EUROPEAN SCIENCE FOUNDATION

AIT AUSTRIAN INSTITUTE OF TECHNOLOGY
TOMORROW TODAY

http://qurope.eu/projects/farquest

FARQUEST is a **prospective analysis** of quantum information science and technology. The goal is to synthesise **scenarios of future developments** for collaborative significant problem-solving with answers and ideas **outside the core disciplines of quantum information and inspired by cross-disciplinary** fields.

Related goals are to **raise the awareness** of the current and future potential of quantum information and its technologies, and to **shed light on present needs** in terms of matching research questions, societal needs, research programmes, infrastructures, science policy, and education.

Present co-chairs

Addendum to the 2nd ESF Forward Look workshop "FARQUEST CHALLENGES"

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Exhibit I: Common ground, goals, strategic issues, first (joint) project ideas.

Discussion results	Flip charts / Posters

Leading Questions

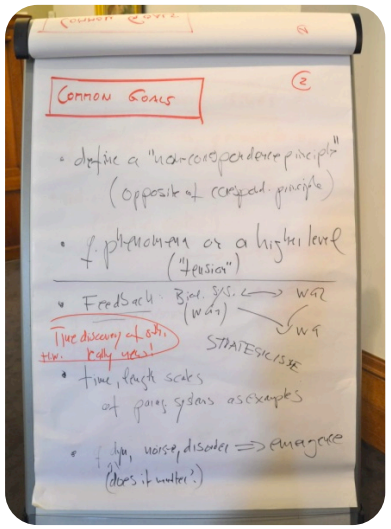
- **Common goals interlinking our individual goals**
- **Common strategic issues framing our individual topics**
- **Key research questions guiding our scientific activities**
- **Project ideas calling for our diverse competence**

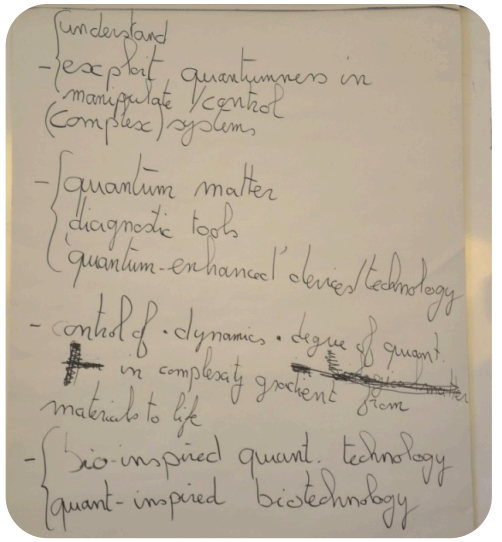
Common Ground

- Understand and exploit quantumness in order to manipulate resp. control (complex) systems
- Quantum matter, diagnostic tools, “quantum-enhanced” devices and technology
- Control of dynamics, degree of quantumness in complexity gradient from materials to life
- Bio-inspired quantum technology / Quantum-inspired biotechnology

Common Goals

- Dynamic meets noise / collective behaviour
  - Insulating from noise
  - Use noise productively
- Identify genuine quantum signatures
- Insulating from noise / Use noise productively
- Biological evolution of quantum behaviour → Tune to influence variables (Is quantum physics involved?)
- Successfully evolve such a system without quantum noise
- Can we use noise? Deductive light?

