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Current Glycomics' Approaches: Subprojects and Journals

Vitor H. Pomin

Program of Glycobiology, Institute of Medical Biochemistry, and Hospital Universitário Clementino Fraga Filho, Federal University of Rio de Janeiro, Brazil

After the era of genome, proteome, metabolome, and lipidome, the age of glycome has launched in biology bringing so far more challenges than the first "ome" projects. The long major conception of carbohydrates as just energetically involved class of biomolecules (basically until early 80's) has fallen apart as innumerable other essential biological roles have been documented. The current glycomics' boom [1] has been proving the importance of this class of molecules in many fields regarding the sciences of chemistry and biology. And nowadays the amount of data concerning biological actions of carbohydrates is very high which turned out to be impossible to enlist all types of action together at once. Such actions involve not only essential roles in cell [2] like growth, migration, differentiation or signaling events, or in physiology [2] like immunology, hematology, and histology, but within a different context, carbohydrates can also exhibit potent biomedical applications as anticoagulant, antithrombotic, anti-inflammatory, antivirotic, antipathogenic, antitumorigenic, antimetastatic, anti-angiogenic agents, among other therapeutic uses [3,4].

The diversity in biological and biomedical functions of glycans is not the only main reason for the high complexity of glycomics. Glycome has became the most challenging "ome" project perhaps mostly because of the variety of structures that carbohydrates can form [1,5], the many regulative determinants in their biosynthetic routes [1], and the big number of families.

Among biomolecules, carbohydrate is very far the most structurally diverse, in which approximately 100 naturally occurring monosaccharide types together with enantiomericity, anomeric configurations, linkage types, presence and differential position of chemical groups in branched or linear, homo or heteropolymers, end up to enhance immensely the possibilities of structural forms. The flexibility and high thermodynamic behaviors of carbohydrates are also another aggravation in structural elucidation which consequently increases the challenges in glycomics. Recent technologies and new high-throughput methods of analysis have inclusively been developed, such as those involving ^{15}N-NMR-based structural analysis of glycosaminoglycans [6-9].

Unlike nucleic acids and proteins, carbohydrates are biosynthesized through a non-driven template mechanism in which the available amounts of substrates (nucleotide-sugar donors) and the levels in expression of biosynthetic or modifying enzymes are essential actors. Carbohydrates can be considered directly products influenced by other "ome" projects mainly genome, proteome and metabolome. Hence carbohydrates cannot even be assumed as the major protagonists in their own glycome project since other molecules than carbohydrates could be working as the main regulators of carbohydrate structural features in specific biological conditions. This can be easily observed with the relevant differentiation of sulfation patterns in glycosaminoglycans of cell-surface proteoglycans during pathological conditions such as cancer [10]. Specific sulfotransferases with their differential expression levels were reported to be the protagonists in this pathological scene inside glycomics [11].

Moreover, the diversity in sugar types and respective classes are also a considering factor to collaborate into the complexity of glycome project. Sialylated glycoconjugates like glycolipids, *N*- or *O*-linked glycoproteins, and many glycosaminoglycan families in proteoglycans are the most famous sugar classes in mammals. In glycobiology, the number of subtopics is vast as the length of their contents. Hence, subdivision in glycomics has naturally started to appeared within new terminologies like proteoglycanome [12,13], glycosaminoglycanome[14,15], heparanome [9,16], glycoproteome [17], glycolipidome [18], and sialome [5]. These new terminologies were built to define specific sub-segments in glycome due to the natural overwhelming complexity of sugar families, with their respective content of information regarding structures, biological functions, and metabolic influences in biosynthetic systems. Glycomics is so extensive project that this subdivision is in fact demanded for its natural progress. However, it should be reasonable if other non-mammalian polymers like sulfated galactans (agaran, and carrageenan) [4,19,20], and sulfated fucans [4,19] from marine organisms, and peptidoglycans or heteroglycans like glucuroxylomannans (GXM) [21] in bacteria and fungi organisms respectively, would have also their own segments for study with specific terminologies in glycomics. This classification or systematic division of glycome into the proposed sub-segments would make easier the accomplishment of any scientific step related to these particular glycans (such as research lines/groups, publication types, topics to be discussed in meetings, journal types, etc), besides making these relatively new glycan families more noticeable throughout the scientific community. Moreover, the global relevance and interest of glycomics project would be considerably improved with the fact that additional projects concerning therapeutically and pathogenically relevant sugars have became now more publically noted. Such new terminologies would comprise, for example, galactanome (agaranome, carrageenome), fucanome, peptidoglycanome, glucuroxylomannome with respect to the respective sugar types above-mentioned, and the suffix "omics" with respect to their studies, like galactanomics for the science of galactans. It is worth to mention that these proposed glycomics subprojects would embrace any study or information related to their respective sugar classes. Like in galactanomics, biosynthetic mechanisms and their influences, structure deposition and correlation with organisms of biosynthesis, functions including the biological ones inside the own organisms of occurrence as well as the alternative therapeutic actions in mammalians, among other areas, would comprise research lines inside this subtopic of glycomics. An tentative list of glycomics subprojects, including those already established, those to be shortly considered and those to be established any time in the future is shown in Table 1.

