Nucleic Acids Research, 2007, Vol. 35, No. Web Server issue ***W3–W5***
doi:10.1093/nar/gkm459

Conducting Research on the Web: 2007 Update for the Bioinformatics Links Directory

Joanne A. Fox, Scott McMillan and B. F. Francis Ouellette*

UBC Bioinformatics Centre (http://bioinformatics.ubc.ca/), University of British Columbia, 2185 East Mall, Vancouver, British Columbia, Canada, V6T 1Z4

Received May 18, 2007; Accepted May 22, 2007

ABSTRACT

The Bioinformatics Links Directory, http://bioinformatics.ca/links_directory, is an actively maintained compilation of servers published in this and previous issues of *Nucleic Acids Research* issues together with many other useful tools, databases and resources for life sciences research. The 2007 update includes the 130 websites highlighted in the July 2007 Web Server issue of *Nucleic Acids Research* and brings the total number of servers listed in the Bioinformatics Links Directory to just under 1200 links. In addition to the updated content, the 2007 update of the Bioinformatics Links Directory includes new features for improved navigation, accessibility and open data exchange. A complete listing of all links listed in this *Nucleic Acids Research* 2007 Web Server issue can be accessed online at, http://bioinformatics.ca/links_directory/narweb2007. The 2007 update of the Bioinformatics Links Directory, which includes the Web Server list and summaries is also available online, at the *Nucleic Acids Research* web site, http://nar.oupjournals.org.

COMMENTARY

With the publication of the 2007 *Nucleic Acids Research* Web Server issue, we have a chance to reflect on how the web has transformed the way we conduct scientific research. The internet helps us to communicate, to rapidly access and exchange data, to connect ideas, and to bridge expertise across disciplines. As with any endeavor, it is important that scientists keep pace. In computational biology, we have the development of new tools and algorithms for scientific research that harness the power of the web for accessibility, data sharing and exchange of ideas. With collaborative technologies such as blogs, application programming interfaces (APIs), wikis and Really Simple Syndication (RSS), the pace of progress is accelerating and scientists increasingly need to rely on trusted directories, portals and useful search engines to keep up with the latest science. The Bioinformatics Links Directory is one such directory that includes a compilation of molecular biology servers, bioinformatics tools and online resources for life sciences research.

The Bioinformatics Links Directory, http://bioinformatics.ca/links_directory, is a listing of specialized servers and general purpose resources that aims to help scientists navigate the rapidly changing landscape of online research tools. Researchers can find relevant servers using the straight forward keyword search or by navigating to the biological categories, where tools that do similar tasks are grouped together. Each entry in the Bioinformatics Links Directory is highlighted by providing a short description for each link, listing relevant PubMed citations, and identifying links as servers from the *Nucleic Acids Research* Web Server Issue. This directory is designed to make it easy to connect information together. Any researcher can assemble a comprehensive listing of resources by downloading and importing the RSS feeds, a format used to publish frequently updated content (http://en.wikipedia.org/wiki/RSS). For example, a researcher can import the RSS feed for a search of the Bioinformatics Links Directory for 'transcription factor binding site' and publish it on her wiki alongside the feeds from the 'RNA, Structure Prediction, Visualization, and Design' and the 'Protein, Interactions, Pathways and Enzymes' subcategories as a resource for the whole research laboratory interested in transcriptional regulatory mechanisms.

The 2007 update of the Bioinformatics Links Directory includes the 130 servers published in this Web Server issue of *Nucleic Acids Research*. Over the past 5 years, the Web Server issues have published a rich collection of over 680 different internet resources (1,2). The 2007 update brings the total number of servers listed in the Bioinformatics Links Directory close to 1200 links (Table 1). A complete listing of servers from the 2007 Web Server issue can be accessed online at http://bioinformatics.ca/links_directory/narweb2007. The complete update of the Bioinformatics Links Directory, which includes the Web Server list and summaries, is also

*To whom correspondence should be addressed. Tel: +1 604 822 3648; Fax: +1 604 608 4795; Email: francis@bioinformatics.ubc.ca

Table 1. Summary of the number of web servers listed in each subcategory of the Bioinformatics Links Directory

Name	URL[a]
Computer Related	
Bio-* Programming Tools	20
C/C++	3
Databases	2
Java	4
Linux/Unix	11
PERL	5
PHP	1
Statistics	9
Web Development	2
Web Services	7
DNA	
Annotations	56
Gene Prediction	33
Mapping and Assembly	15
Phylogeny Reconstruction	43
Sequence Feature Detection	142
Sequence Polymorphisms	39
Sequence Retrieval and Submission	30
Tools For the Bench	63
Utilities	20
Education	
Bioinformatics Related News Sources	9
Community	24
Courses, Programs and Workshops	5
Directories and Portals	15
General	14
Tutorials and Directed Learning Resources	9
Expression	
cDNA, EST, SAGE	36
Gene Regulation	119
Microarrays	89
Protein Expression	9
Splicing	19
Human Genome	
Annotations	37
Ethics	8
Genomics	3
Health and Disease	19
Other Resources	29
Sequence Polymorphisms	33
Literature	
Goldmines	6
Open Access Resources	2
Search Tools	12
Text Mining	15
Model Organisms	
Fish	11
Fly	17
General Resources	27
Microbes	38
Mouse and Rat	35
Other Organisms	21
Other Vertebrates	10
Plants	19
Worm	9
Yeast	18
Other Molecules	
Carbohydrates	6
Metabolites	3
Small Molecules	6
Protein	
2-D Structure Prediction	58
3-D Structural Features	70
3-D Structure Comparison	45
3-D Structure Prediction	59
3-D Structure Retrieval, Viewing	51
Biochemical Features	40
Do-it-all Tools for Protein	8
Domains and Motifs	112
Function	44
Interactions, Pathways, Enzymes	88
Localization and Targeting	38
Molecular Dynamics and Docking	21
Phylogeny Reconstruction	44
Presentation and Format	14
Protein Expression	8
Proteomics	27
Sequence Data	8
Sequence Features	31
Sequence Retrieval	29
RNA	
Functional RNAs	19
General Resources	10
Motifs	21
Sequence Retrieval	10
Structure Prediction, Visualization, and Design	47
Sequence Comparison	
Alignment Editing and Visualization	21
Analysis of Aligned Sequences	59
Comparative Genomics	33
Multiple Sequence Alignments	50
Other Alignment Tools	11
Pairwise Sequence Alignments	23
Similarity Searching	47