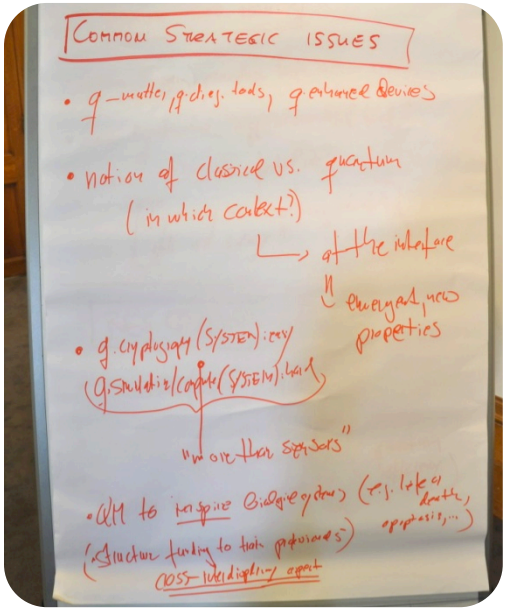


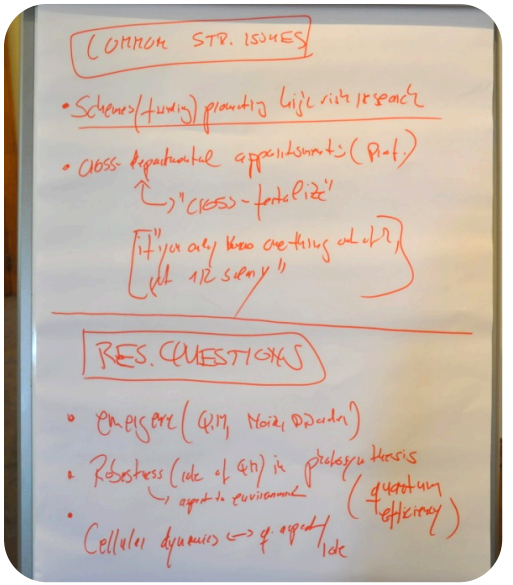


- Revolutionary quantum behaviour (i.e. unexpected quantum behaviour)
- Tune quantum behaviour to influence microscopic behaviour
- Opposite of the correspondence principle: Define a “non-corresponding principle”
- Quantum phenomena on a higher level: Time-length scales of paradigmatic systems as examples (“tension”)
- Quantum dynamics / Noise / Disorder: Does it matter for emergence?

Common strategic issues

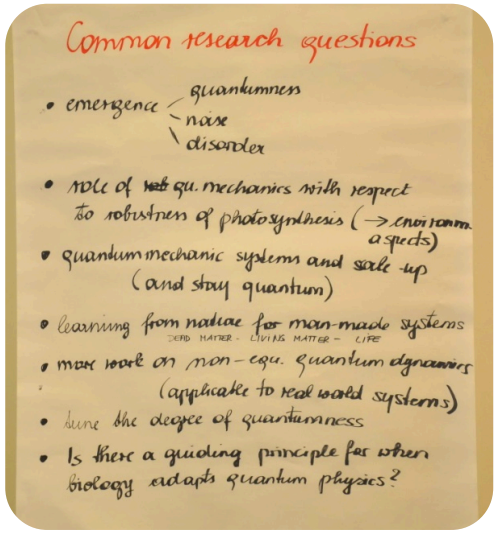
- Quantum…
  - matter
  - diagnostic tools
  - enhanced devices and technologies
- Quantum vs. classical: In which context? → Emergent new properties
- “More than sensors”: What is in between cryptography and simulation?
- Quantum mechanics to “inspire” biological systems (life-death or apoptosis-decisions)
- Suitable funding schemes promoting high-risk research
- Cross-departmental appointments for Professors – cross-fertilisation
- Strategy that will lead to raise common goals
- Structural funding and professional development in a cross-scenario action
- Breakthrough of a type of quantum mechanics: Inspire a paradigm shift in quantumness

