Chances and challenges in Europe

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When faced with the most cutting-edge problems in materials science, the 'right' research infrastructure can be as important as the quality of the scientific ideas. European researchers are being asked to consider a more inclusive way of doing science.

Most major advances in materials science emerge from multidisciplinary collaborations. In this respect, modern materials science can learn something from 'Mother Nature'. Nature makes use of simple physical processes to control and direct organization at different levels — right up to the macroscopic scale. For example, molecular self-assembly relies on interactions between complex, sometimes large, molecules containing specific functional groups. Both the local arrangement of these chemical groups and the physical properties (mechanical, optical and so on) resulting from organization at a larger scale provide the performance and functions needed in biological systems and materials. But, at present, we are still far from being able to copy the most basic biological organization, either in the laboratory or in our research communities. Much more effort has to be invested in establishing the best research infrastructure with the potential to advance materials science in the most efficient manner.

It is recognized that if one wants to create materials with high levels of complexity and functionality in the laboratory, knowledge and expertise from various disciplines have to be combined (Fig. 1). On the one hand one needs biologist and chemists, who are now able to isolate or synthesize extremely 'intelligent' molecules. On the other hand, engineers and physicist have to be involved in organizing these molecules on large scales. In its Sixth Framework Programme, launched in November 2002, the European Union proposes new ways of organizing European research that have the potential to gather an enormous number of researchers (several hundred) within a single research collaboration.

These new collaborations, known as Integrated Projects or Networks of Excellence, are intended to combine all the expertise and competence needed to achieve ambitious objectives in modern science[1]. A consequence of the large size of these research collaborations is the ability to coordinate and to integrate research activities across the whole of Europe. The ultimate vision of the bureaucrats in Brussels is to create a true European Research Area, which combats the fragmented nature of research in Europe, while strengthening its impact. For example, there are many national programmes in nanotechnology that are not at all coordinated, so there is a significant risk that similar activities are performed in parallel and waste resources. Of course, most scientists want to avoid repeating work done by others, but this is made harder when the research community is fragmented.

Although science is considered a global enterprise, with international societies, meetings and journals, in some respects it can also be very parochial, which reinforces fragmentation. Part of the problem in Europe is that national programmes (usually the biggest source of funds) are sometimes considered more important than

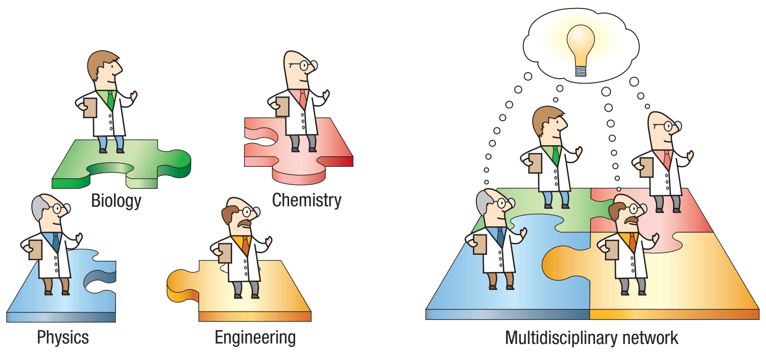

Figure 1 **The philosophy behind the new European large-scale research collaborations is to join forces and combine knowledge and expertise from biology, chemistry and physics, covering theoretical, experimental and applied aspects of a given field. Researchers in individual disciplines may only appreciate one aspect of a research question, but as part of a multidisciplinary network together they can see the full picture.**

Box 1: A 'NETWORK OF EXCELLENCE' IN EMBRYO

Broadly speaking, building functional nanostructured and responsive materials is considered one of the major challenges we face in materials science. Ultimately, the focus is on synthetic molecular devices that can act and organize in a controlled way, store and process information, synthesize chemicals and respond 'intelligently' to external stimuli or signals. Successful research in the field of nanostructured materials relies on bringing together expertise from different fields because the core concepts are highly cross-disciplinary. This is demonstrated in particular by the example of polymeric nanomaterials.

European expertise in functional nanostructures and mesoscale surface engineering lies mostly in small individual research groups, which individually do not have sufficient 'critical mass' to have real impact in scientific or industrial terms. In total, however, Europe has considerable potential in this field. At present, performance is not optimal because of fragmentation and lack of focus. Thus, it is important that a co-ordinated European research effort focuses on selected, clearly defined tasks. The proposed POLYFUNCTION network, in which we are all involved, aims to provide such a platform.

The structure of the POLYFUNCTION network (see below) integrates research tasks performed by about 50 European groups (containing up to 500 researchers), which are co-ordinated in five competence platforms. A scientific committee is responsible for the selection of the tasks, the definition of the goals and the supervision of progress. The organization and management structure is also responsible for improving communication between disparate groups, and for encouraging training and staff mobility.

