtures and promotes the most effective interdisciplinary environment.

Advantages of the co-location model include the following:

- Housing everyone under one roof provides a concentration of people with diverse expertise, mixing daily in a formal and informal manner, nurturing relationships and promoting interdisciplinary working.
- Researchers stand at less risk of becoming siloed within academic departments, and are less vulnerable to departmental pressures such as having to show for tenure or review that their research fits within the established norms of that discipline.
- Institutes can acquire dedicated staff trained in areas such as product development, team management and administrators, core platform developers and technologists, which are catalytic for many interdisciplinary projects.
- Co-location can provide an effective mechanism for changing culture and promoting openness, trust, creative thinking and collaborative working, particularly for early-career researchers.

It isn't clear that there yet exists a good model for an institute established solely for the purpose of fostering interdisciplinary research, with all models discussed emerging from the need to convene different expertise around a specific scientific or technological vision. Indeed, for some academics the university model with departmental affiliations is regarded as more advantageous in terms of career structure and a sense of security and shared goals.

Alternative mechanisms to co-location that work well to foster collaboration were also discussed and included:

- The rapid evolution of teleconferencing methods and other virtual communications means that remote interactions can be much more useful, regular and productive than they once were.
- Workshops and secondments can assist mutual understanding between disciplines.
- Existing buildings and laboratories can be adapted to meet the needs of multiple disciplines.
- There is an intermediate situation, exemplified by the Wyss Institute for Biologically Inspired Engineering at Harvard: a physical space with no permanent faculty, to which people may come temporarily to work on a project while retaining positions in their respective departments.
- There is a model for such spaces in the Silicon Roundabout-style "co-working spaces" patronised by start-up entrepreneurs – a mode of working that may be particularly familiar and conducive for the next generation of researchers.

In summary, co-location is not essential for interdisciplinarity to work, and housing everyone under one roof does not automatically ensure that collaborations will flourish. However, co-location and the institute model can go a long way to facilitating IR research if people are brought together with a defined purpose or vision, and if there is the right leadership and culture to nurture the collaborations.

Lessons learnt
- Support for IR should not be based on one specific structure or model, but rather, should focus on supporting good researchers who have good ideas. A balanced portfolio of funding options should be available to support different visions.
- A means of celebrating IR would add great benefit: for example, awards to people or projects that have excelled in this area with proven leadership skills.
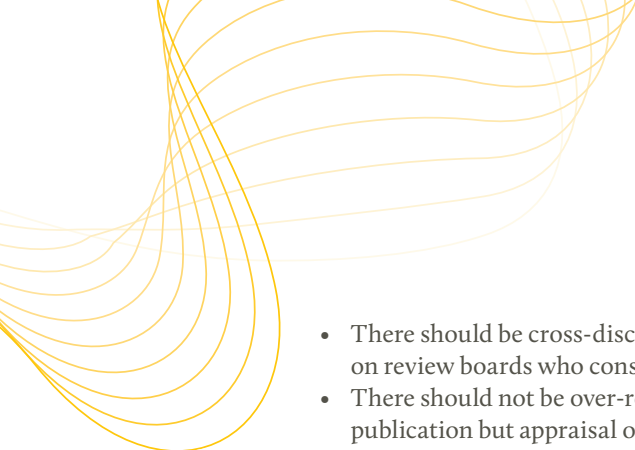
What are the problems with funding structures?

Difficulties in securing funding are one of the most often cited reasons why IR is hard to do. There are many reasons for this:

- Interdisciplinary applications often fail because they are deemed too risky and ambitious, particularly if an individual lacks a publication history or proven track record in one of the disciplines. Early-career researchers are particularly disadvantaged by this when they are trying to establish a reputation or to build effective peer networks. This frequently discourages them from riskier interdisciplinary research.
- Peer review of grants can suffer from disciplinary myopia, with applications often failing because they are considered not ground-breaking enough by each of the component disciplines.
- There are differences in standards and expectations between different fields. Proposals in biology are more often required to post a hypothesis or specific question they wish to address, while in the physical sciences it is more acceptable for research to be open-ended and exploratory. This places physical scientists at a disadvantage when trying to gain funding to work in the life sciences.
- The demand for short-term payoffs and the pressure to publish is particularly damaging to IR, which can often take many years to mature, placing unrealistic demand on researchers. Again this is often more keenly felt by early-career researchers that need to establish themselves.

There is clearly no simple and foolproof method of identifying which research deserves support. But there are some considerations that might help:

- Interdisciplinarity needs to be genuinely so, such that a project has expertise from all of the areas in question.
- Criteria for assessing an interdisciplinary proposal should be based not on "which specific hypothesis it will test" but rather on "what the aim of the research is" to enable exploration of good ideas and prevent projects being constrained by a particular question.