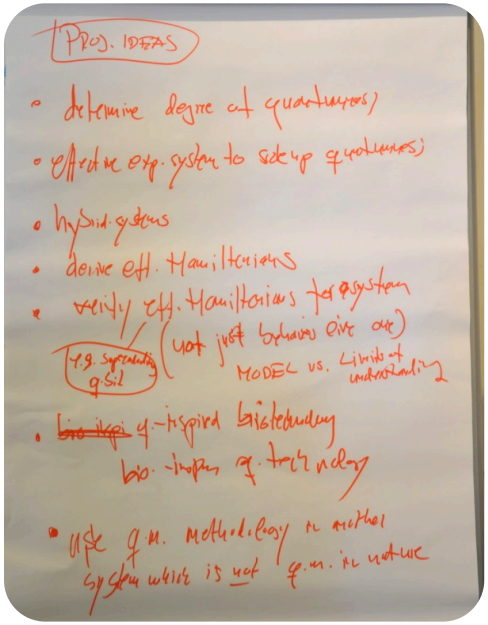




Key research questions

- Role of quantum mechanics with respect to robustness of photosynthesis (→ The environmental aspect)
- Quantum mechanics systems: Scale-up (and 'stay quantum')
- Learning from nature for man-made systems: Dead matter – Living matter – Life
- More work on non-equilibrium quantum dynamics (applicable to real world systems)
- Tune the degree of quantumness
- Is there a guiding principle for when biology adapts quantum physics?
- Emergence (Quantum Mechanics / Noise / Disorder)
- Robustness (role of quantum mechanics) in photosynthesis (quantum efficiency) – aspect of environment conditions and adaption
- Cellular dynamics: Quantum aspect?
- How far can you scale a quantum system and it still 'stays quantum'?
- Is biology ahead of us (i.e. exploiting quantum mechanics)? – Certain things nature does really well, and if we understand ('steal') it, can we make it better than nature?
- General principles for when biology meets quantum: Is there a particular pattern or a particular signature?
- Control aspect: Control of the dynamics / Control of the degree of quantumness (from dead to living matter)
- Export quantumness in manipulated vertical complex systems, such that it is possible to learn from complex systems
- Bio and non-bio: Get into the debate what distinguishes living systems from non-living – Look with respect to manmade systems (that is what we want to do: our own devices)
- Need to change perspective / Need to change we look at systems (not necessarily bound to existing knowledge)





- Trade-off: Fantastically robust and reliable vs. Better trade-off using quantum mechanics (→ Finding this trade-off) - Using discussed tools for other systems than complex ones **Project ideas** - Define / determine degree of quantumness - Effectively explore systems to scale up quantumness - Quantumness in hybrid systems - Derive effective Hamiltonians: What is the effective Hamiltonian for a system? Verify effective Hamiltonians for a system - Bio-inspired quantum technology / Quantum-inspired biotechnology - Make a discovery which is explained by quantum mechanics and is itself not quantum mechanics (i.e. research on the explanatory power of quantum mechanics) - Use quantum mechanics methodology in a 'mother system' which is not quantum mechanics in nature	

Exhibit II: Projects – competences, strengths, weaknesses.

Leading Questions

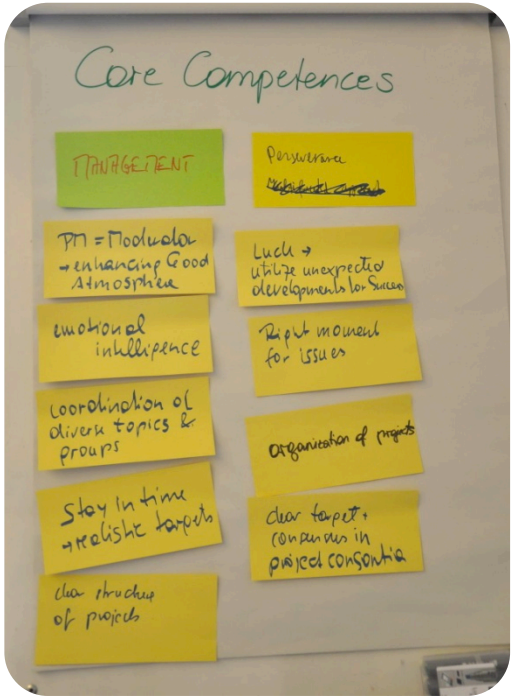
- **Identifying strengths of working-groups, discussing opportunities and threats in the context of current drivers and developments affecting our research directions, goals and results**
- **What are required core competences?**
- **Which factors caused failure in previous projects?**
- **Which factors brought forth successful projects?**

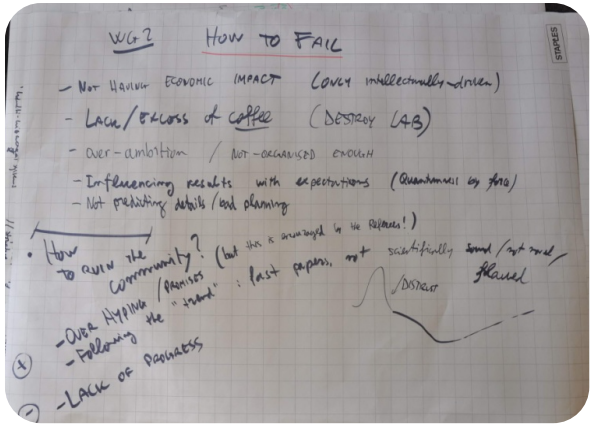
Core Competences

- Organisation of projects
- Clear structure of projects
- Stay in time → Realistic targets
- Management (group, facilities, etc.): Find the “right” people
- Clear target and consensus in project consortia
- Coordination of diverse topics and groups
- Enhancing creative atmosphere
- Perseverance
- Emotional intelligence / Anticipate the right moment for issues
- Luck → Utilise unexpected developments for success