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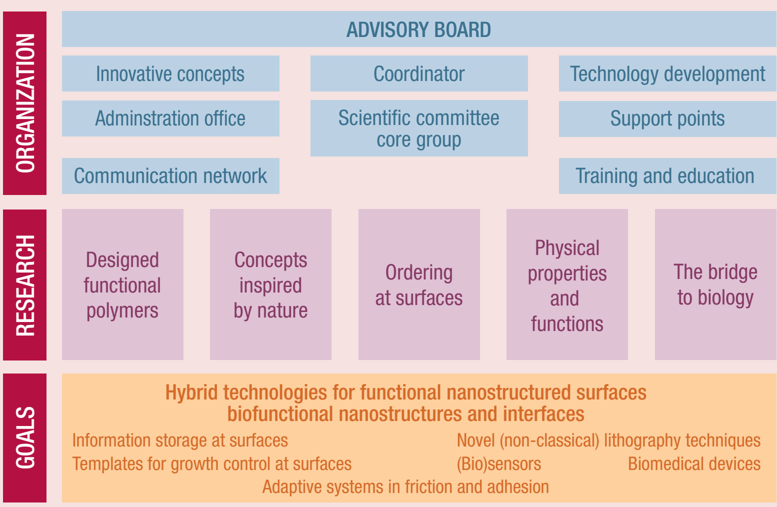
POLYFUNCTION

Polymers for functional nanostructures and mesoscale surface engineering



collaborations with international experts who may be able to provide the most appropriate input. In addition, in small national communities evaluation of research proposals may be less stringent (non-scientific arguments come into play) and competition is less fierce (fewer people working in the same area). Also, in some European countries there can be a language barrier, which prevents the most suitable (perhaps non-national) experts being chosen to review a funding proposal. Many nations are aware of this problem, and there are already European funding agencies that favour international projects, but the Sixth Framework Programme has made integration its central goal.

The European Framework Programmes have been in place since 1984, and are a means of channelling research funds provided by member states to targeted areas of science and technology. The overall budget of the Sixth Framework Programme is €17.5 billion, of which €1.3 billion is earmarked for nanotechnology, multifunctional materials and processing. The European Union has only ever supported projects involving researchers from several nations, but in almost all previous framework programmes, once the funding stopped, the collaboration stopped. So the Sixth Framework Programme is aimed at generating lasting collaborations, with the overall goal of restructuring European research. The main tools for this job are Integrated Projects with specific research objectives (funded for 3–5 years), and Networks of Excellence[2], which integrate all the expertise in a given field (funded for 5–7 years). Of course, the European Commission hopes that once they have experienced the advantages of cross-disciplinary collaborations, such networks will last for much longer than the lifetime of a specific project.

So is bigger always better? Bringing together a large number of groups should allow a consortium (if properly integrated) to attack complex and visionary questions and problems that a single group, or even a team of several groups, would never dare tackle (Box 1). The risk of failure is often just too high. But with a pool of complementary expertise one can establish a fully competent research centre, albeit a virtual one, with the power to solve even the most complex and multifaceted problems. The pool should not contain only general physicists, chemists or biologists, but researchers specialized in all the essential facets of the problem. A Network of Excellence can potentially bring together scientists that would not usually collaborate because their central interests are too far apart. But within such networks — spanning a large spectrum of ideas and competencies — they can find their place.

The main political and economic driving force behind this new programme of large-scale multidisciplinary research is to improve the competitiveness of Europe in relation to the rest of the world. So, not surprisingly, the programme adapts and, to some extent, expands existing concepts such as the Materials Research Science and Engineering Centers (MRSECs) in the United States[3]. These already perform interdisciplinary materials research and education of a scope and complexity that would not be feasible under traditional funding for individual research projects or small groups. But the biggest difference between a MRSEC and a Network of Excellence (apart from the scale) is the ability to pick research partners from any laboratory in Europe, whereas MRSECS are mostly located at one or two university centres in the same geographical location. It is also true that because of the number of groups and countries involved, the possibility of true multidisciplinarity is potentially larger. One benefit of the MRSEC program (now entering its tenth year) is that materials researchers in the US seem more convinced that multidisciplinary collaborations are not just desirable, but necessary. In Europe, we all still have colleagues who show little interest in areas that are not close to their expertise.

Complementary to national activities, such as MRSECs, international collaborations supported by funding agencies worldwide (National Science Foundation in the USA[4], European Science Foundation within Europe[5], or MEXT in Japan[6]), try to combine the strengths of individual groups from different countries to encourage more efficient research of highest impact. The Sixth Framework Programme also has the ability (yet to be implemented) to support the integration of entire national programmes in a particular research field. This option, known as Article 169, is a distant dream in our opinion. However successful a given Network of Excellence might be, we would still be surprised if, say, France and Germany were to combine their research budgets and apply Article 169 to support its continuation in the future. But in the long run this is certainly desirable, and most plans for European integration suffer from similar scepticism initially. Some success has been had, for example, with the idea of having a European Physical Journal (instead of one per nation).

