Towards a European Strategy
for Synthetic Biology

TESSY Deliverable D2.4

Results of the participatory process

February 2008

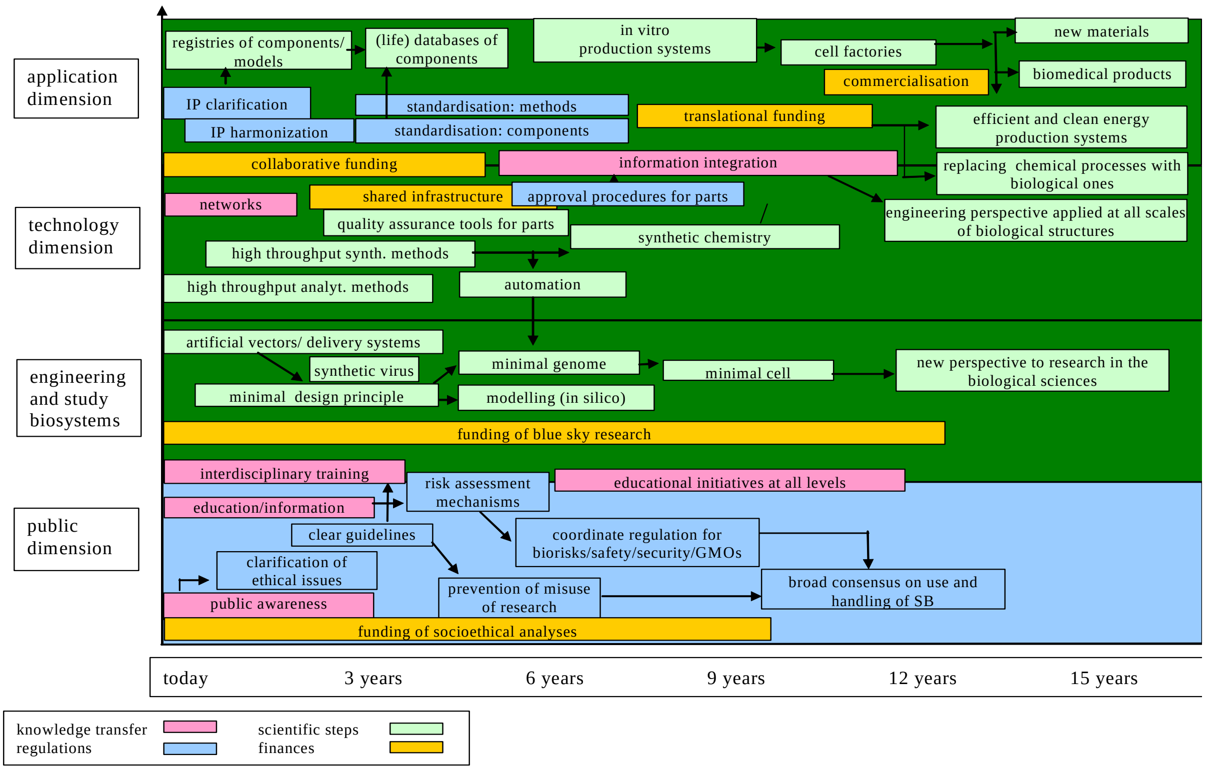
Content

1 Introduction

Based on a sound literature analysis and discussions in the expert advisory board the TESSY consortium elaborated a draft roadmap for synthetic biology in Europe. The roadmap spans a time horizon of 15 years and summarizes both scientific-technical milestones and the required framework conditions (Figure 1).

In order to grasp the perception of a broad community the draft roadmap was discussed in a web-based survey that covered the discussion of the already identified aspects of the roadmap both with respect to timing and relevance and aimed at the identification of additional topics. The results will feed in the elaboration of a final roadmap.

Figure 1: Draft Roadmap Version October 2007



2 Methodology

In order to identify research groups and other actors with interest in Synthetic Biology a three-step strategy was applied. In a first step search engines were used to identify country-specific internet pages. The second step continued on a URL-specific and country-specific level in order to search in magazines, in the membership lists of national and international associations, publication databases and recent conference documentations. In the third step members of the advisory board were asked to supplement the list of addressees.

Additionally the survey used a co-nominate process. By means of this feature the persons that received the invitation to participate in the survey could send an invitation to interested colleagues who could easily gain a personalized access to the survey by sending an email to the survey host.

Thirdly the online-survey was promoted on two international conferences, the SB 3.0 in Zurich, Switzerland and the ESF-Conference on Synthetic Biology in Sant Feliu de Guixols, Spain. Interested persons could also join the process via the co-nomination procedure.

The survey was hosted at the company b-wise[1]. All information was stored anonymously under an ID number. The assignment of ID number and email address was only possible via an algorithm that was kept confidential at the Fraunhofer-ISI team. Invited participants could opt out of the survey at any time.

The public dimension, the application and technology dimension and the engineering and study of biological systems were assessed by the actors by an estimate of the relevance and the time horizon to the European SB agenda. In order to evaluate the relevance of the respective topics the actors could choose one of the given answers, which were “low”, “medium”, “high”, “very high” and “cannot answer” (n/a). The time frame in which the respective topics have a major focus on the European SB agenda should be determined by indicating the start and end point. The time horizon was separated into the following segments “today”, “3 years”, “6 years”, “9 years”, “12 years”, “15 years” and “>15 years”.

In order to analyze the time horizon the number of answers for the estimated start and end point were counted and afterwards the expectancy value for the start and end point were calculated. In this calculation “today” was replaced by the value 0, "3 years" by the value 1.5, "6 years" by the value 4.5, etc. and “> 15 years” was replaced by the value 16.5. With these values the calculation of the expectancy value (E) of the start point was carried out as follows:

$$E = \frac{a \times 0 + b \times 1.5 + c \times 4.5 + d \times 7.5 + e \times 10.5 + f \times 13.5 + g \times 16.5}{a + b + c + d + e + f + g}$$

a = number of answers saying start point should be today
b = number of answers saying start point should be within 3 years
c = number of answers saying start point should be within 6 years
d = number of answers saying start point should be within 9 years
e = number of answers saying start point should be within 12 years
f = number of answers saying start point should be within 15 years
g = number of answers saying start point should be in over 15 years

[1] www.b-wise.de

The same formula was used for the calculation of the expectancy value of the end point, but the variables were replaced by the values of the answers given for the end point.

The relevance of each activity was analyzed by the calculation of the share of persons in each of the given categories (“low”, “medium”, “high”, “very high”) out of all persons answering the question. Persons that did not assess the relevance according to one of the categories or checked the “cannot answer” (n/a) category were not included in the sample, thus the denominator is the total of persons that assessed the relevance of the respective activity. In order to allow a quick comparison of the relevance of each activity, milestone or measure a relevance factor was calculated. The relevance factor (RF) was calculated as follows:

$$RF = \frac{a \times 1 + b \times 2 + c \times 3 + d \times 4}{a + b + c + d}$$

a = number of answers saying relevance is low
b = number of answers saying relevance is medium
c = number of answers saying relevance is high
d = number of answers saying relevance is very high

Thus the higher the relevance factor the higher is the overall assessed relevance.

3 Results

3.1 Sample size and response rate

The sample consisted of 588 persons. 27 emails could not be delivered, as the correct email-address could not be determined. The sample covered most European countries; however, the number of identified persons with possible interest in Synthetic Biology per country differed considerably. The strongest SB communities were identified in the UK (189 contacts), Germany (106 contacts), Spain (74 contacts), Switzerland (41 contacts), France (36 contacts) and Italy (30 contacts). In total 211 persons out of the 561 addressees replied which results in a response rate of 37.6 %. An overview on the sample is summarized in Table 1.

6 persons opted out of the survey prior to opening the link, 42 persons opened the link and answered the background information but did not complete the survey. 163 answers could be included in the analysis. This results in a share of answers that could be analysed of 29.1 %.

As described in the methodology section the co-nomination procedure allowed persons that were not primarily identified to join the survey. 32 persons opened the co-nomination link and received a personal ID. 29 persons answered the introductory section on type of institution and research topics. 13 persons completed the survey and could be included in the survey. Thus 176 answers could be analysed, this leads to an overall response rate of 29.7 %[2].

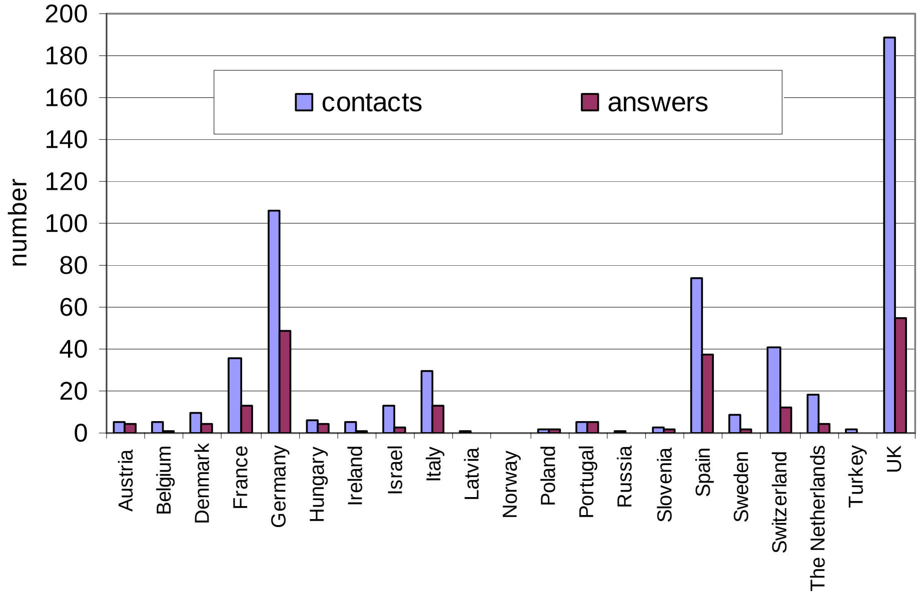
With respect to national distribution there is a dominance of a number of countries for which a high number of interested persons were identified. In the UK, Germany, Spain, France and Italy a relatively high number of actors were determined. Their response rate was in the range of 30 to 50 %. In contrast some countries with a smaller number of persons originally identified as being interested in the field of synthetic biology showed a high response rate of over 60 % (Austria, Hungary, Poland, Portugal, Slovenia). In a third category there are countries with a moderate number of actors identified as being interested in Synthetic Biology and a low response rate of in the range of 20 % (e.g. The Netherlands, Israel)(Figure 2).

Table 1: National composition and response rate of the online survey

Country	contacts	answers	response rate
Austria	5	4	80,0
Belgium	5	1	20,0
Denmark	10	4	40,0
France	36	13	36,1
Germany	106	49	46,2
Hungary	6	4	66,7
Ireland	5	1	20,0
Israel	13	3	23,1
Italy	30	13	43,3
Latvia	1	0	0,0
Norway	0	0	0,0
Poland	2	2	100,0
Portugal	5	5	100,0
Russia	1	0	0,0
Slovenia	3	2	66,7
Spain	74	37	50,0
Sweden	9	2	22,2
Switzerland	41	12	29,3
The Netherlands	18	4	22,2
Turkey	2	0	0,0
UK	189	55	29,1
total	**561**	**211**	**37,6**

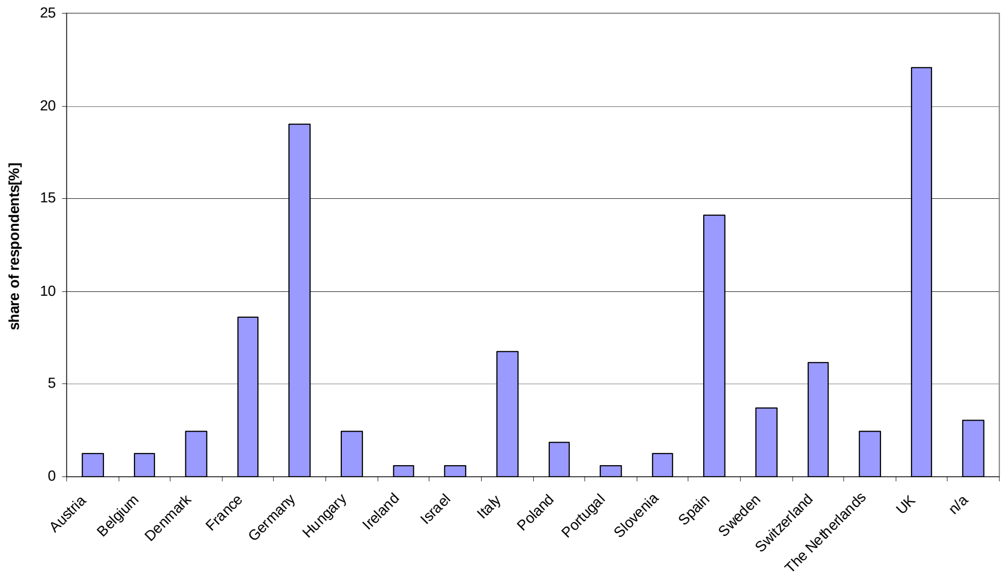
[2] The overall response rate was calculated as share of all answers that could be analysed (163+13) divided by all persons that were contacted (561+ 32).

Figure 2: Number of identified persons in the sample and answers from the respective country



As a result of the heterogeneous composition of the sample three quarters of the answers results from the six biggest countries: UK (22 %), Germany (19 %), Spain (14 %), France (9 %), Italy (7 %), Switzerland (6 %) (Figure 3). A country specific analysis of smaller countries is planned to show whether there is a difference in the estimates between the presently leading countries and the others.

Figure 3: National contribution. Share of answers from each country out of total sample.



The sample contained all disciplines that seem to contribute currently to Synthetic Biology. With nearly 60 % biologists were the strongest group, followed by chemists and computer scientists both with 24.7 %, engineers (17.0 %) and physicists (10.8 %). Others had a background in philosophy, ethics, technology assessment, custom manufacturing, and mathematics/statistics (Figure 4).

Nearly two thirds of the persons were affiliated with universities and 26 % with other public research organisations. 7 % of answers came from industry; policy-associated responses and the financing sector contributed with 1 % each to the answers, and NGOs accounted for 2 % (Figure 5). This composition was also observed on the leading SB conferences in the past. Due to the early developmental stage of SB the field is dominated by research with only a few companies. Policy starts to be interested in the field with a number of observers participating in international conferences.