Factors for project failures

- Bad project management (e.g., selection of the students, team, partners, expertise, timing, use of time, organization and coordination, no trust-relations, atmosphere, progress, difference between project manager and people with expertise and intuition)
- Choosing of the wrong model

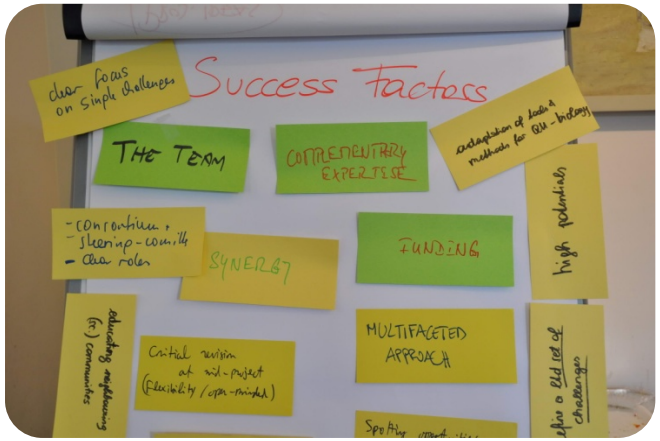


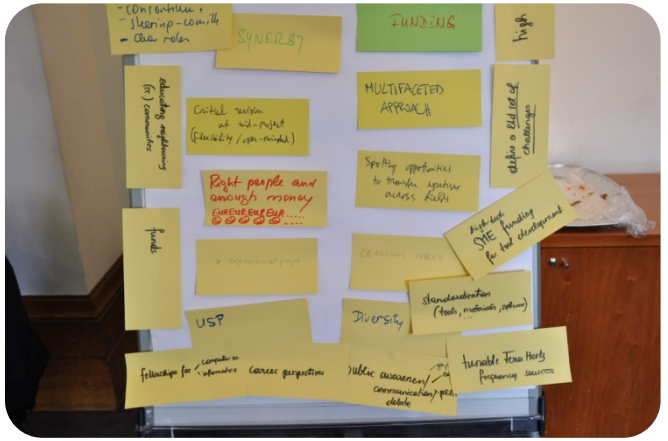


- Overambitious goals / Overhyping / promises (But is encouraged by the peer-review)
- Influencing results with expectations ("quantumness by force")
- Not having economic impact (only intellectually driven)
- Following the "trend": Fast papers, not scientifically sound /Not moral / Flawed
- Infrastructure / general and administrative conditions in science
- External reviewers: Respected external expert criticizes research

Success factors

- The team...
  - small enough to be able to collaborate (interdisciplinary)
  - complementary expertise
  - interest of team to work with one another synergistically
- Good management
- Funding
- Recognising strengths in people / Experienced people / High potentials
- Perseverance
- Multi-facet approach / Develop a spectrum of activities to address ones challenges / Clear focus on simple challenges (define a limited set of challenges)
- Standardization between the different people acting within a project (samples, computer languages, procedures, etc.) → Wiki
- Adaption of tools or methods for quantum biology
- Spotting opportunities to transfer / bridge expertise across fields
- Critical revision at mid-project (flexibility, open-mindedness)
- Educating neighbouring (scientific) communities
- Big consortium – Big consensus / Consortium and steering committee, clear roles, etc.
- Team/ Community / Society / Science politics





- Public awareness / Communication / Political debate
- Fellowships for physicists, computer scientists, informatics
- “Chance to have a future”: Career rewards, perspectives
- Economic success
- High-tech SME funding for tool development
- Tunable terahertz frequency sources

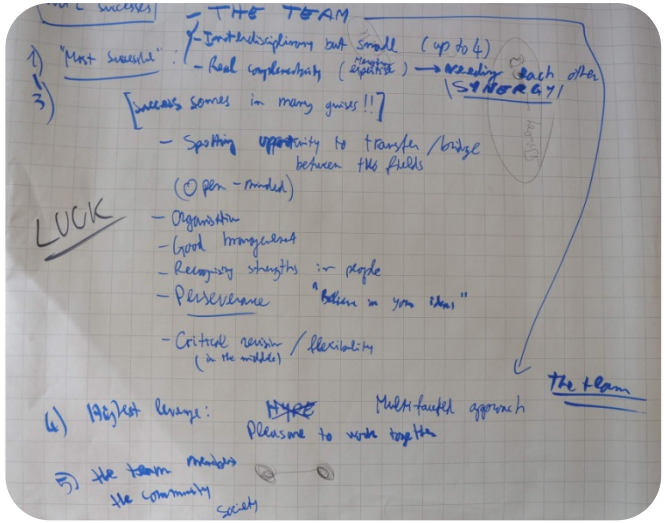


Exhibit III: Analysis of external factors.