Collaboration is deemed essential, but how important is competition in science? Traditionally, competition has driven many developments in science and technology; do we want to do away with it altogether? Large-scale consortia may find themselves forced to establish significant internal competition in order to achieve the ambitious goals of their collaboration. The new collaborations may even create more competition. If you want to be part of a Network of Excellence you have to demonstrate a strong track record. To stay part of the collaboration you have to continue achieving set goals. Thus, internal competition and evaluation will be essential to their success. In fact, one can view a Network of Excellence as a 'test bed' for new and competing ideas, which may provide a more efficient and direct method of evaluation.

Large collaborations can only be successful and productive if they focus on well-defined scientific questions and/or technological objectives with clearly identified goals. In the absence of such a focus, the risk of having a collection of non-interacting research groups is quite high. The honest wish to perform research together has to be the most important reason for forming a network. All participants must be able to identify their role in the whole project, and the importance and relevance of their contributions have to be clearly visible. Idealistically, this more open way of doing research and communicating could create an extremely fruitful atmosphere for developing new ideas: a 'melting pot' of complementary views and approaches. It may even lead to the creation of new concepts, approaches and research domains.

The biggest uncertainty is whether these collaborations are likely to have a lasting impact on the way people do research. There are two arguments in their favour. First, the barrier to entry is quite high. This is partly because the financial incentive is low: it is easier for an individual group to get higher funding from national sources. So, only those groups who see a real advantage in collaborating will be prepared to invest their time and resources in setting it up. Second, at a workshop we organized last October to discuss a potential collaboration (Box 1), we found that many of our colleagues are inspired by the new possibilities offered by these networks. For example, if you are a theorist interested in a topic with biological relevance, you may find it difficult to initiate a direct collaboration with a biologist. This is partly because writing a successful proposal together will require investing considerable time and effort, with a high risk of failure. But within a large-scale multidisciplinary collaboration you have the chance to collaborate with a biologist in a much looser way than a small joint collaboration would allow. In short, one of the main advantages of these networks is bringing people together who otherwise would find it more difficult to collaborate.

The success of the Sixth Framework Programme will depend not only on the quality of the proposed networks and the excellence of the participating groups, but also, at least in part, on how the proposals are selected. With a limited budget, the European research community must concentrate on narrow research areas, so a fair and transparent selection process is essential. Many colleagues fear that a fair evaluation by peer review is not possible. Given the size of the proposed networks, each proposal has to be presented in such a way that non-experts of certain aspects of the research will be able to judge the whole project, but detailed enough that specialists are able to identify the novel ideas and concepts. As a result, proposals may become too formal, keywords become more important than novel concepts, and selection criteria may not be transparent. In the end, the arguments on which a decision is based risk being too general, vague and unclear for the decision to satisfy everyone. Moreover, thanks to the inclusive nature of these new networks, the selection committee may be forced to look outside Europe for independent experts. Finding enough reviewers of the right quality (of which there must be at least five) will not be easy.

And five years from now, how do you define and measure excellence? As with all new concepts for reorganizing research, it is almost impossible to do a control experiment, in which research groups continue with their old habits — collaborating only when necessary — but are not forced to work within a larger consortium. Scientific results can be measured and compared in some respects, but less tangible notions, such as restructuring European research and reducing fragmentation, will be much harder to evaluate. The success criteria for the new Networks of Excellence remain far from clear. But we believe that thorough internal evaluation will be key. For example, a network can set up internal bidding among its members, which would force them to choose the most qualified group to solve a specific scientific question.

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In conclusion, there are obvious difficulties to overcome in organizing and managing large-scale collaborations. The selection, evaluation and success criteria are not yet fully clear. But the mere chance of forming a collaboration on such large scales has already created a lot of enthusiasm among the scientific community in Europe, and not just because of the extra money involved (the financial gain of each participating group is never very high). Complementing the desire of the European Commission to create a truly integrated European Research Area, quite a few scientists see also an almost unique chance for a new, highly promising and experimental way of performing research.

Further reading

1. http://europa.eu.int/comm/research/fp6/pdf/brochurefp6.pdf
2. http://europa.eu.int/comm/research/fp6/pdf/noe_111102final.pdf
3. http://www.nsf.gov/mps/divisions/dmr/research; http://www.mrsec.org/home
4. Proposals for Cooperative Activities in Materials Research between US and European Investigators, http://www.nsf.gov/pubs/2002/nsf02135//nsf02135.htm
5. European Science Foundation Collaborative Research Programme in Self-Organised Nano-Structures (SONS) http://www.esf.org/sons
6. Internationalization Strategy of Science and Technology Activities in Japan, http://www.mext.go.jp/english/news/2002/06/021001.htm