[a]A complete listing of all URLs listed in the *Nucleic Acids Research* 2007 Web Server Issue can be accessed online at: http://bioinformatics.ca/links_directory/narweb2007

available online at the *Nucleic Acids Research* website, http://nar.oupjournals.org. Together with the long standing Database issue (3), these special issues at *Nucleic Acids Research* represent a valuable directory of resources for the global life sciences research community.

In addition to the updated content, the 2007 update of the Bioinformatics Links Directory includes new features that embrace accessibility and open data exchange. For example, the Bioinformatics Links Directory has become a LinkOut provider for the NCBI (4). With this data exchange, it is now easier for researchers to jump directly from searches in PubMed to Web Server listings in the Bioinformatics Links Directory. Since the last update, we have also implemented a new CSS based design to improve the look and feel of the Bioinformatics Links Directory (http://en.wikipedia.org/wiki/Css). This new design makes it easier to browse the categories of the directory and is fully compliant with current web standards (http://webstandards.org/learn/faq/). RSS feeds are now available for any page that you can navigate to in the Bioinformatics Links Directory. The Bioinformatics Links Directory is an example of a community resource driven by researchers who invest considerable efforts ensuring that their research is freely accessible and in the public domain. Suggestions for additions, revisions or corrections to the Bioinformatics Links Directory are strongly encouraged. Please use the suggested URL link found at http://bioinformatics.ca/links_directory/add.php or email your suggestions directly to links@bioinformatics.ca.

Many scientists are now recognizing the value of harnessing the power of the web for conducting world-class research. To this end, many of the new features that we have incorporated into the 2007 update of the Bioinformatics Links Directory were driven by Web 2.0 concepts (O'Reilly, T. 2005. What is Web 2.0: Design Patterns and Business Models for the next generation of software. http://www.oreillynet.com/pub/a/oreilly/tim/news/2005/09/30/what-is-web-20.html). Scientists already embrace many of these Web 2.0 concepts, such as the value of very large data sets and open exchange of software, ideas and publications. There are also a number of research servers that provide APIs for programmatic access to their resources (5). However, there are some Web 2.0 concepts that could help to increase the value of the online resources coming from scientific groups. For example, an improved focus on users and usability of servers is needed. In addition, very few of the Web Servers listed here are compliant with current web standards, such as XHTML accessibility and CSS-based design (http://webstandards.org/learn/faq/). Increased use of emerging web technologies such as RSS feeds, APIs and wikis that encourage easy data exchange, aggregation, and participation would also be an advantage. The research groups who design, develop and host servers for the scientific community who also stay at the forefront of web technologies will be at a distinct advantage. These concepts will bring users to your tools, and make your servers accessible to non-experts. Recognizing your community of users as a valuable resource will help aid the development of your server and push the boundaries of your own research. This two way interaction mediated through the web represents a new collaborative atmosphere in which we should all want to conduct science.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the efforts of *Nucleic Acids Research* and the researchers and developers worldwide who invest considerable efforts ensuring that their research is freely accessible to all. The Bioinformatics Links Directory is a community resource built on this commitment to the spirit of open access. In particular, the authors would like to recognize all contributors listed on the Acknowledgements page of the Bioinformatics Links Directory, http://bioinformatics.ca/links_directory/acknowledgments.php, for their valuable input and suggestions for improvements to the Bioinformatics Links Directory. The Open Access publication charge for this paper has been waived by Oxford University Press in recognition of the work on behalf of the journal.

Conflict of interest statement. None declared.

REFERENCES

1. Fox,J.A., McMillan,S. and Ouellette,B.F. (2006) A compilation of molecular biology web servers: 2006 update on the Bioinformatics Links Directory. *Nucleic Acids Res.*, **34**, W3–W5.
2. Fox,J.A., Butland,S.L., McMillan,S., Campbell,G. and Ouellette,B.F. (2005) The Bioinformatics Links Directory: a compilation of molecular biology web servers. *Nucleic Acids Res.*, **33**, W3–W24.
3. Galperin,M.Y. (2007) The Molecular Biology Database Collection: 2007 update. *Nucleic Acids Res.*, **35**, D3–D4.
4. Wheeler,D.L., Barret,T., Benson,D.A., Bryant,S.H., Canese,K., Chetvernin,V., Church,D.M., DiCuccio,M., Edgar,R. *et al.* (2007) Database resources of the National Center for Biotechnology Information. *Nucleic Acids Res.*, **35**, D5–D12.
5. Labarga,A., Valentin,F., Anderson,M. and Lopez,R. (2007) Web Services at the European Bioinformatics Institute. *Nucleic Acids Res.*, **35**, (in press).