As shown in Figure 6 two third of respondents are active in research in the field of engineering and study biological systems, 18 % are involved in technology development and 10 % in product development. 5.3 % of all respondents deal with social issues and the public dimension. 1.8 % could not categorise themselves within the four dimensions. They defined their activities as being in coordination, technology assessment, and ethics.

Figure 4: Scientific background of sample

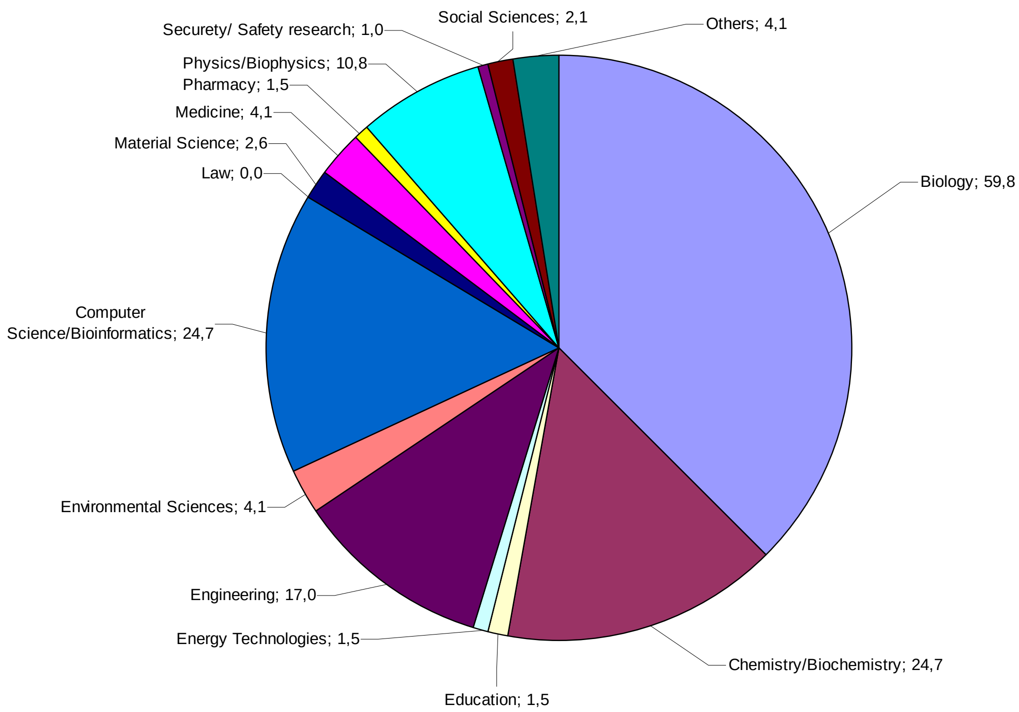


Figure 5: Share of institutions participating in the survey

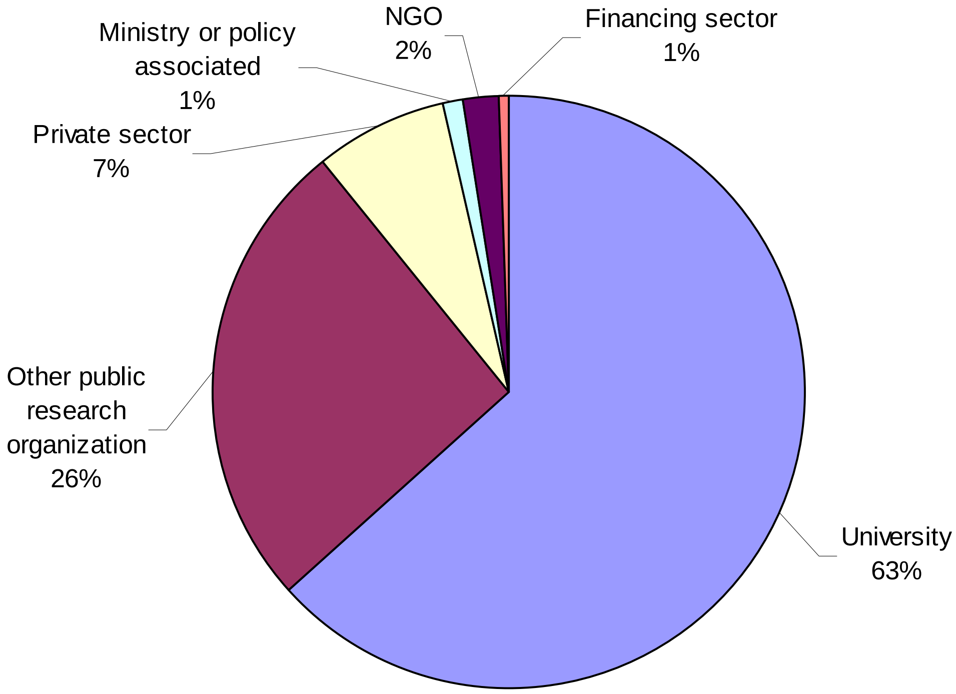
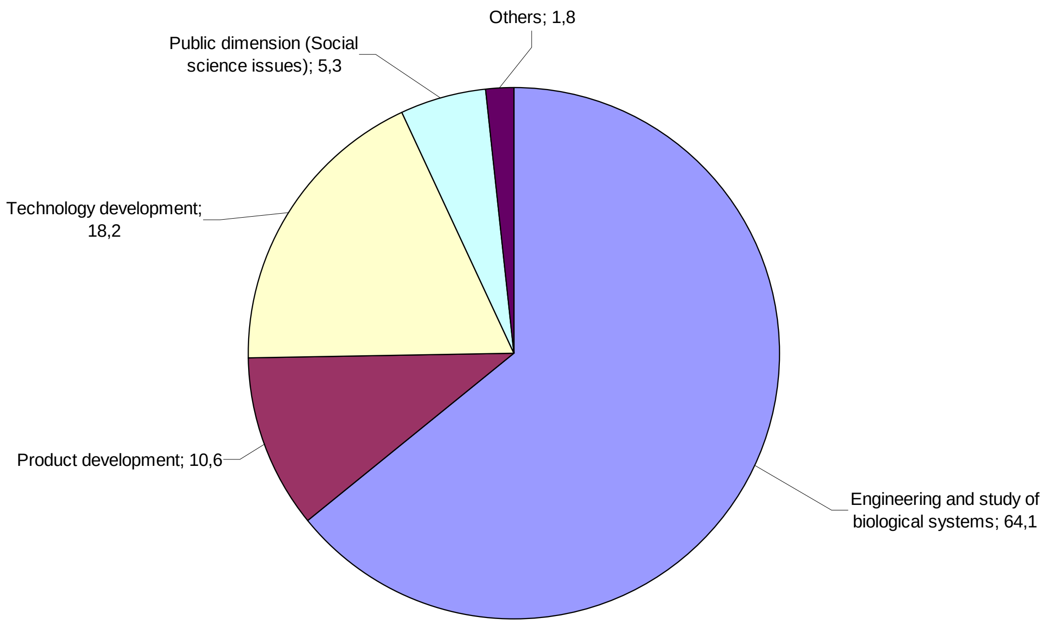


Figure 6: Share of activities of the respondents



3.2 Public dimension of SB (Dimension 1)

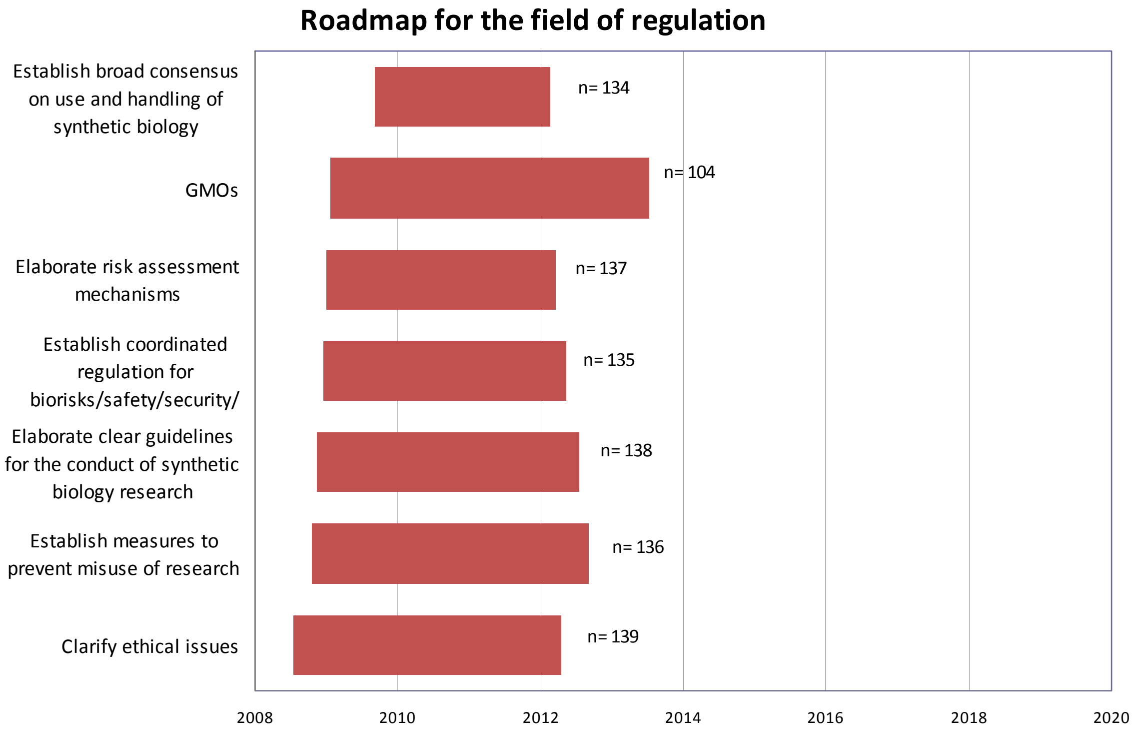
The public dimension of SB summarized aspects in the fields of regulation, education and public involvement. As it can be seen in Figure 7 regulatory issues are assessed to be rather early on the agenda, i.e. within the next year. They are expected to be clarified by 2012. Highest relevance have the establishment of a coordinated regulation for biorisk, safety, and security and the establishment of measures to prevent misuse of research followed by the clarification of ethical issues and the elaboration of clear guidelines for the conduct of synthetic biology and

With respect to funding the majority of respondents (approx. 70 %) see high relevance in the provision of funding for teaching which is assessed to be initiated within the ongoing year. Funding for socio-ethical analyses is assessed to be of less importance. It is expected to be started within 2009 (Figure 8). This later onset may be explained by the fact that research is thought to be in a very early developmental stage that does not allow precise analysis of possible societal effects. However the later onset and lower relevance of socio-ethical analysis is contradictory to the requested early onset and relatively high relevance of the clarification of ethical issues and should be discussed thoroughly.

By far the most important aspect in the field of knowledge transfer is the postulated need for the establishment of interdisciplinary training and curricula. 80 % of all respondents assess the relevance as high or very high. However the respondents have mainly knowledge transfer activities in mind that address the academic sector. Activities that address the public such as "educational initiatives at all levels" and "raise public awareness" are assessed to be of lower relevance and are expected to be later on the agenda (Figure 9).

In the field "Public Dimension" the share of persons responding to the questions was in the range of 90 %. These are 10 – 15 percentage points more than in the other dimension. Only for the questions "Regulation of GMO" and "Offer educational initiatives at all levels" the response rate was considerably lower: 73 % and 85 % respectively. Especially the question on GMOs was often commented as unclear and not understandable ("*What do you mean with "GMOs" they are already regulated?*"). This indicates that SB has to be very precise in terminology of expected products. The legal status of new organisms derived from synthetic biology strategies has to be clarified and the newly synthesized organism named accordingly to allow their identification.