The list proposed in Table 1 is far away to survey the total possible

Corresponding author: Vitor H. Pomin, Program of Glycobiology, Institute of Medical Biochemistry, and Hospital Universitário Clementino Fraga Filho, Federal University of Rio de Janeiro, Rio de Janeiro, RJ, 21941-590, Brazil. Tel: +55 - 21-2562-2939; Fax: +55 - 21 – 2562-2090; E-mail: vhpomin@gmail.com

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Glycome	- **Glycolipidome**	- Cerebrosides	
		- Globosides	
		- Gangliosides	- **Sialome** (e.g. sialylated gangliosides)
	- **Glycoproteome**	- *N*-linked glycans	- Mannomics (e.g. high mannose)
		- *O*-Linked glycans	- **Sialome** (e.g. E-selectin Sialyl Lewis^X)
	- **Proteoglycanome**	- **Glycosaminoglycanome**	- **Heparanome** (heparan sulfate)
			- *Heparinome* (heparin)
		- *Galactosaminoglycanome*	- *Dermatanome* (dermatan sulfate)
			- *Chondroitinome* (chondroitin sulfate)
	- **Glycometabolome**	(metabolomics related to glycobiology)	
	- *Peptidoglycanome*	(bacterial wall heteropolysaccharides)	
	- *Galactanome* (galactans)	- agaranome (agaran)	
		- carrageenome (carrageenan)	
	- *Fucanome* (fucans)		
	- Fungal polysaccharides	- glucuronoxylomannome (e.g. glucuronoxylomannan)	

Table 1: Summarized list of the main glycomics subprojects already in use (bold fonts), about to be used (italic fonts) and possible to be used in the near future (regular fonts).

segments in glycomics as well as to anticipatedly assure that the suggested segments will certainly occur in the future, although they have been indicating that they most likely will. On the other hand, this list pictures surely how complex and big the glycomics project itself really is. The process of splitting glycomics into subprojects is necessary for its natural development and it shows that each of the subprojects already represents enormous projects of research themselves. Nevertheless, the thought that subdivision of glycomics would significantly reduce the complexity of the main project has proved to be untrue. The updated glycomics' view turned out to be more a collection of subprojects rather than a single scientific project. And the division is just an easier method for study and annotation of results. In analogy to what was previously mentioned: "The Sialome – far more than the sum of its parts" [5], here we reiterate: "The Glycome – bigger than the division of its total".

It's worth mentioning that the classification step is just a fact of convention and sometimes it will be quite questionable. E.g. certain sugar types and their data may belong to more than one segment. For example, heparan sulfate-related data directly studied by its heparanome subproject can be included in the upper level glycosaminoglycanomics as well as further in the broader project proteoglycanomics, as finally in glycomics itself. These levels of hierarchy brings different specificities, relevance and impact for each segment, but certainly diminishes the complexity directly deposited under the biggest segment named glycomics. Another conventionalism can be seen in the use of glycoproteomics, peptidoglycanomics, and proteoglycanomics. These terminologies can be considered intersections between glycomics and proteomics, which make possible the results about glycoproteins, peptidoglycans and proteoglycans be deposited in either one.

Glycomics project therefore differentiate from previous "ome" projects mainly genome and proteome especially due to its great complexity (both in terms of structure and function) and because of its broad internal classification. It also differentiates from others "omics" with respect to its short age. It´s important to remind that glycomics is the newest era. Therefore, in genome and proteome, each project has already its specific journals, and research projects solidly established by international networks. The famous one was the "human genome project" [22,23]. In addition to splitting glycomics into its subprojects another currently demand would be the creation of specific journals to glycobiology. Suggestive names are Glycomics, Journal of Glycomics, or the Journal of Glycome Research in analogy to the already founded Proteomics and Genomics, Journal of Proteomics, and Journal of Proteome Research. Others journals concerning the subprojects such as Glycosaminoglycanomics, Proteoglycanomics, or Sialomics would certainly be of interest too in the near future. The creation of these journals is justified not only based on the large number of data could come from different families of carbohydrates but also from the current impact that such sugar types have on cell biology, chemistry, human health and physiology. Even if these journals were founded, glycomics project is still far away to conceive an approach like "human glycome project". Conversely, we surely are much closer to a "human sialome project" or "algal galactanome project" instead.

Fortunately, OMICS Publishing Group has already started in contributing towards this current glycomics´ demand with the foundation of specific journals such as "Journal of Glycomics & Lipidomics" and "Journal of Glycobiology". Hopefully, diverse publications therein can make classes of glycans as well as their structural and functional features more relevant throughout the public audience, not only inside the Society of Glycobiology, but also to the scientific community as a whole. We expect for the great success of these journals and their impacting contribution in the progress of glycomics, and consequently of glycobiology.

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