- There should be cross-disciplinary representation on review boards who consider such proposals.
- There should not be over-reliance on metrics and publication but appraisal of a much wider range of approaches and research outputs (see later).
- More grants are now being given to large centres and collaborations than to projects with a single PI. Such large projects tend to advance through a tightly planned series of milestones that leave little room for innovation, spontaneity, or accepting the risk of failure. There should be equal weight to grants for single PIs, small groups of PIs (which will often be interdisciplinary), and large centres. Moreover, for projects with multiple PIs there needs to be a way of avoiding a hierarchy that affords (or insists on) precedence to any one group.
- Funding decisions could be less "democratic", (relying on a wide range of referees) and rather be more "capitalistic" and guided by the decisions of a few well-informed individuals.
- Funding agencies need to accept that research is generally not linear and interdisciplinary research in particular will often go off in unexpected directions, which can lead to valuable applications in other disciplines.

Advice to funders
- Introduce schemes for small-scale (perhaps micro) seed funding that can support promising but potentially high-risk ventures based on an interesting idea at any career stage. These would need to be able to respond very quickly to applications.
- Investment in developing scientific infrastructure, such as stronger networks between existing centres and supporting researchers to visit for short periods.
- Funders should offer a balanced portfolio of options: including seed funding for young researchers to explore ideas at an early stage; funding for centres; and funding that isn't nationally/regionally limited to support international collaborations.
- Guidelines and rules could be introduced into grants compelling institutions and PIs to adhere to certain principles around issues such as career support, education and protection from departmental silos.

The broader piece around academic culture

A number of key challenges facing interdisciplinary research are in fact problems inherent in academic culture, which pervade all of modern science and research, including:
- Current success, reward and merit structures in research are quite conservative and do not provide adequate credit for different contributions to a project in terms of authorship nor do they adequately recognise and reward the different research outputs that can be produced, such as the development of a prototype, dataset or new technology.
- Technical researchers and administrative staff generally are undervalued. In many universities there is no real career development path for them, nor are there awards, prizes and other recognition schemes. As a result, some departments and teams find it hard to retain highly valued technical and administrative support, which are the fundamental "glue" of any interdisciplinary project.

Advice to funders
- Reward structures could be changed to better recognise and credit those who provide core facilities and platforms that underpin biomedical research, such as technicians and administrators. Funders should celebrate these "unsung heroes" who are key to effective collaborations.
- Peer review structures need to be revised to overcome inherent conservatism: PIs should be able to respond directly to reviewers, who should be more willing to accept risk.
- Reward structures could be changed to better recognise and credit those who integrate ideas/ techniques rather than just those who excel in individual areas. Reward for contributions needs to move beyond authorship position in publications.
- Many of the issues around academic culture need to be addressed by funders and research councils working in partnership.

What is the role of the humanities and social sciences?

Social science, arts and humanities offer a wider perspective in biomedical research by bringing context to the problem and challenging certain assumptions. However, at present they are often included in a project as an 'add-on' at a late stage: an exercise in ticking boxes to take care of the "impact" and ethical issues. This can create challenges in areas such as public health, where often it isn't a matter of discovering more science but of understanding the social and cultural questions involved in order to plan an effective strategy for implementing a treatment or preventative measure.

There is a pervasive conception of hierarchies in the sciences, with the "hard" sciences more respected and valued, and seen as having more intellectual weight, than the "soft" sciences. This leads to inequalities between the voices of different disciplines, and can leave social scientists marginalised and under-appreciated.

Advice to funders
- The social sciences must be considered a serious partner in collaboration and should be equally recognised as co-PIs at an early stage.
- There must be respect for the fact that different disciplines have different approaches.
- There is an opportunity for social scientists to be commissioned to undertake qualitative research on the practice of research, how interdisciplinary funding happens, and what the pitfalls are. Such research could help funders to identify key common features or best practices.

What is the role of education and implications for early-career development?

- Interdisciplinary degrees aren't necessarily considered to be the most appropriate mechanism to facilitate effective communication across disciplines. IR teams tend to value depth of experience above breadth in young researchers.
- Maintaining an interdisciplinary mindset is more about exposure and experiencing different disciplines.
- Even if students are not to be trained in interdisciplinary degrees specifically, there are benefits to broad training. For example, it can help young researchers to develop a problem-based approach, establish networks early, and establish skills as 'facilitators' with the ability to translate between different disciplines.
- With that in mind, it is both possible to, and desirable to, introduce breadth and diversity into training without sacrificing depth: for example, to teach maths, statistics and programming skills to biologists as illustrated by the Oxford Doctoral Training Centre. Alternatively, interdisciplinary training courses can be offered that aim to foster open and informed thinking without attempting to give students the detailed skills to work in more than one area.
- Early disciplinary specialisation in UK higher education reduces the breadth and openness of students and can particularly discourage interest in physics and maths at an early age in those who perceive these as "hard" subjects.