Figure 7: Time horizon (a) and relevance (b) of regulatory issues in dimension 1



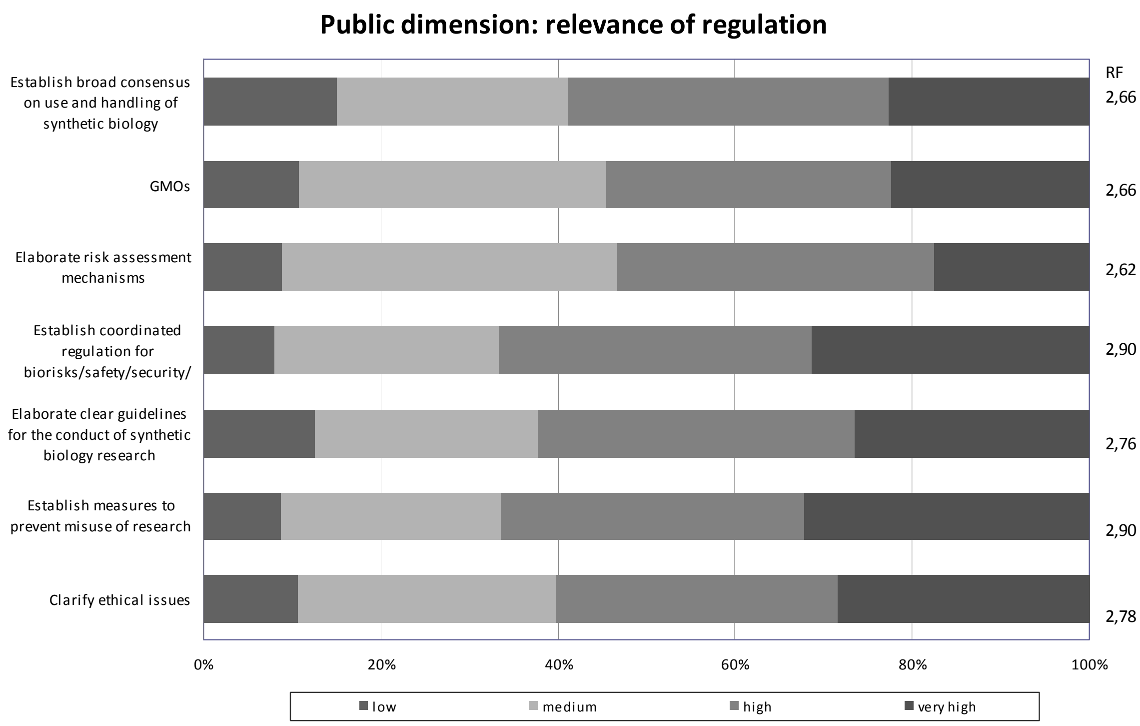
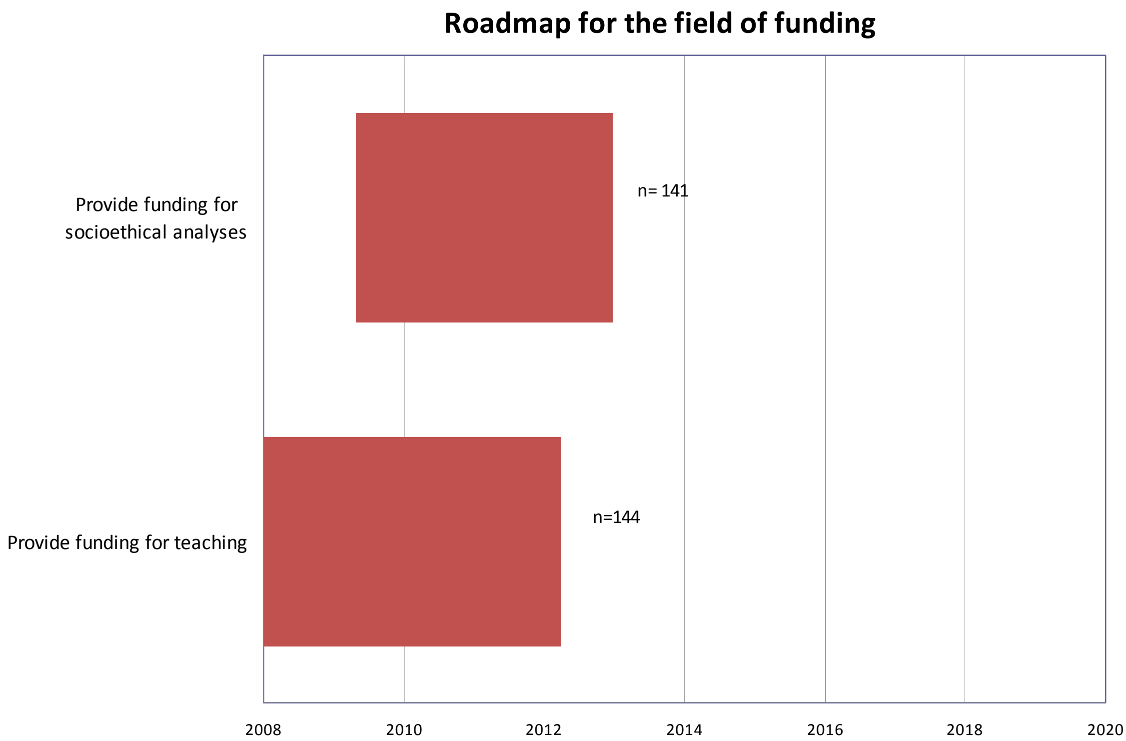


Figure 8: Time horizon (a) and relevance (b) of funding issues in dimension 1



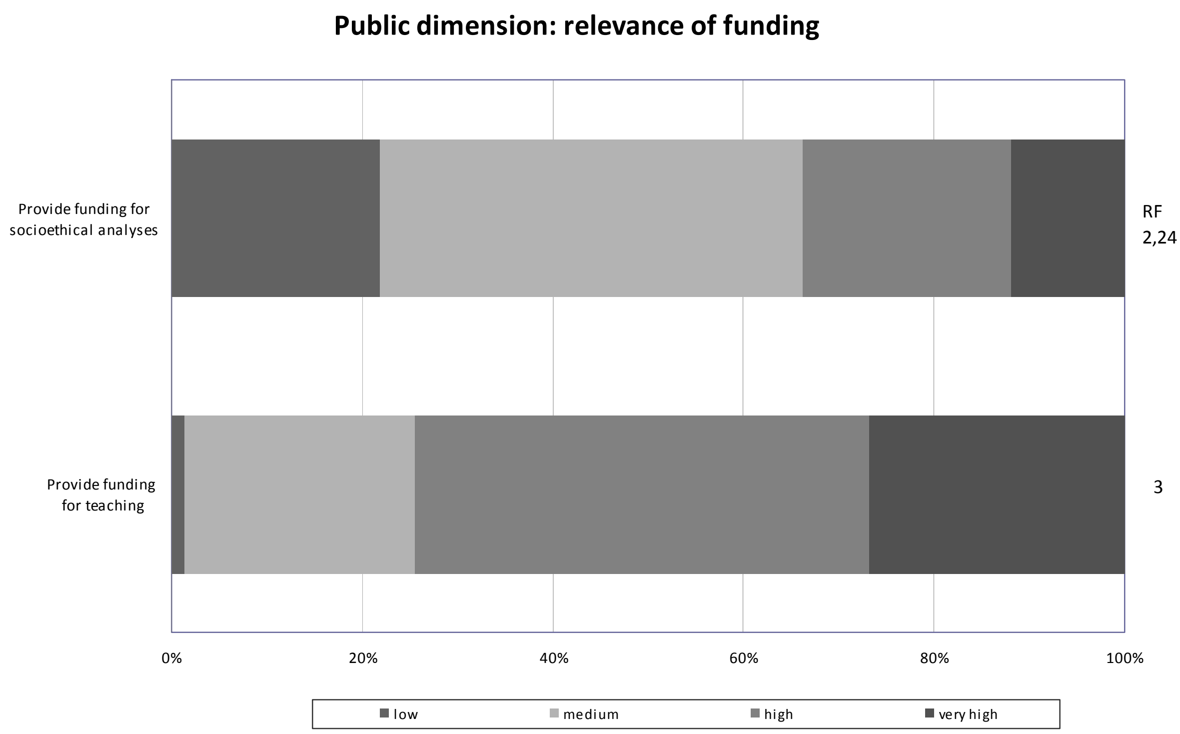
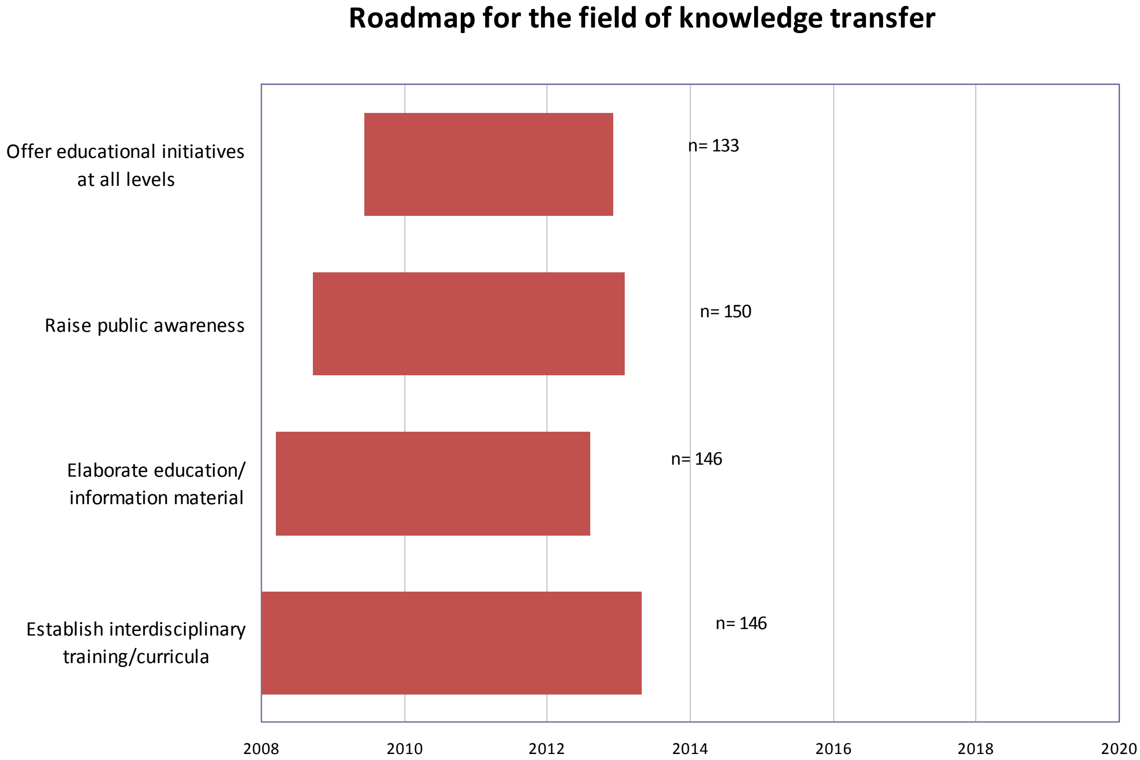
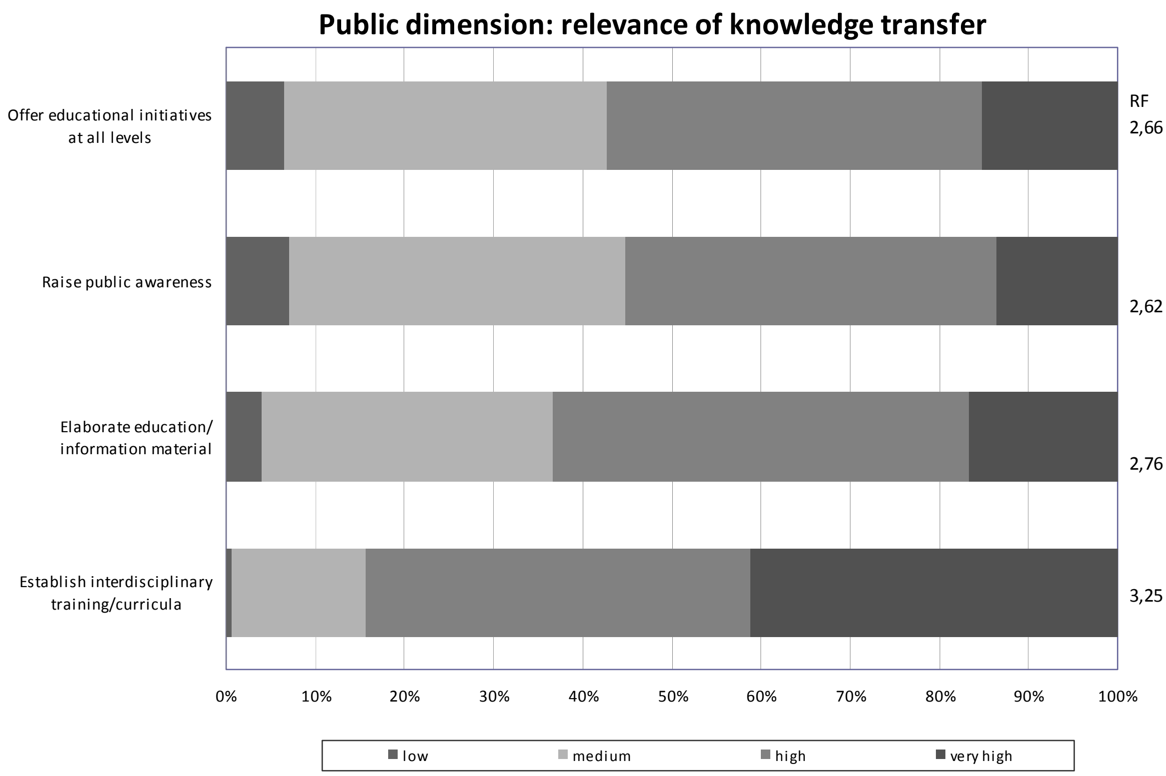


Figure 9: Time horizon (a) and relevance (b) in the field of knowledge transfer in dimension 1





3.3 Engineering and study biosystems (Dimension 2)

Two thirds of all respondents assigned their activities to the research field "engineering and study biological systems". 75 % to 80 % of all respondents answered the questions in this dimension. They claimed a very high need for blue sky research funding for the next 6 years. This period of time is equivalent to the planning horizon in basic research as outlined by a researcher and does not indicate that there will not be additional need for blue sky funding after 2014. Respondents seem to assess their own research in the field of engineering and study biosystems as relatively unrisky as illustrated by some of the comments on the survey:

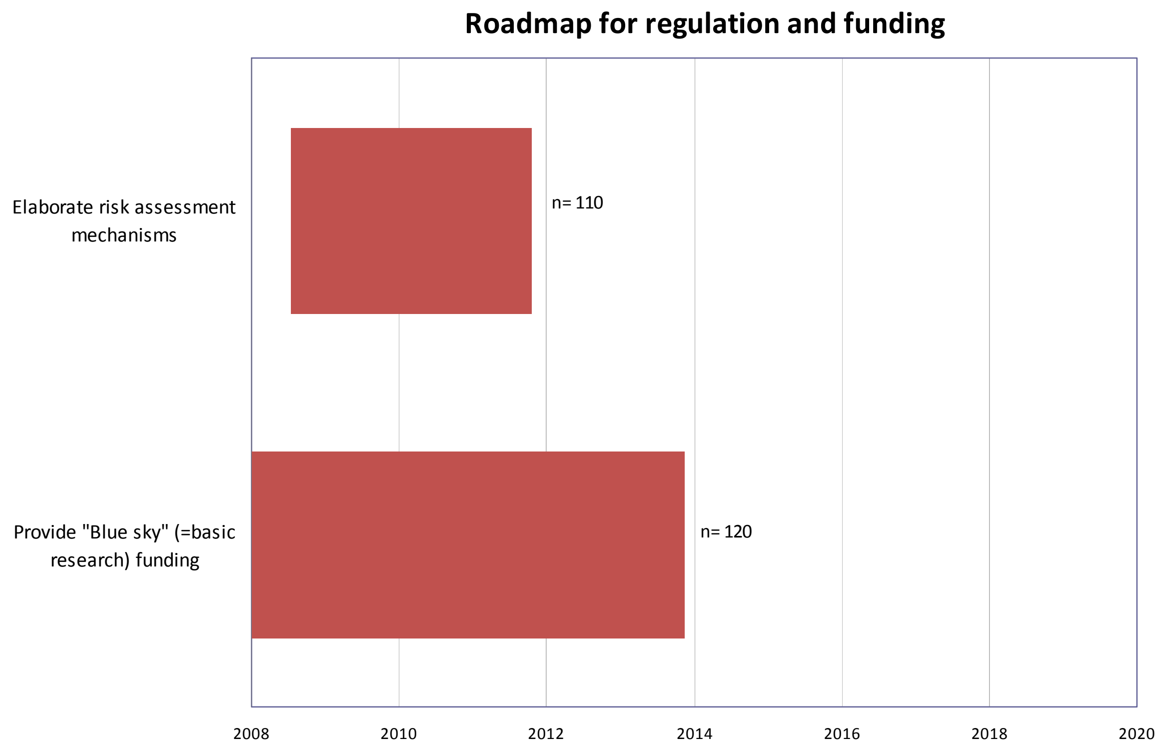
"The questions are puzzling: the only risk with synthetic biology (a serious one) is that the technology will allow reconstruction of dangerous pathogens in an unobtrusive way. Other ideas (Viktor and Dr Frankenstein) are just bad dreams of ignorant persons. The main danger is to stress danger where it does not exist, as it will divert attention from the serious problem of biosecurity. Natural organisms will always be much more dangerous than artificial ones, and the more natural the more dangerous."