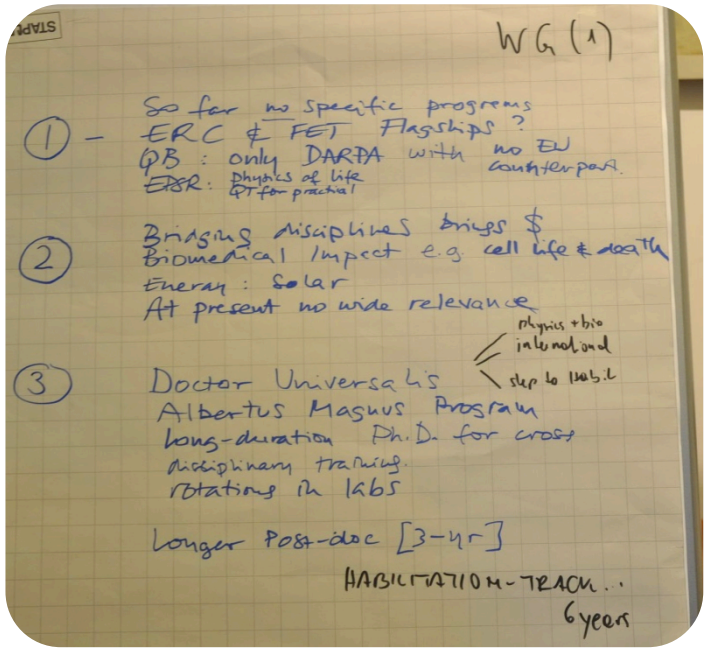
Leading questions

- **External factors, which support the success of the own research?**
- **Why should funding agencies invest in our projects?**
- **Which funding sources and programs have we tapped so far?**
- **Are there programs for interdisciplinary cooperation?**

Environmental Analysis

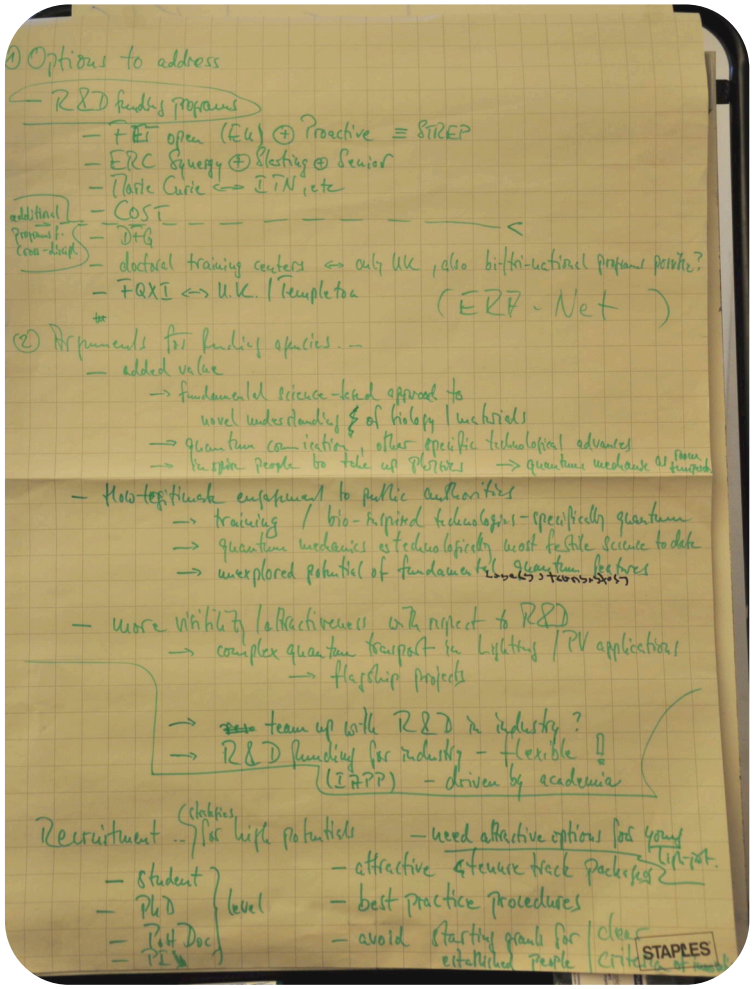
Working-group 1 (WG1)