Early-career researchers were seen as natural collaborators and an asset to interdisciplinary projects. However, interdisciplinary working is particularly challenging for early-career researchers, who are under pressure to prove themselves quickly in a competitive and uncertain environment and to establish a clear scientific identity and reputation – which is hard if you are at risk of seeming to "dabble" in several different fields.

As alluded to above, early-career researchers can more keenly feel the challenge of IR working in terms of funding and reward structures:
- Short-term fellowships discourage risk-taking and give little time and flexibility to get interdisciplinary projects off the ground.
- Publication-based metrics are a disadvantage to researchers working across disciplines when research falls between disciplines.

- Recruitment of the required skills and collaborators can be difficult for young PIs without an established reputation.
- Criteria and eligibility for fellowships, for example linking funding to university tenure decisions, can create perverse disincentives for early-career researchers.

There was intense debate about the value of "fear" given that academics with tenure can be considered to get too comfortable, complacent and can become less innovative. A degree of uncertainty can be said to focus the mind and a regular turnover of staff in an institution can inspire people to be more productive and innovative. On the other hand, many agreed – and the young Frontiers Innovators confirmed – that there was already too much fear and insecurity for early-career researchers, and there was little positive value in adding to that.

Advice to funders
- Funders need to offer career schemes which provide the time and flexibility needed to achieve results in difficult interdisciplinary areas. Extending the length of fellowship support for up to 10 years was frequently discussed, as this was said to allow time for productive mistakes and learning in the discovery process and for projects to mature.
- More career flexibility is needed at all stages to allow for breaks, opportunistic moves and changes of direction, without penalties for failure.
- Providing support for fellowships or secondments that would enable researchers to pursue independent projects in established interdisciplinary institutes. This would provide exposure to the right culture whilst enabling new relationships and collaborations to form.
- Clarification is needed around criteria and eligibility for fellowships to prevent disincentives.
- Mentorship is a lifeline. Not only can senior mentors provide valuable guidance and technical advice, but they can act as champions for mentees and hold departments to account in recognising worthwhile research, even if it is not producing a steady stream of high-profile publications. Mentorship schemes should be created or facilitated to support these relationships and help young researchers to develop promising ideas.