45 % assess the relevance for the elaboration of risk assessment mechanisms as high or very high. This activity should be started within the next 2 years (Figure 10).

Though the various scientific milestones cover a relatively long period of time with some overlap the responses indicate a clear chronological order. Based on the supply of artificial vectors and delivery systems and the general elaboration of minimal design principles it will be a major research task to design minimal genomes (starting in 2009), synthetic viruses (starting 2010) and minimal cells (2011). This design process is accompanied over the whole period of time by the elaboration of modelling. With respect to relevance those scientific milestones with a beginning in the near future (modelling, vectors, general design principles) are assessed as being of higher relevance than those milestones that are predicted to start later (design of minimal genome, synthetic viruses, minimal cells) (Figure 11).

Knowledge transfer is an important issue in the research field "engineering and study biosystems". All activities are expected to start fairly soon, with the establishment of SB networks and the implementation of interdisciplinary sciences in 2008. Other activities such as the integration of SB in existing curricula, the set up of information integration tools and the development of new SB curricula is thought to start a bit later (second half of 2008). Highest priority has the implementation of inter-disciplinary sciences, followed by the need for the establishment of SB networks (Figure 12).

Figure 10: Time horizon (a) and relevance (b) for regulation and funding in dimension 2



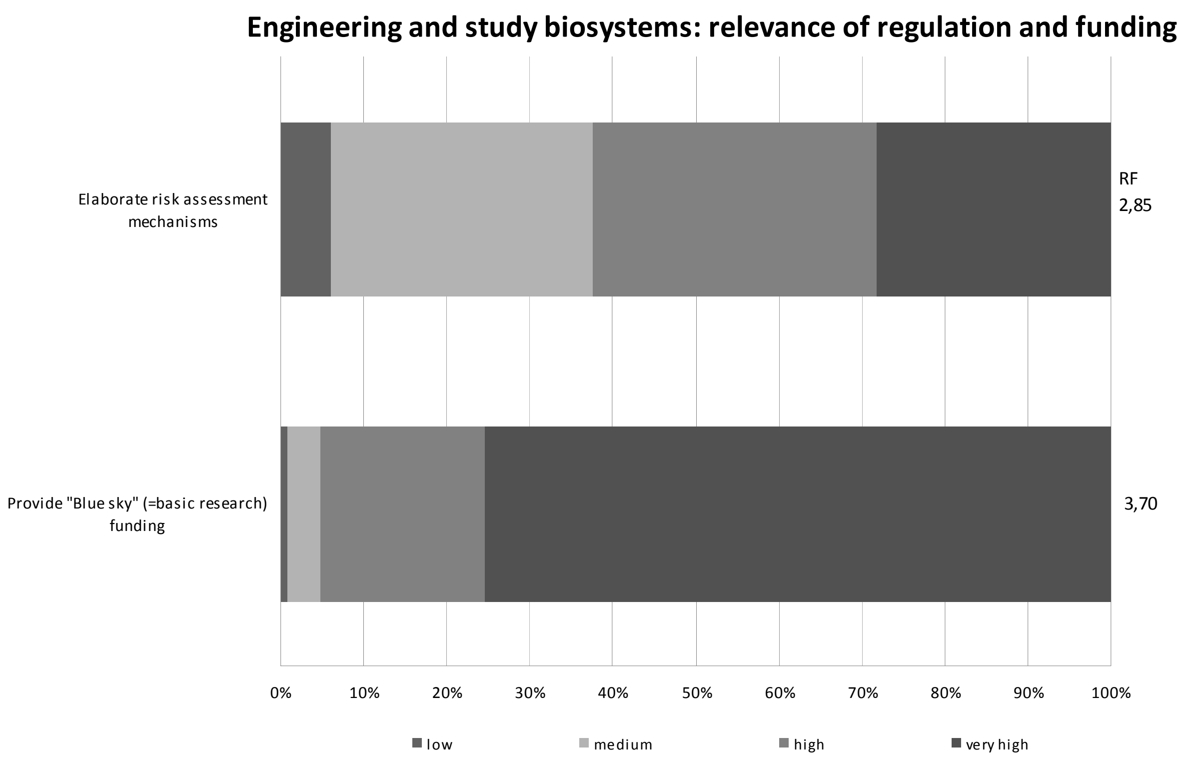
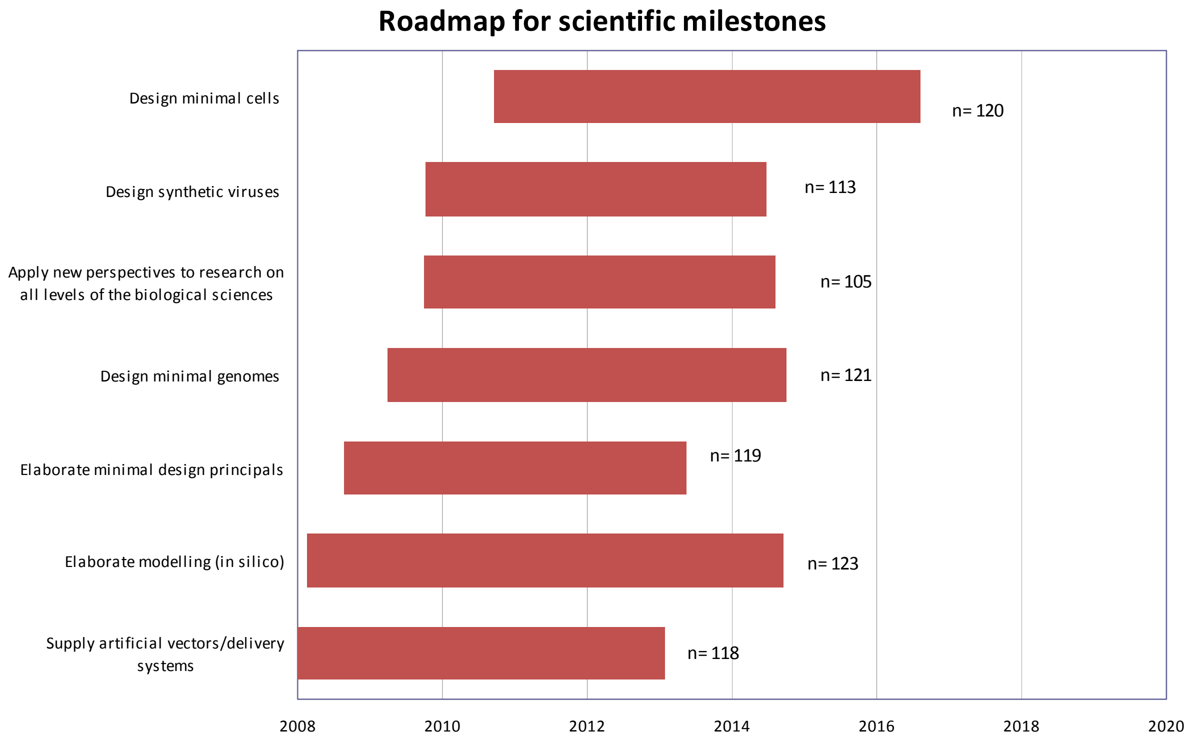


Figure 11: Time horizon (a) and relevance (b) of scientific milestones in dimension 2



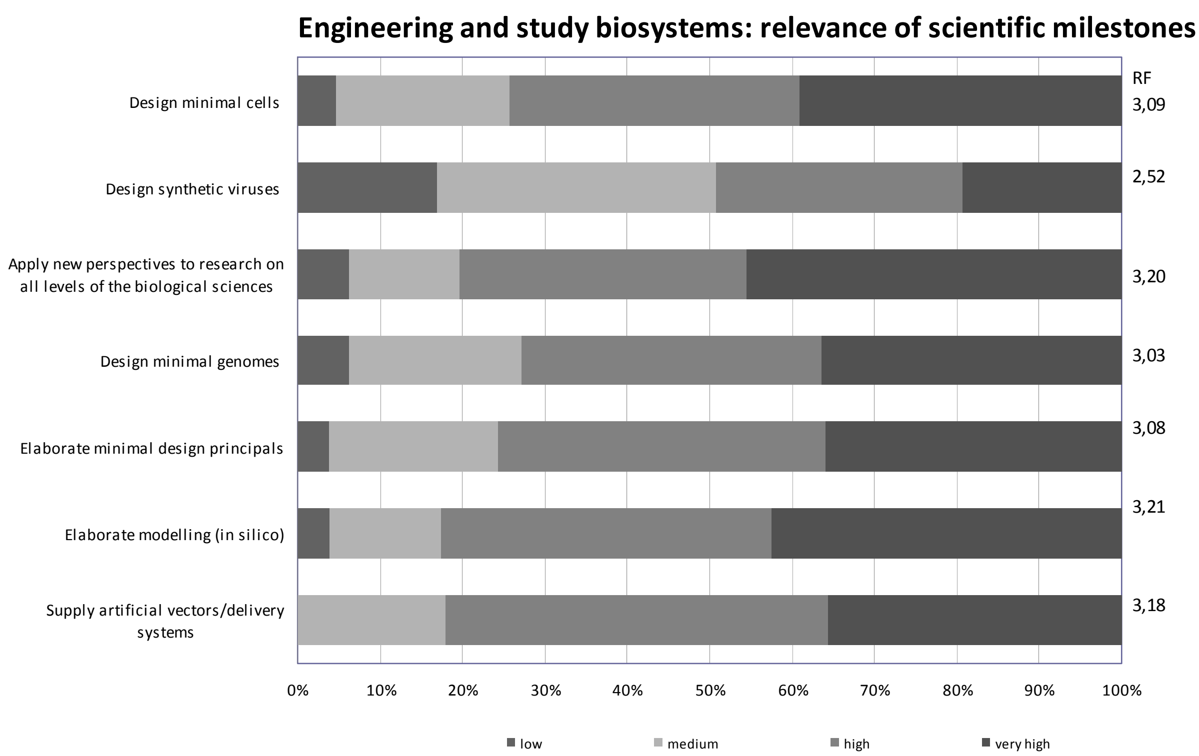
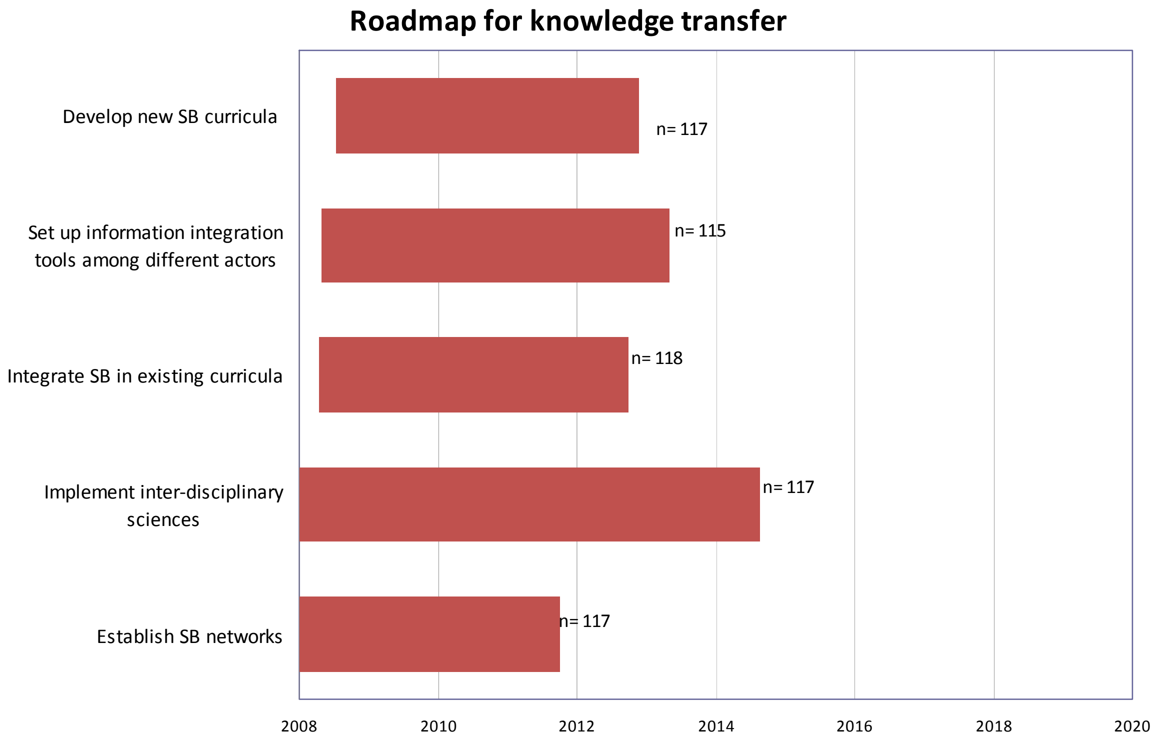
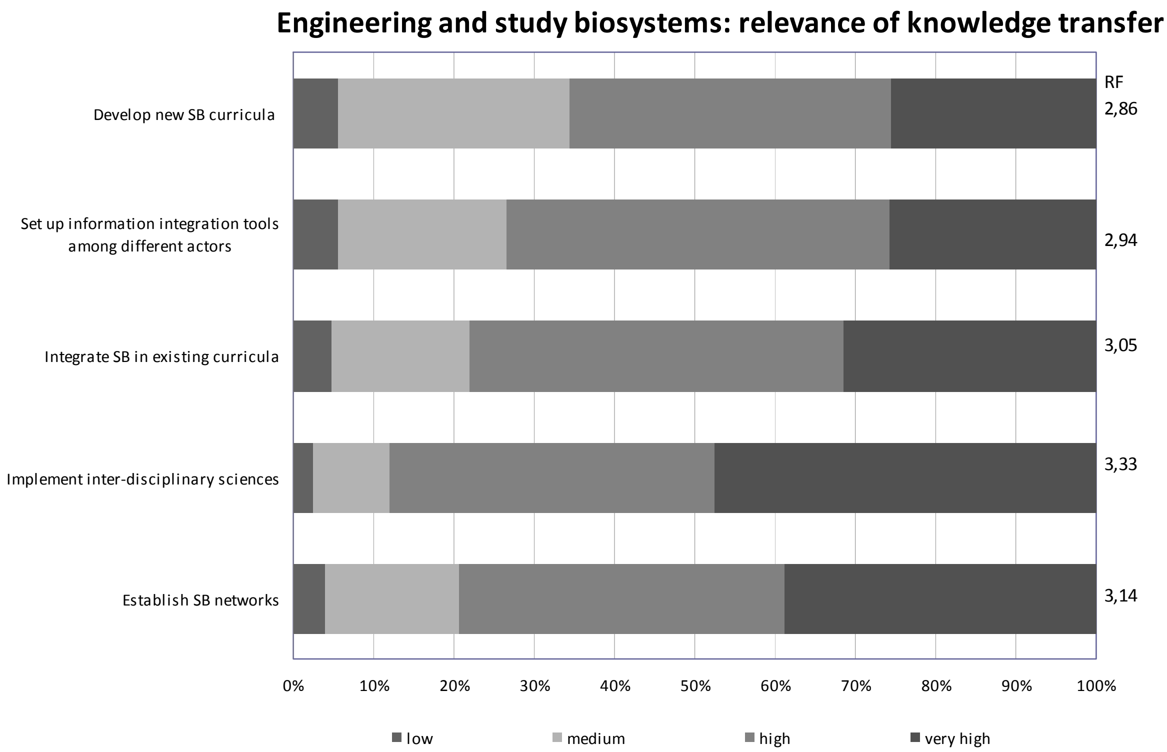