- So far, no specific programmes
  - ERC, FET Flagships?
  - Quantum Biology: So far only DARPA programmes with no EU counterpart
  - EPSR: Physics of life, quantum technology for practical [purposes]
- Bridging disciplines brings money
  - Biomedical impact, e.g., cell life and death
  - Energy – Solar
  - At present no wide relevance
- Education: *Dr. Universales* (physics and bio, international, step to habilitation)
  - Albertus Magnus Program
  - Long-duration PhD for cross-disciplinary training (3-4 years)
  - Little bit like the DSC (GB) or *Docteur de Science* (F)
  - The now existing 1 year contracts for post-docs are a disaster, political trends emphasizes this problem
  - This whole topic has implications on how we evaluate research and researchers (especially performance of people)



Working-group 2 (WG2)

- R&D funding programs
  - FET open (EU) + FET Proactive
  - ERC
  - Marie Curie – ITN, etc.
  - COST programme
- Additional programs for cross-disciplinary research
  - DFG
  - Doctoral training centres – only UK, also bi-/tri-national programs possible (?)
  - FQXI – UK /Templeton
  - (ERA Net)
- Arguments for funding agencies
  - Added value
  - Fundamental science-based approach to novel understandings of biology / materials
  - Quantum communication, other specific technological advances
  - Inspire people to take up physics → Quantum mechanics at room temperature
- How legitimate engagement to public authorities?
  - Training/bio-inspired technologies (specifically quantum [mechanics])
  - Quantum mechanics as technologically most fertile science to date
  - Unexplored potential of fundamental quantum features
- More visibility/attractiveness with respect to R&D
  - Complex quantum transport in photovoltaic (PV) applications
  - Flagship projects
  - Team up with R&D in industry / R&D funding for industry



- Recruitment strategies for high potentials
    - Student, PhD, Post Doc, PI level
    - Attractive tenure track package
    - Best practice procedures
    - Avoid Starting Grants for established people
    - Clear criteria of promotion

Synthesis

- Today's arguments for (science) funding are not that unique, other fields present similar arguments
- Present community is much to closed in its own field, should open itself more to other fields and a broader spectrum, e.g., we are working on the basic principles of life
- Basic arguments for quantum mechanics are made / It is not about the selling issues, there is already an "overload" of good arguments / It is about fighting for "our" standards, about communicating it and the pride of own work and added-value
- How to convey authenticity resp. enthusiasm of research to public (rather than "why" and "for what")
- Consensus view on where this is going → Manifested in "life" as selling point (Information → Quantum and Physics)
- Quantum mechanics did supply technology
- Outreach / S&T communication / Convince society of the added-value of basic research / Convincing arguments for science funders (real USPs)
- Programs should be open to not "trendy" issues and topics and fields, and open to failure
- Which fundamental question [gives rise to | is] real innovation?
- What Nobel prizes are going to be won?