Conclusion

Interdisciplinary research is becoming a necessary norm to solve modern science and health problems. There is no "one size fits all" approach for effective interdisciplinary working; however the best collaboration will only be achieved if led by the right people, with a strong shared vision or purpose for the collaboration and a culture that fosters trust and openness. Funders should offer a diverse range of funding models from centres to team science to the PI and institute model in order to provide adequate supportive structures for a range of different people and projects. Interdisciplinary research cannot be advanced through one big solution, but adaptation of a number of current activities could go a long way to further nurture collaboration. However, many of these challenges need to be considered as part of a much broader piece of changes needed to improve academic culture and the research environment, which will only be achieved if funders and research councils work in partnership.
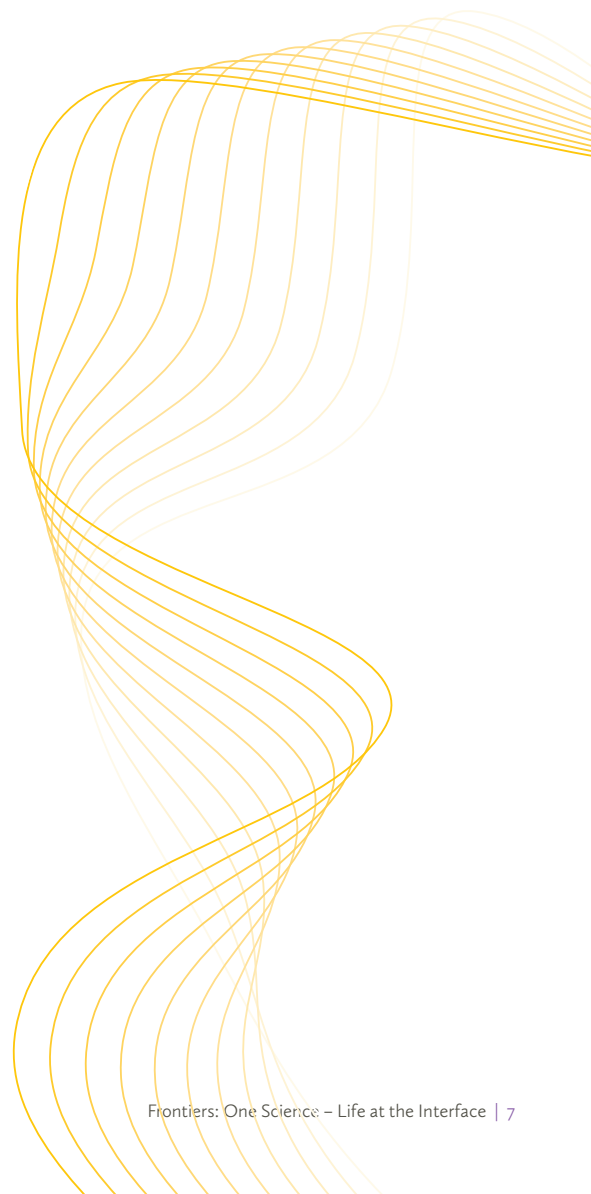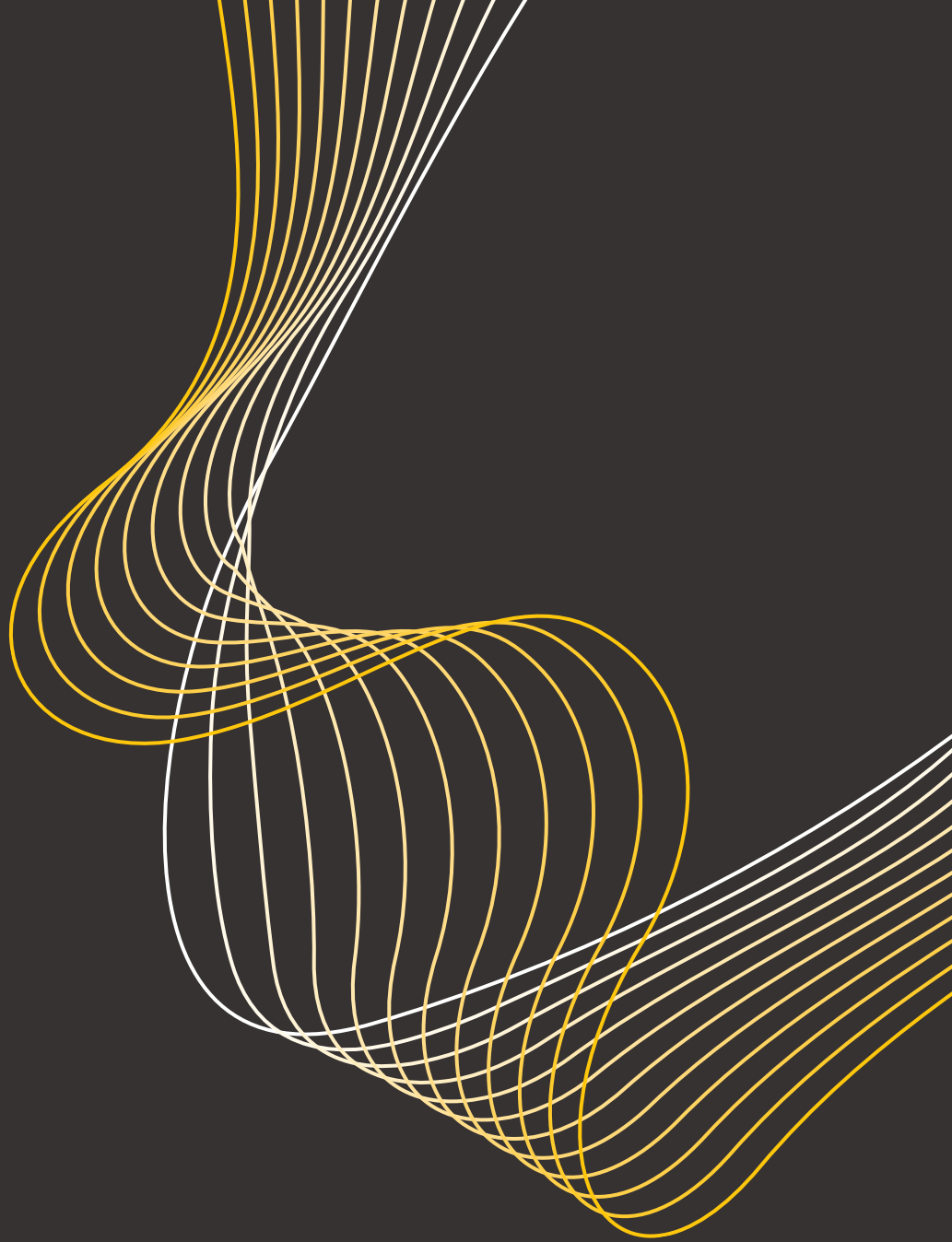
Wellcome Trust

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