Figure 12: Time horizon (a) and relevance (b) in the field of knowledge transfer in dimension 2





3.4 Technology and application dimension (Dimension 3)

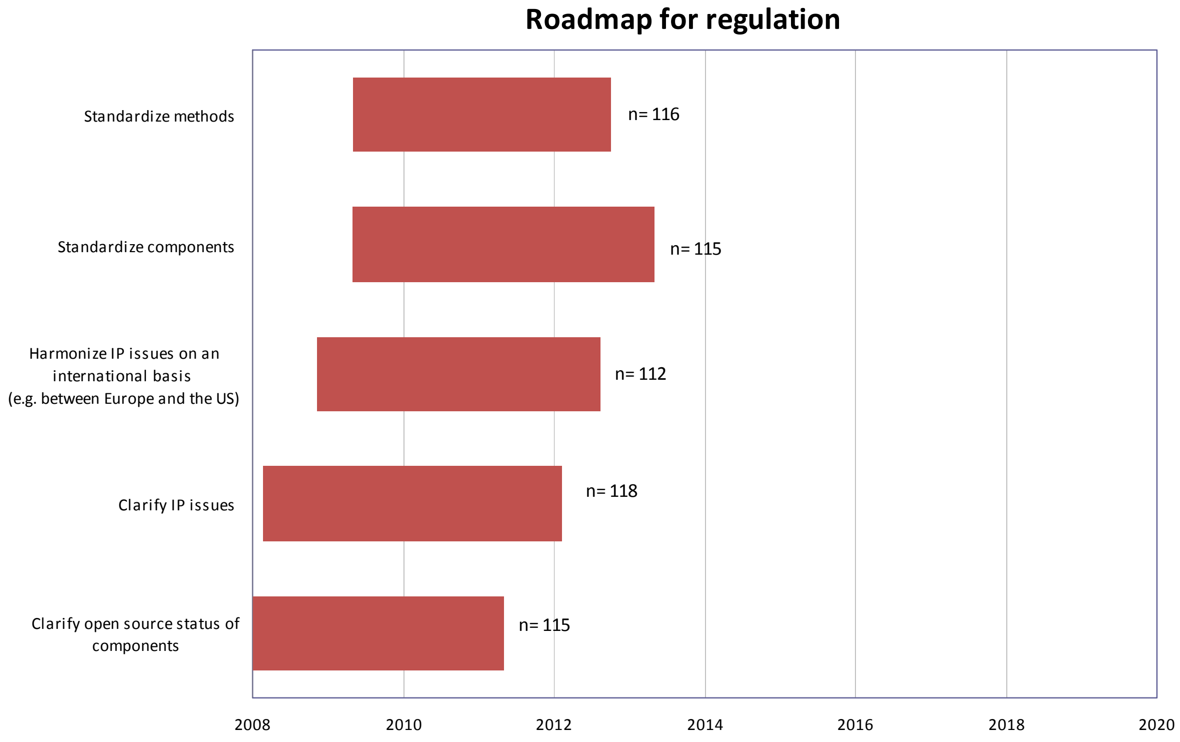
The most important step with respect to regulation in the field development of technologies and applications is the clarification of the open source status of components. The respondents commented that in their opinion research should not inhibited by ("rubbish") patents and that public research should be open source. The clarification of these issues is expected to be on the agenda in 2008, followed by a more general clarification of IP issues and the harmonization of IP issues on an international basis. The standardization of methods and components is expected to be an issue after 2009 with a slightly lower priority than the IP issues (Figure 13).

Funding both on an individual basis and for collaborative projects is expected to be on the agenda in 2008 with high priority. Translational funding is required later (2009) and a need for support for commercialization is not expected before 2011. The respondents prefer collaborative and individual funding rather than topic related funding (Figure 14).

With respect to scientific milestones there is a clear chronological ranking. The establishment of high throughput analytical methods, the establishment of registries (life) databases are first steps starting in 2008. Next steps are thought to be in vitro production systems and the set up of high throughput synthetic methods in 2009. With a medium term perspective the respondents assessed the set up of automation. Starting in 2011 the experts see the application of engineering perspective at all scales of biological structures, the establishment of efficient and large scale (bio)-synthetic chemistry and the use of efficient and clean energy production systems. A scientific breakthrough with respect to the replacement of chemical processes, the production of (xeno-)biochemical products and new materials is expected to become realistic in 2012, but it is assumed that these aspects will be subject to long-term research until 2018. Though most issues are assessed as fairly relevant there are two categories that are especially emphasised. With a short term perspective these are the establishment of high throughput analytical/ synthetic methods and life databases; with a long term perspective the use of clean and efficient energy production systems and production of biomedical products are considered to be of high relevance (Figure 15).

In the sector knowledge transfer the trends are similar as described above for the dimension 2 "engineering and study biosystems". A strong requirement is postulated in the establishment of inter-disciplinarity, the set up of SB networks and the integration of SB in existing curricula. The set up of a shared infrastructure is assessed as highly relevant by only 40 % of respondents and only with a medium-term perspective (Figure 16). 75 % to 80 % of all respondents answered the questions in this dimension.

Figure 13: Time horizon (a) and relevance (b) for regulation and funding in dimension 3



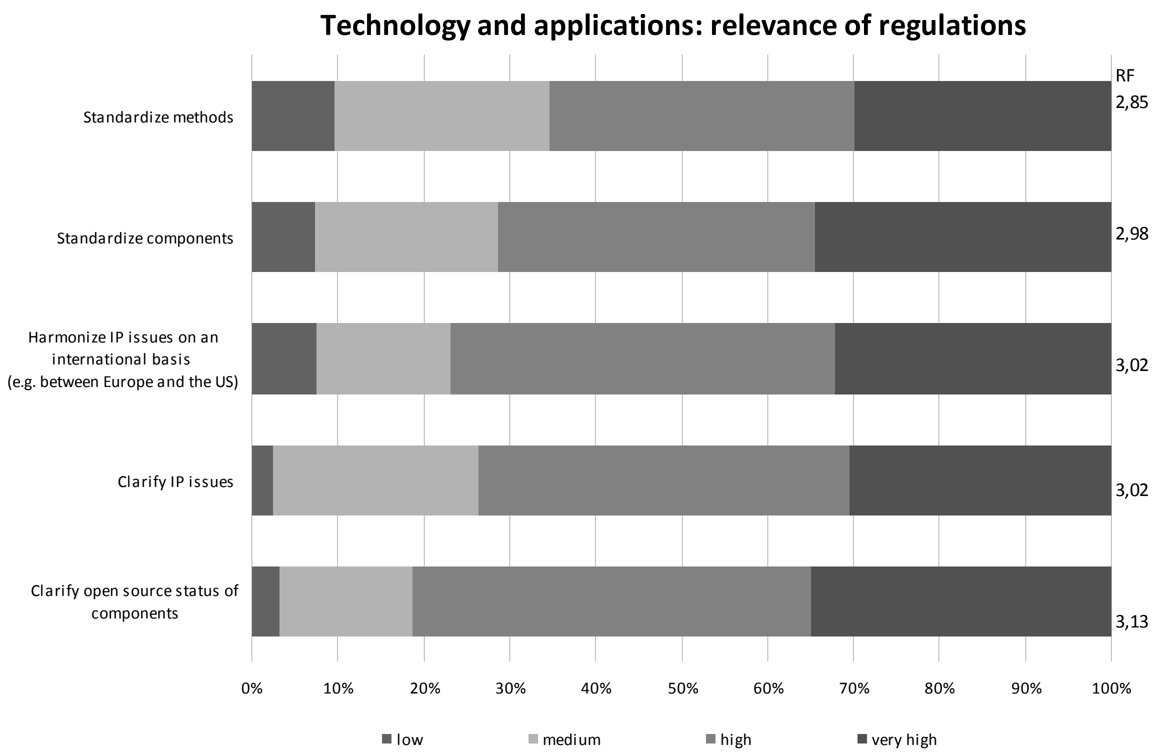
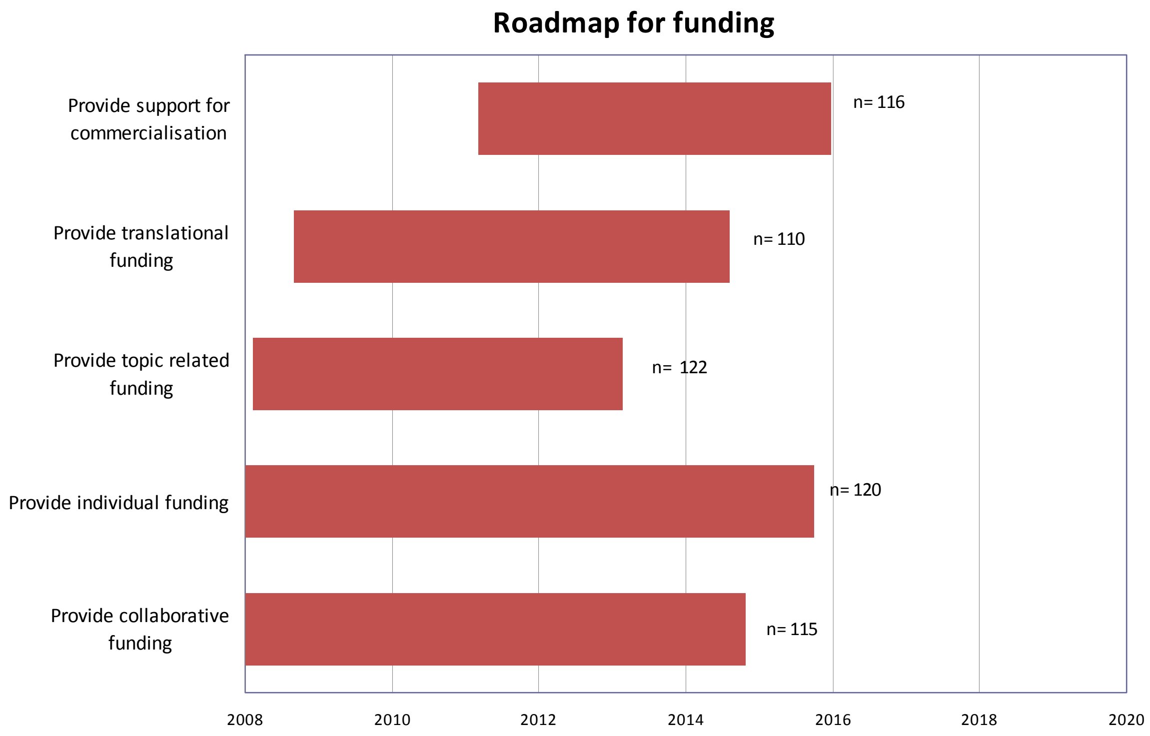


Figure 14: Time horizon (a) and relevance (b) for funding and finance in dimension 3