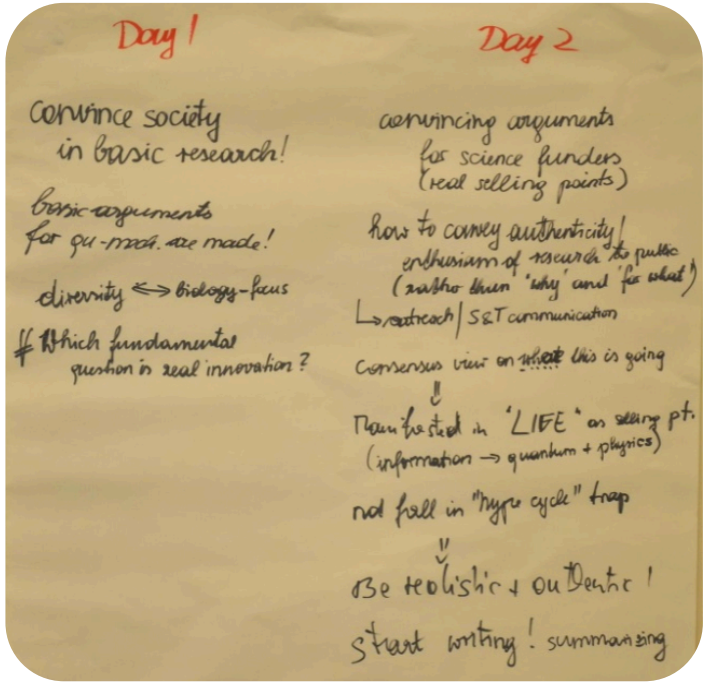


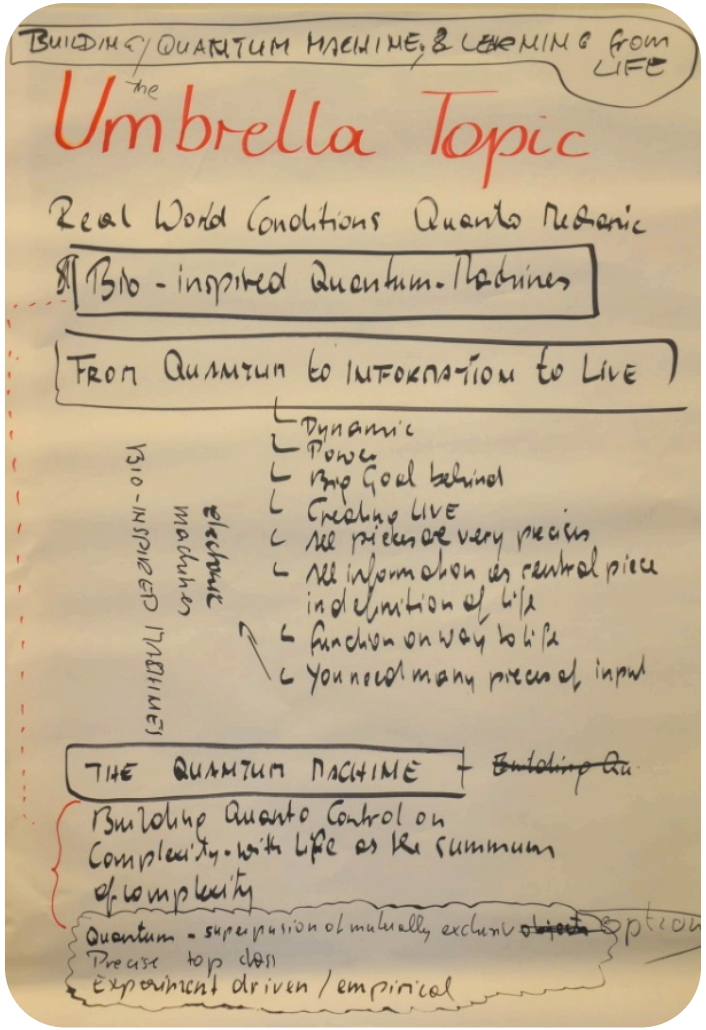
Exhibit IV: Overarching research goal joining working-groups.

Leading questions

- **Identifying links for cooperation**
- **Highlighting points of contact**
- **Formulating a title / header for a common strategic report**

Umbrella Topic

- **Building the quantum machine and learning from life**
  - The quantum machine has a fundamental flavour. integrates bio and mechanics
  - Compatibility between machine and life, machine to explore life – life to develop machine
  - Tooth cleaning molecules as a picture for the intertwined topics of machine and life
- **Quantum mechanics in real-world conditions (wet and noisy systems)**
- **Bio-inspired quantum machines**
  - Bio-inspired quantum machines is a dangerous topic as communities are divided
  - Learning from life is an important aspect
  - Bio-inspired might lead to the notion of bio-inspired life ("which is crap")
  - Building the quantum machine, THE = basic principles for building a quantum machine, implicates uniqueness
  - Quantum machine is a title which indicates a certain level of complexity
- **From quantum to information to life**
  - Dynamical
  - Suggests power behind the title