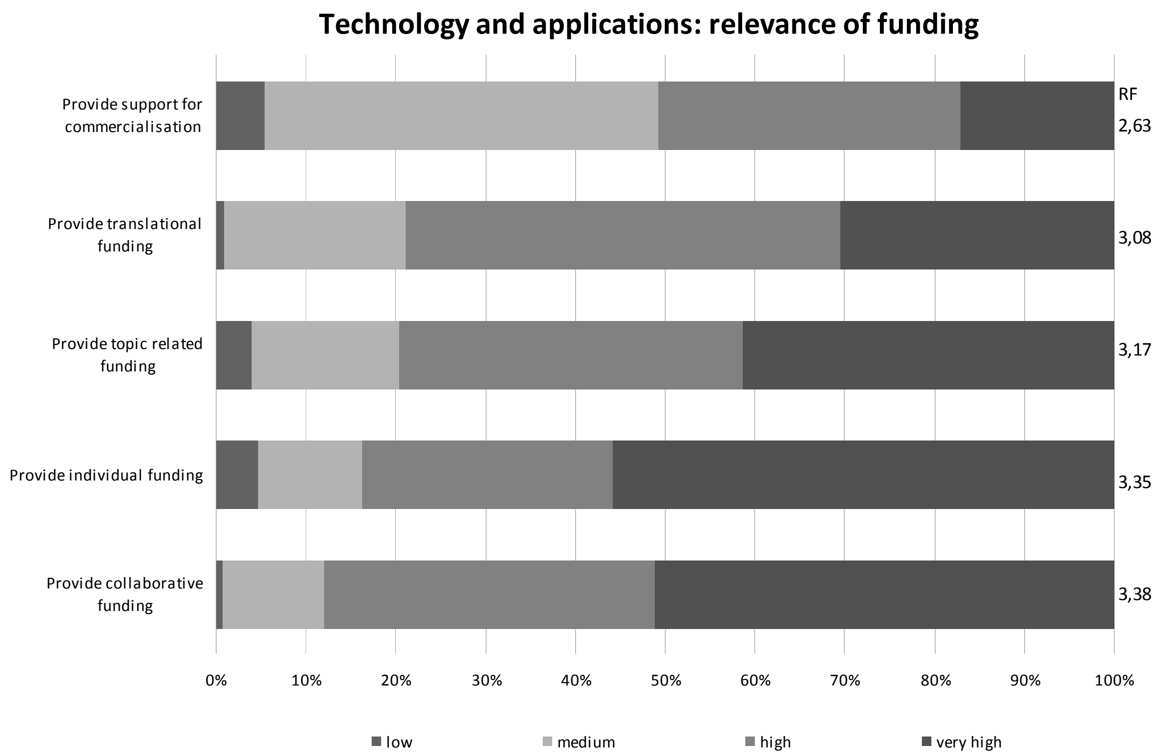
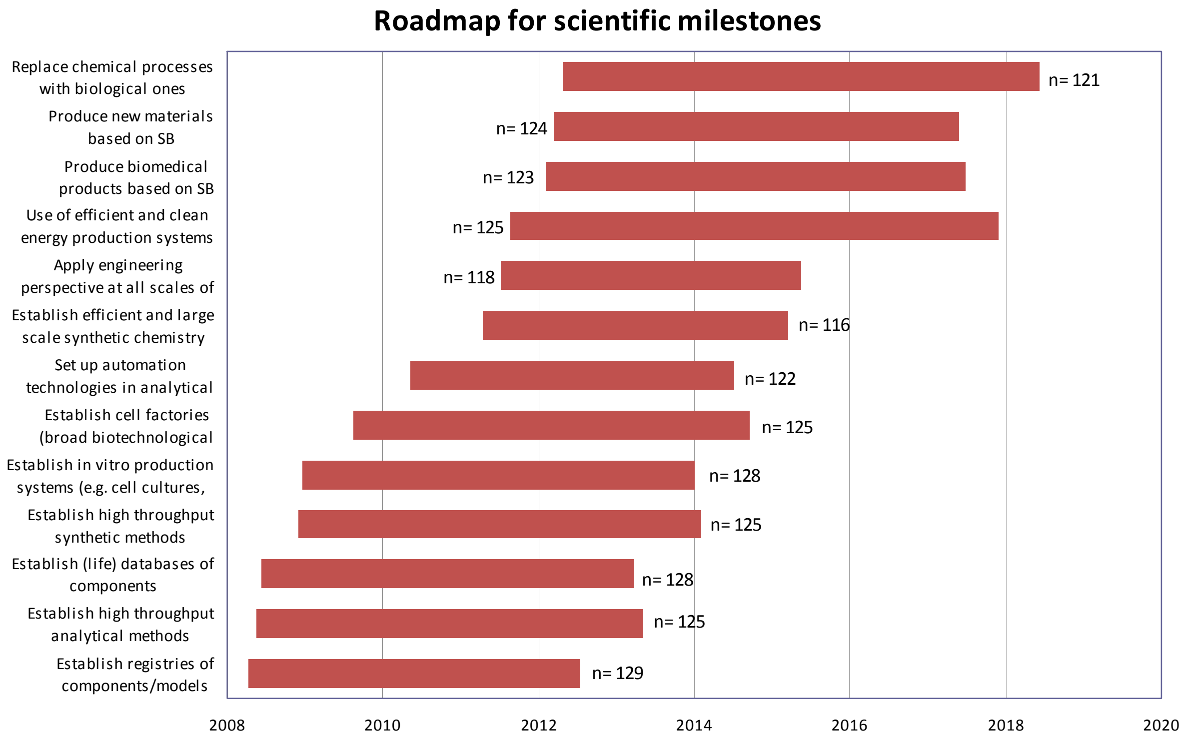


Figure 15: Time horizon (a) and relevance (b) of scientific milestones in dimension 3



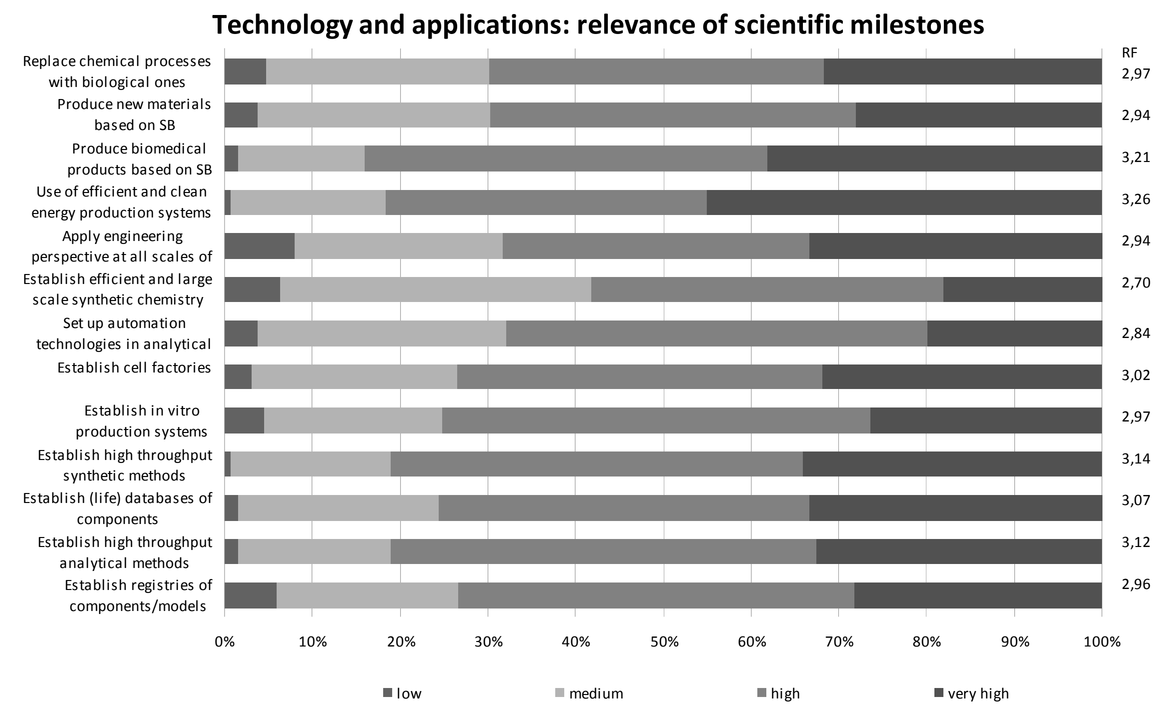
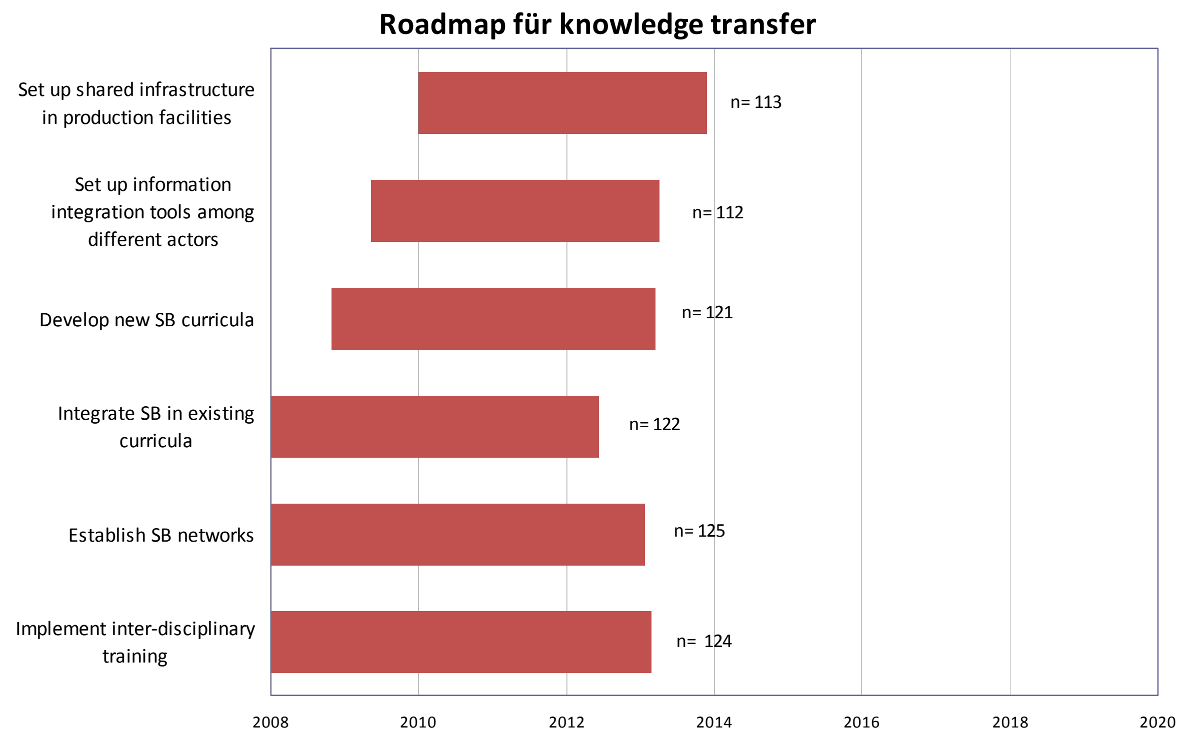
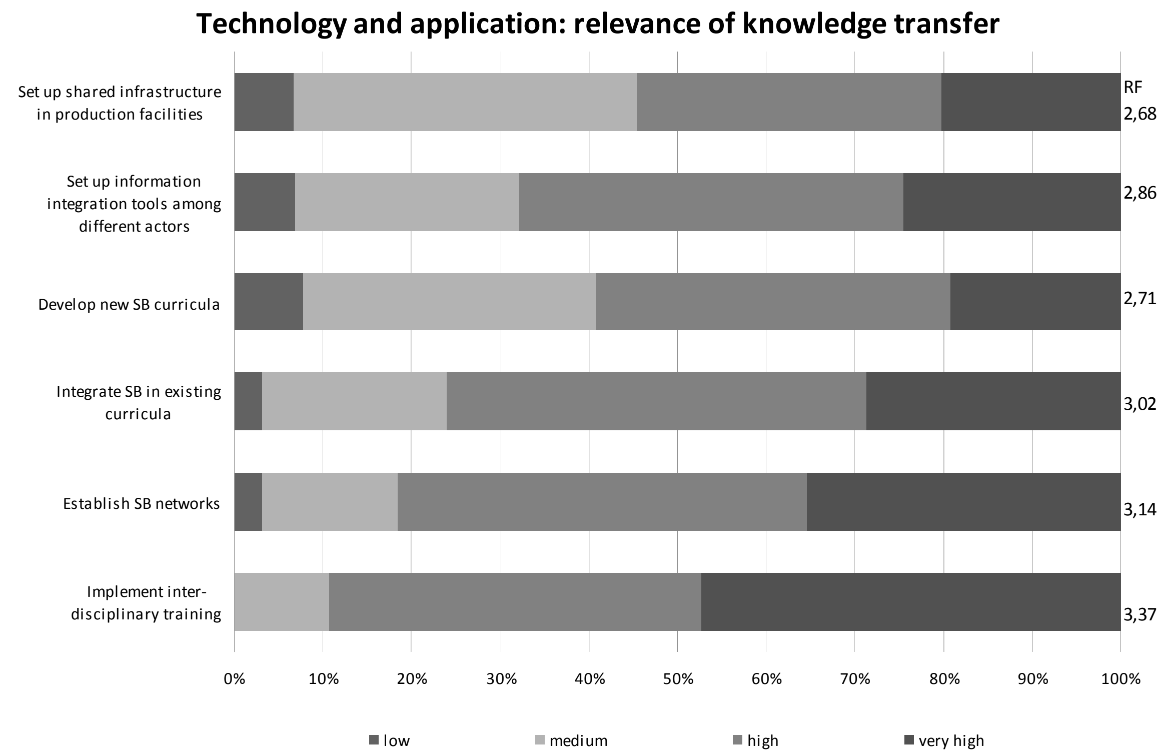


Figure 16: Time horizon (a) and relevance (b) in the field of knowledge transfer in dimension 3





4 Conclusion

The online survey revealed a distinct opinion within the broader synthetic biology community about the next steps, the requirements and the fostering factors in synthetic biology. Comments of the participants showed that this strategic project is assessed as being helpful for the formation of a strong SB field in Europe. However, it illustrated also the fear of researchers of too much bureaucracy possibly inhibiting free development of SB.

One basic comment of a number of respondents dealt with the question, whether SB is actually a novel discipline. In this matter opinions were contradictory. While the assessment of the sequence of the next steps in scientific and technological development was rather consistent, some contradictions and inconsistencies could be observed with respect to the evaluation of framework conditions and societal/ethical implications of SB. In particular such issues need further analysis and discussion.

5 Next steps

The suggestions of this working paper will form the basis for detailed discussions with the advisory board of the TESSY project and will feed in the final roadmap.

6 Annex

6.1 Online-questionnaire

Towards a European Strategy for Synthetic Biology

Your experience

1a) Please specify your scientific background and the type of institution you work in (tick all appropriate boxes)

Scientific background	Institution
q01_1 Biology	q02_1 University
q01_2 Chemistry	q02_2 Other public research organization
q01_3 Education	q02_3 Private sector
q01_4 Energy Technologies	q02_4 Ministry or policy associated
q01_5 Engineering	q02_5 NGO
q01_6 Environmental Sciences	q02_6 Financing sector
q01_7 Informatics	q02_7 Other (specify) q02_7x
q01_8 Law	
q01_9 Material Science	
q01_10 Medicine	
q01_11 Pharmacy	
q01_12 Physics	
q01_13 Security/safety research	
q01_14 Social Sciences	
q01_15 Other (specify) q01_15x	

1b) In which country do you work at the moment?

q03

I am currently not working in Europe but in the following country
q03x

1c) Are you currently working in the field of synthetic biology (according to definition above)?

q04

If yes: Which field of synthetic biology are you involved in?

q05_1 Engineering and study of biological systems
q05_2 Product development
q05_3 Technology development
q05_4 Public dimension (Social science issues)
q05_5 Other (specify) q05_5x

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I. Public dimension

Relevance: please tick one of the categories "low", "medium", "high", or "very high"

Time horizon: please indicate start and end point when the respective topic should be a major focus on the European SB agenda by ticking both start and end year

	Relevance				Time horizon							
	low	medium	high	very high	today	3 Years	6 Years	9 Years	12 Years	15 Years	> 15 Years	cannot answer
Knowledge transfer/dissemination												
Raise public awareness	var1_2				var1_31	var1_32	var1_33	var1_34	var1_35	var1_36	var1_37	var1_1
Elaborate education/ information material	var2_2				var2_31	var2_32	var2_33	var2_34	var2_35	var2_36	var2_37	var2_1
Establish interdisciplinary training/curricula	var3_2				var3_31	var3_32	var3_33	var3_34	var3_35	var3_36	var3_37	var3_1
Offer educational initiatives at all levels	var4_2				var4_31	var4_32	var4_33	var4_34	var4_35	var4_36	var4_37	var4_1
Others (specify) var5_2x	var5_2				var5_31	var5_32	var5_33	var5_34	var5_35	var5_36	var5_37	var5_1
Others (specify) var6_2x	var6_2				var6_31	var6_32	var6_33	var6_34	var6_35	var6_36	var6_37	var6_1
Funding/finances												
Provide funding for socioethical analyses	var7_2				var7_31	var7_32	var7_33	var7_34	var7_35	var7_36	var7_37	var7_1
Provide funding for teaching	var8_2				var8_31	var8_32	var8_33	var8_34	var8_35	var8_36	var8_37	var8_1
Others (specify) var9_2x	var9_2				var9_31	var9_32	var9_33	var9_34	var9_35	var9_36	var9_37	var9_1
Regulation												
Clarify ethical issues	var10_2				var10_31	var10_32	var10_33	var10_34	var10_35	var10_36	var10_37	var10_1
Elaborate clear guidelines for the conduct of synthetic biology research	var11_2				var11_31	var11_32	var11_33	var11_34	var11_35	var11_36	var11_37	var11_1

Establish measures to prevent misuse of research	var12_2	var12_31	var12_32	var12_33	var12_34	var12_35	var12_36	var12_37	var12_1
Establish coordinated regulation for biorisks/safety/security/	var13_2	var13_31	var13_32	var13_33	var13_34	var13_35	var13_36	var13_37	var13_1
GMOs	var14_2	var14_31	var14_32	var14_33	var14_34	var14_35	var14_36	var14_37	var14_1
Elaborate risk assessment mechanisms	var15_2	var15_31	var15_32	var15_33	var15_34	var15_35	var15_36	var15_37	var15_1
Establish broad consensus on use and handling of synthetic biology	var16_2	var16_31	var16_32	var16_33	var16_34	var16_35	var16_36	var16_37	var16_1
Others (specify) var17_2x	var17_2	var17_31	var17_32	var17_33	var17_34	var17_35	var17_36	var17_37	var17_1
Others (specify) var18_2x	var18_2	var18_31	var18_32	var18_33	var18_34	var18_35	var18_36	var18_37	var18_1

Your comments and additional topics that should be added to the roadmap.
var_comment1

Towards a European Strategy for Synthetic Biology

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II. Application and technology dimension

Relevance: please tick one of the categories "low", "medium", "high", or "very high"

Time horizon: please indicate start and end point when the respective topic should be a major focus on the European SB agenda by ticking both start and end year

Scientific milestones	Relevance (low / medium / high / very high)	Time horizon: today	3 Years	6 Years	9 Years	12 Years	15 Years	>15 Years	cannot answer
Establish registries of components/models	var19_2	var19_31	var19_32	var19_33	var19_34	var19_35	var19_36	var19_37	var19_1
Establish (life) databases of components	var20_2	var20_31	var20_32	var20_33	var20_34	var20_35	var20_36	var20_37	var20_1
Establish in vitro production systems (e.g. cell cultures, in vitro translation, production with isolated/novel enzymes etc.)	var21_2	var21_31	var21_32	var21_33	var21_34	var21_35	var21_36	var21_37	var21_1
Establish cell factories (broad biotechnological production in microbial or eukaryotic cells)	var22_2	var22_31	var22_32	var22_33	var22_34	var22_35	var22_36	var22_37	var22_1
Establish high throughput analytical methods	var23_2	var23_31	var23_32	var23_33	var23_34	var23_35	var23_36	var23_37	var23_1
Establish high throughput synthetic methods	var24_2	var24_31	var24_32	var24_33	var24_34	var24_35	var24_36	var24_37	var24_1
Set up automation technologies in analytical and synthetic processes as standard procedures	var25_2	var25_31	var25_32	var25_33	var25_34	var25_35	var25_36	var25_37	var25_1
Establish efficient and large scale synthetic chemistry production processes	var26_2	var26_31	var26_32	var26_33	var26_34	var26_35	var26_36	var26_37	var26_1

Produce new materials based on SB	var27_2	var27_31	var27_32	var27_33	var27_34	var27_35	var27_36	var27_37	var27_1
Produce biomedical products based on SB	var28_2	var28_31	var28_32	var28_33	var28_34	var28_35	var28_36	var28_37	var28_1
Use of efficient and clean energy production systems	var29_2	var29_31	var29_32	var29_33	var29_34	var29_35	var29_36	var29_37	var29_1
Replace chemical processes with biological ones	var30_2	var30_31	var30_32	var30_33	var30_34	var30_35	var30_36	var30_37	var30_1
Apply engineering perspective at all scales of biological structures	var31_2	var31_31	var31_32	var31_33	var31_34	var31_35	var31_36	var31_37	var31_1
others (specify) var32_2x	var32_2	var32_31	var32_32	var32_33	var32_34	var32_35	var32_36	var32_37	var32_1
others (specify) var33_2x	var33_2	var33_31	var33_32	var33_33	var33_34	var33_35	var33_36	var33_37	var33_1
others (specify) var34_2x	var34_2	var34_31	var34_32	var34_33	var34_34	var34_35	var34_36	var34_37	var34_1
Knowledge transfer/dissemination									
Develop new SB curricula	var35_2	var35_31	var35_32	var35_33	var35_34	var35_35	var35_36	var35_37	var35_1
Integrate SB in existing curricula	var36_2	var36_31	var36_32	var36_33	var36_34	var36_35	var36_36	var36_37	var36_1
Establish SB networks	var37_2	var37_31	var37_32	var37_33	var37_34	var37_35	var37_36	var37_37	var37_1
Implement inter-disciplinary training	var38_2	var38_31	var38_32	var38_33	var38_34	var38_35	var38_36	var38_37	var38_1
Set up shared infrastructure in production facilities	var39_2	var39_31	var39_32	var39_33	var39_34	var39_35	var39_36	var39_37	var39_1
Set up information integration tools among different actors	var40_2	var40_31	var40_32	var40_33	var40_34	var40_35	var40_36	var40_37	var40_1
others (specify) var41_2x	var41_2	var41_31	var41_32	var41_33	var41_34	var41_35	var41_36	var41_37	var41_1
others (specify) var42_2x	var42_2	var42_31	var42_32	var42_33	var42_34	var42_35	var42_36	var42_37	var42_1
Funding/finances									
Provide collaborative funding	var43_2	var43_31	var43_32	var43_33	var43_34	var43_35	var43_36	var43_37	var43_1
Provide translational funding	var44_2	var44_31	var44_32	var44_33	var44_34	var44_35	var44_36	var44_37	var44_1
Provide support for commercialisation	var45_2	var45_31	var45_32	var45_33	var45_34	var45_35	var45_36	var45_37	var45_1
Provide individual funding	var46_2	var46_31	var46_32	var46_33	var46_34	var46_35	var46_36	var46_37	var46_1

Provide topic related funding	var47_2	var47_31	var47_32	var47_33	var47_34	var47_35	var47_36	var47_37	var47_1
Others (specify) var48_2x	var48_2	var48_31	var48_32	var48_33	var48_34	var48_35	var48_36	var48_37	var48_1
Others (specify) var49_2x	var49_2	var49_31	var49_32	var49_33	var49_34	var49_35	var49_36	var49_37	var49_1
Regulation									
Clarify IP issues	var50_2	var50_31	var50_32	var50_33	var50_34	var50_35	var50_36	var50_37	var50_1
Clarify open source status of components	var51_2	var51_31	var51_32	var51_33	var51_34	var51_35	var51_36	var51_37	var51_1
Harmonize IP issues on an international basis (e.g. between Europe and the US)	var52_2	var52_31	var52_32	var52_33	var52_34	var52_35	var52_36	var52_37	var52_1
Standardize components	var53_2	var53_31	var53_32	var53_33	var53_34	var53_35	var53_36	var53_37	var53_1
Standardize methods	var54_2	var54_31	var54_32	var54_33	var54_34	var54_35	var54_36	var54_37	var54_1
Others (specify) var55_2x	var55_2	var55_31	var55_32	var55_33	var55_34	var55_35	var55_36	var55_37	var55_1
Others (specify) var56_2x	var56_2	var56_31	var56_32	var56_33	var56_34	var56_35	var56_36	var56_37	var56_1

Your comments and additional topics that should be added to the roadmap.
var_comment2

Towards a European Strategy for Synthetic Biology

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III. Engineering and study of biological systems

Relevance: please tick one of the categories "low", "medium", "high", or "very high"

Time horizon: please indicate start and end point when the respective topic should be a major focus on the European SB agenda by ticking both start and end year

	Relevance	Time horizon							
	low / medium / high / very high	today	3 Years	6 Years	9 Years	12 Years	15 Years	>15 Years	cannot answer
Scientific milestones									
Elaborate modelling (in silico)	var57_2	var57_31	var57_32	var57_33	var57_34	var57_35	var57_36	var57_37	var57_1
Supply artificial vectors/delivery systems	var58_2	var58_31	var58_32	var58_33	var58_34	var58_35	var58_36	var58_37	var58_1
Elaborate minimal design principals	var59_2	var59_31	var59_32	var59_33	var59_34	var59_35	var59_36	var59_37	var59_1
Design synthetic viruses	var60_2	var60_31	var60_32	var60_33	var60_34	var60_35	var60_36	var60_37	var60_1
Design minimal genomes	var61_2	var61_31	var61_32	var61_33	var61_34	var61_35	var61_36	var61_37	var61_1
Design minimal cells	var62_2	var62_31	var62_32	var62_33	var62_34	var62_35	var62_36	var62_37	var62_1
Apply new perspectives to research on all levels of the biological sciences	var63_2	var63_31	var63_32	var63_33	var63_34	var63_35	var63_36	var63_37	var63_1
Others (specify) var64_2x	var64_2	var64_31	var64_32	var64_33	var64_34	var64_35	var64_36	var64_37	var64_1
Others (specify) var65_2x	var65_2	var65_31	var65_32	var65_33	var65_34	var65_35	var65_36	var65_37	var65_1
Others (specify) var66_2x	var66_2	var66_31	var66_32	var66_33	var66_34	var66_35	var66_36	var66_37	var66_1
Knowledge transfer/dissemination									
Set up information integration tools among different actors	var67_2	var67_31	var67_32	var67_33	var67_34	var67_35	var67_36	var67_37	var67_1
Develop new SB curricula	var68_2	var68_31	var68_32	var68_33	var68_34	var68_35	var68_36	var68_37	var68_1

Integrate SB in existing curricula	var69_2	var69_31	var69_32	var69_33	var69_34	var69_35	var69_36	var69_37	var69_1
Implement inter-disciplinary sciences	var70_2	var70_31	var70_32	var70_33	var70_34	var70_35	var70_36	var70_37	var70_1
Establish SB networks	var71_2	var71_31	var71_32	var71_33	var71_34	var71_35	var71_36	var71_37	var71_1
Others (specify) var72_2x	var72_2	var72_31	var72_32	var72_33	var72_34	var72_35	var72_36	var72_37	var72_1
Others (specify) var73_2x	var73_2	var73_31	var73_32	var73_33	var73_34	var73_35	var73_36	var73_37	var73_1
Funding/Finances									
Provide "Blue sky" (=basic research) funding	var74_2	var74_31	var74_32	var74_33	var74_34	var74_35	var74_36	var74_37	var74_1
others (specify) var75_2x	var75_2	var75_31	var75_32	var75_33	var75_34	var75_35	var75_36	var75_37	var75_1
Regulation									
Elaborate risk assessment mechanisms	var76_2	var76_31	var76_32	var76_33	var76_34	var76_35	var76_36	var76_37	var76_1
Others (specify) var77_2x	var77_2	var77_31	var77_32	var77_33	var77_34	var77_35	var77_36	var77_37	var77_1
Others (specify) var78_2x	var78_2	var78_31	var78_32	var78_33	var78_34	var78_35	var78_36	var78_37	var78_1

Your comments and additional topics that should be added to the roadmap.
var_comment3

Towards a European Strategy for Synthetic Biology

Comments

Concluding comments on Synthetic Biology in Europe in general and/or the roadmapping process

var_comment

Please send me a final roadmap

q06

6.2 Comments on SB given by the survey respondents

6.2.1 Comments on dimension 1 "Public dimension"

6.2.1.1 General Comments

- What we need is grants, more grants to trigger innovation so we can compete with the US. We need to spark interest in this field from young graduates by EU sponsored competitions. What we don't need is a huge amount of new EU bureaucracy (Regulation) slowing everything down. All academic institutions have policies in place for genetically modified organisms already. Just because you call it "synthetic biology" doesn't make it inherently more dangerous than what has already been done.
- Ownership of modified organisms and cells. Current patent law in relation to conventially and GMO bred crops is weighted against the rights of farmers etc and towards industry. Chemical biology will create similar scenarios and concepts of ownership need to be refined and European/worldwide patent law adapted accordingly to favour interests of people on the planet, not of lobby groups, which are only a subset which tend to dominate legislation around patent law.
- It is very relevant to inform people at all level in society of the vantages of Synthetic Biology and its applications in all field, from health to agriculture, from energy industries to food industries and pharmaceutical industries, for the benefit of society as a whole. Once the people is well informed of the benefit of this technology we can then explain the risks and the ethical issue requiring roles and regulations for our safety
- Public dissemination through radio, TV and scientific debate at universities
- In my deep opinion, you ought to create additional working places in a biotechnology, but not to growth a bureaucracy. Don't dramatize the situation, please. It would be better, if you will not follow an American paranoia. There is nothing new in SB, if you compared it with the biotechnology carefully. Why is no any panic in a nanotechnology? Because, scientists working well know own business. Opposite, people promoting SB are mostly dilettantes in biology. Could you begin with a psychoanalyze of ‘SB leaders'? It will be really a social research. And eventually, iGEM it's not a synthetic biology at all!
- I see synthetic biology as a whole new area of possibilities to use biological systems as tools for an engineering approach. The possibilities will continue to open up when the scientific community learns more and is more and more able to control biological processes. That means that the will not be a certain time in the near future (certainly not within 15 years) where we have managed all aspects of synthetic biology, instead it will be more of a process of constantly evolving opportunities. Therefore several issues you present here have to be ongoing ad accompanying.
  What do you mean with "GMOs" they are already regulated? I don't understand the point, what is the question?
- The questions are puzzling: the only risk with synthetic biology (a serious one) is that the technology will allow reconstruction of dangerous pathogens in an unobtrusive way. Other ideas (Viktor and Dr Frankenstein) are just bad dreams of ignorant persons. The main danger is to stress danger where it does not exist, as it will divert attention from the serious problem of biosecurity. Natural organisms will always be much more dangerous than artificial ones, and the more natural the more dangerous... This is quite visible with the poor debate on

GMOs, where people appear to be afraid of plant GMOs and not animal GMOs while, of course, animal GMOs are potentially much more dangerous (in particular xenotransplantation) than plant GMOs. Sociology of the question is highly revealing.