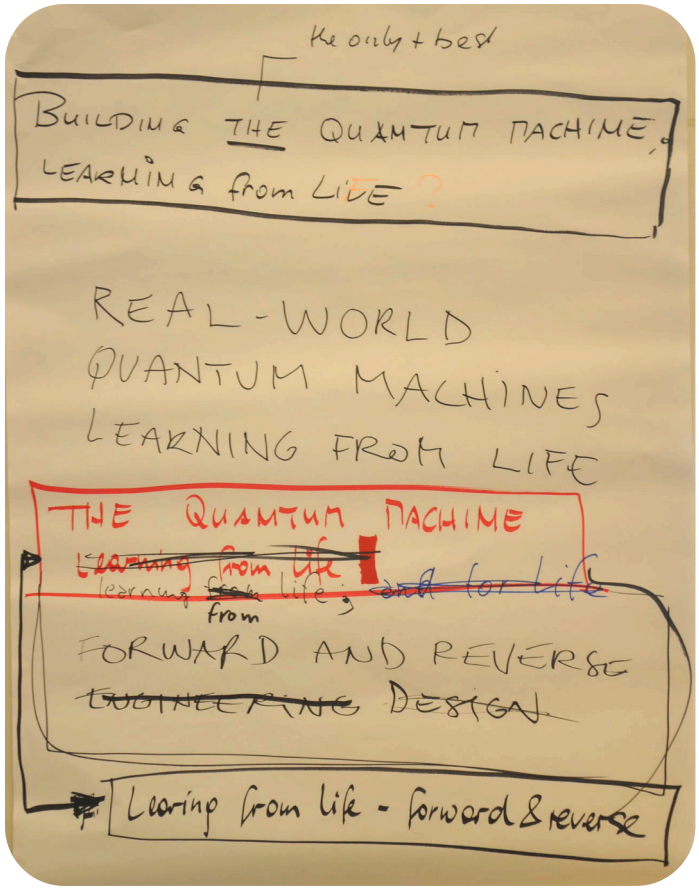


- Big goal behind the title
- Creating life
- All pieces are very precise
- Manhattan project
- All information as central piece in definition of life
- Notion of functionality
- Not mechanical implementation
- Artificial machinery, electronic machines
- Function on way to life
- You need many pieces of input

- **The quantum machine**
  - Building quantum control on complexity with life as the summum of complexity
- **Quantum superposition of mutually exclusive options**
  - Precise and top-class science
  - Experiments set up to search for quantum mechanical phenomena – experiment driven/empirical
  - New quantum mechanics or something entirely new
- **Learning from life for quantum machines**

Discussion

- Real-world conditions seem to be the critical factor, the distinctive criterion
- Still it depends on who is addressed
- Real-world quantum machines learning from life could be a proper title for politicians or the general public; could be problematic within the different communities as a distinctive criterion
- Bio-inspired is redundant
- Quantum machine is very attractive for policy makers, they need something that can be sold, they want the machine



- The quantum machine is not a very short-term vision, this might be a problem when selling it to funders, policy makers
- The Quantum machine, subtitle: Learning from life and for life
- We learned from life that we could have a real-world quantum machine
- Difference between quantum machine, quantum computer, quantum sensors, etc.: The quantum machine is a broader term including all the other things
- Still it should be made clear that all that is going to happen under this title is not subsumable under learning from life – it is a broader understanding
- Quantum biologists – reverse engineers
- Quantum mechanics – forward engineers
- Forward and reverse engineering, forward and reverse design
- Learning from life: Forward and reverse
- Real-world quantum machines – Learning from life – Forward and reverse
- “The Bloomsbury Project”

Exhibit V: Third workshop.

Expectations next workshop

- Blueprint of final report / Concept document that can be documented on / Bring in diversity but with a clear focus in mind (the one of today)
- Outline of the chapters of the report and a common view on the outline (agenda, structure, work piece)
- From the title to the main text, keep the focus
- Example of a quantum machine
- No editorial board or committee, but a clear structure for the report and a bunch of very good idea of recommendations
- Produce something that you can read on the plane
- Enforce some discipline regarding the structure / Writing session in small groups / Would be good that participants come with little pieces of writing that are going to be merged / Reassess key words for clear recommendations / Professional science writing support
- Well written text: written by one person, not a committee
- See a clear vision of a program / Research programs to address, clearly not much confusion
- Writing a recommendation together / What are the recommendations going to be and how are they going to converge in a document / Working concretely on some recommendations
- Find a common ground resp. agreement on what is possible
- Last session was good;:we need one guideline, focus on umbrella topics
- Bring technology people in (WG3) /
- Timing of WS / Workshop not in the middle of nowhere, more central location, London or Brussels
- Conception of text: middle of June is too early, end of September, three months to process results of this workshop