- what does GMOs mean in terms of time horizon?
- Much of what needs to be done has been done in related areas. We therefore need primarily harmonisation of what exists already, with a focus on possible new developments.
- Some "systems" will clearly be easier than others to study. For example synthetic viruses will most likely preceed new cells. Thus ethical issues should in the initial phase concern the easy experiments.
- Many of the ethical issues are important but they are not unique to synthetic biology, which is why I see specific measures and regulation in this area to be of low priority.
- Trying to elaborate risk assessment mechanisms appears premature to me at this point. However, I think it is very important to establish clear guidelines for the conduct of synthetic biology research and to make sure that these guidelines are based on a broad consensus.
- Promote clear international treaties and national laws, not intricate, casuistic guild regulations by professional guilds.
- There is a clear difference (at least, in intent) between synthetic biology aimed at discovering more about the living world and synthetic biology aimed at the fabrication of devices for industrial or therapeutic use. Regulatory measures should ensure that impediments to the former are minimised while public concerns concerning the latter are fully satisfied.

6.2.1.2 Other activities to be considered in the roadmap

Knowledge transfer

- epistemology, history of sciences
- Increased mobility to transfer expertise
- meetings and conferences
- Professional networking
- synthetic biology institutions
- security (safety optional, as standard)

Funding/ finance

- technological developments, infrastructures, knowledge dissemination
- Provide funding for the scientific research in SB
- how about funding for basic and applied research and technology development

Regulation

- watch and break patent-monopolization
- Promote international treaties and national laws, not guild regulations
- intellectual property rights
- protect registries of parts as free exchange platforms

6.2.2 Comments on the dimension 2 "Engineering and study of biological systems"

6.2.2.1 General comments

- it would be very important to establish new centers of excellence for SB in europe and new faculty jobs for European scientists.
- The best way to prevent a risk is to be self-restricted. It’s practically impossible to prevent a government or corporative research in weapons and a professional terrorism. And it’s not a job for scientists.
- What is called SB is well on its way since more than 30 years. One should strictly avoid creating a "Hype" via shallow slogans and making predictions and promises which will not materialize, as regularly experienced in other areas of research, where so called policy makers carelessly left the solid base of scientific reasoning.
- Nature has spent billions of years optimising the individual expression and activities of enzymes in pathways to achieve optimal fluxes and metabolite concentrations which are absolutely crucial to the performance of the system. A key point in the success of SB is that we start thinking about how we vary the individual expression of the several or numerous enzymes required in an artificial pathway. Clearly, using inducible expression systems will not be feasible and one will probably need to use synthetic promoter libraries or equivalent techniques.

6.2.2.2 Other activities to be considered in the roadmap

Scientific milestones:

- Design cells with appropriate function
- Design tools for tailored gene regulation

Knowledge transfer:

- SB is NOT a new discipline and does not need more attention than its parent disciplines!!

Funding/Finance:

- fundamental theoretical research
- provide applied and technology development and KMU funding

Regulation:

- adapt biosafety regulations to synthetic biology
- work towards international regulations and guidelines

6.2.3 Comments on the dimension 3 "Application and technology dimension"

6.2.3.1 General Comments

- The crucial factor here is funding of individual researchers doing genuinely innovative research. Collaborative grants are painful and overly bureaucratic. A network of researchers and annual conference would be useful. Undergraduate teaching is good but it is hard to teach creativity! *please* do not harmonize our IP with the USA. We need to greatly reduce the amount of patents issued - this is akin to the software patent debate. The way to stifle innovation and move all this to the emerging economies of the East is to give the EU patent office free reign to let everything being patented. Patents must be restricted and shortened. Publicly funded research *must* be contract, be open source to EU researchers and industry. PLEASE!!!

- It is imperative to establish new network for funding and collaboration in between scientists within Europe and avoid the control of this new network from old lobbies. SB must give new opportunities to young scientists with new ideas

- The idea of a standardization coming from MIT is too primitive in the moment. Let do the standardization a bit of later. Biology is not electronics! We don’t know even how living organisms work. What about kind of standardization are you talking? About Biobricks? If you were a master of the cloning PCR, you don’t need any complex restriction/litigation procedures. But, if you were about the protein-protein interactions, it’s ok.

- SB is a new interdisciplinary approach to understanding what life is. As such it needs to be shared by as many people as possible, and it can act as a glue between disciplines. This should be supported in the implementation of curricula.

- Synthetic Biology is by no means a new discipline (first synthetic gene:1969!). Accordingly, it should be treated like other disciplines in Life Sciences with applied potential. Most important: grant support to well chosen individual researchers; No enforced "Networking" no obligatory "Mobility Programmes" and other, original research inhibiting, artificial bureaucratic measures!!!

- Again, it is not obvious to me that these topics, or at least many of them, are specific to synthetic biology. e.g. synthetic biology may raise questions about IP but very few of these questions are not also relevant to generation of IP in the high tech areas.

- For collaborative funding, I think the focus should be on small groups of 2-5 researchers who really collaborate closely. Large networks don't seem very effective in practice.

- Too much component standardization will limit novel findings.

- While standardisation promotes cooperation and interoperability, care must be taken to ensure that it does not become a barrier to innovation.

6.2.3.2 Other activities to be considered in the roadmap

Scientific milestones

- single molecule detection of biomolecules

- artificial NA synthesis

- establish efficient large size DNA synthesis
- Establish new molecular tools for DNA and protein analysis
- DNA synthesis
- establish genetic engineering tools for large scale genomic modifications

Knowledge transfer/dissemination

- CAD tools for SB
- DNA programming

Funding/ finance

- provide education funding
- provide funding for advanced research
- Regulation

6.2.4 General comments on the survey and SB in general

- In my opinion, synthetic biology will be very important in research and industry, leading to changes perhaps comparable to those associated with the initial introduction of genetic modification techniques beginning in the 1970s. Support at a European level will help to ensure that Europe does not fall behind the USA, China and Japan in this growing field. However, synthetic biology cannot be seen in isolation; it will rely upon the development of new basic biological knowledge to increase the relevance and accuracy of models and designs. In this regard, the questions arising from synthetic biology experiments may help to suggest new directions for biological research by highlighting areas where basic understanding is currently not adequate for accurate modeling and design. Likewise, tools developed by synthetic biology may provide new methods for addressing difficult questions in biology. Thus, support for synthetic biology should be seen as an integral part of the development of biology. As the novel viewpoint associated with synthetic biology becomes more prevalent, it may be that synthetic biology as a distinct entity (to the extent that this is currently the case) ceases to exist, becoming fully integrated into biology and/or engineering and becoming a default viewpoint for those working in this area. Design, modeling and synthesis of biological systems may become simply another set of standard tools in the growing toolbox of modern biology and biotechnology, and the associated mathematical/engineering viewpoint as applied to biological systems will lend a new rigour to biology and increased effectiveness to biotechnology.

- What we need is numerous small grants directed towards truly creative and innovative researchers. Good project based teaching to inspire the young. Conferences, networks and competitions as light-weight as possible to encourage collaboration and discussion. Leave all safety regulation to local institutions. Overhaul the intellectual property laws in favour of start up companies not large (mostly American and Japanese) institutions who can destroy start-ups by (rubbish) patents. Open source all publicly funded research. Remember, we have to encourage the same kind of 'nerd' culture of Silicon Valley in the 1980s. The EU is a large beast and might accidentally trample on the green shoots of usefull innovation by patents, overly complex grants and regulation: A light touch not a heavy hand.

- Timely.

- Emphasis needs to be on high quality basic research rather than complex EU consortia that absorb management time, if it is to advance the area significantly.

- We hope for new funding , new jobs for European scientists to promote and exchange research work and collaborations . European scientists must have more mobility from country to country.

- I'd anticipate (hope?) that synthetic biology as a discipline would be a very plastic concept over the timeframe envisaged- as defined it is an approach rather than a field, and the test of success for such an approach is surely in whether it is absorbed by existing disciplines- e.g. whether SB is adopted as a standard tool for testing biological problems, or as a primary means for meeting materials technology challenges.

- I believe in the potential of synthetic biology. A minimal genome/cell is a good starting point. There will have to be a firm ethical understanding and practice, along the line of the research and commercialisation. It will also be a humbling process for us human - since learning a simple bacteria as earnestly as we can, will have a direct consequence upon how well we can benefit from synthetic biology. Thank you for giving me an opportunity to join this effort.
- Freiburg University has succeeded to initiate the first German Synthetic Biology Project through its Centre of Biological Signalling Studies, funded by the German Research Councils Excellence Programme
- Establish a European spirit; avoid Americanism and biosecurity phobia; avoid the bad example of handling GMOs
- It is necessary to provide more funding to develop Synthetic Biology in many European countries, such as Spain
- Synthetic Biology has already come of age, and now new methods and research into methods such as in vitro protein synthesis must be invested in. In my opinion this road map is a realistic one, and must be adhered to achieve the full potential of 'Synthetic Biology'.
- In my opining, there is an immediate need for the development of a new curriculum in the biological sciences (incorporating maths/physics/engineering; or even creating new Quantitative Biology programs).
- I also believe that more financial help to basic research projects related to the understanding of "simple" genetic networks in several model systems is also needed, while embarking on more (and larger) ambitious projects.
- Good luck!!
- It seems that you have not clearly separated biosafety from biosecurity and biorisks. These are different concepts that require separate judgements and regulation.
- You seem to focus a lot on the bioparts aspect of synthetic biology. What about the other aspects of synthetic biology, e.g. the use of alternative biochemicals in biological systems, e.g. third type nucleic acid, or an extended alphabet of base pairs, or the never born proteins, and so on. Please try not to restrict synthetic biology to the standardization of parts. It is only one way (although an important one many will say), but there are many more options opening up that should not be neglected.
- SB is a new, exciting science and future industry, which relies on interdisciplinarity on a previously unknown scale. To break the barriers between traditional scientific areas, and particularly between biologists and non-biologists is the greatest challenge.

Europe, in its diversity and richness, will have to overcome particularly strong barriers, but may have a long term advantage in this area.

- still very early, current programs on EU level somewhat disappointing
- The experimental technology part of SB in Europe is quite weak comparing with the modeling part. It should have more support in the next few years.
- A positive and active approach for the creation of new interdisciplinary scientific groups is required - a mechanism for gradually bring new groupings together, toward large projects, without the wastage of discarding good ideas that have weak grouping. A synthesis of best ideas and strongest groups by staged bids and funding.
- What is called SB is well on its way since more than 30 years. One should strictly avoid creating a "Hype" via shallow slogans and making predictions and promises which will not materialize, as regularly experienced in other areas of research, where so called policy makers carelessly left the solid base of scientific reasoning.
- It is desiderable an integrative effort to support this novel novel research discipline at the interface between life sciences and engineering. The potential of SB are broad and new professional figure could appear. As with all novel, truly interdisciplinary fields, synthetic biology relies on the recruitment of suitably trained people from several fields. Training of researcher in this area is of crucial importance.
- There should be enough diversity of approaches and mind frames, that is, avoid "me-too research" in SB (in particular with regard to the US)so to foster innovation and therefore the global progress of the field
- It is critical to elaborate a European Programme in this new field. We have the history, the critical mass and the capacity for a fruitful exchange of ideas on the topic, something that will provide us also with the capability to create tools for our economy (specially related with environmental and biomedical issues). In addition, as compared with other countries in the World we are really in a better shape to create a better legal regulation as well as to explore the ethical consequences of such a theory and technology.
- I find synthetic biology an exciting field for the future. It is however difficult for me to provide answers to many of your questions as I do not see them as being at all specific to synthetic biology. Further, many of these activities have begun and should continue for a long time, so I found it hard to set a timeline for most of the topics.
- I think the road map should be seen as a dynamic object. At the moment synthetic biology is not a very mature field. I think many of the ambitious goals stated in the roadmap should be pursued with a lot of energy, but as one proceeds, flexibility will be important and it must be possible to adjust the roadmap "on the go".
- Very important topic worthy of strong support

- We do not want to get carried away... Fundamental studies of biological systems must remain the basis of what we do. As always progress will come from new technologies. SB isn't a new technology, it is merely a new way of thinking biological systems. DNA synthesis will certainly be the technology carrying SB, but it will be so only if we are able to predict the behavior of what we synthesize, and there is still a long way to go ! We will not achieve anything more than classical molecular biology work unless we share and provide well and fully characterized "biobricks".

- 1) Synthetic Biology as such is a chimaeric mix with which name I do not agree
  2) At present, the SB concept is more a matter of Bioinformatic than a wet-lab experimental field both in Europe and in US
  3) At present there are different groups working in minimal genomes, minimal cells, artificial virus, and cell factories, and if the SB aim is to try to joint these independent efforts to compete with USA, the SB program, despite its auwtfull name, could help both in basic knowledge of how cells work and in practical application approach.

- European plans for cooperation should aim to facilitate the best "actors' in the different disciplines working together. Europe has a far wider and deeper pool of talent than any individual nation. However, over-prescription of the nature of such cooperation should be avoided since it may create artificial consortia to meet funding criteria and this will slow progress.

- Interdisciplinarity and widespread discussion in the public is needed