The NIH 3D Print Exchange: A Public Resource for Bioscientific and Biomedical 3D Prints

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Abstract

The National Institutes of Health (NIH) has launched the NIH 3D Print Exchange, an online portal for discovering and creating bioscientifically relevant 3D models suitable for 3D printing, to provide both researchers and educators with a trusted source to discover accurate and informative models. There are a number of online resources for 3D prints, but there is a paucity of scientific models, and the expertise required to generate and validate such models remains a barrier. The NIH 3D Print Exchange fills this gap by providing novel, web-based tools that empower users with the ability to create ready-to-print 3D files from molecular structure data, microscopy image stacks, and computed tomography scan data. The NIH 3D Print Exchange facilitates open data sharing in a community-driven environment, and also includes various interactive features, as well as information and tutorials on 3D modeling software. As the first government-sponsored website dedicated to 3D printing, the NIH 3D Print Exchange is an important step forward to bringing 3D printing to the mainstream for scientific research and education.

Introduction

The NIH 3D Print Exchange ("the Exchange") is an online portal from the National Institutes of Health (NIH) for discovering, creating, and sharing bioscientific 3D models that are ready to download and print in 3D (Figure 1). The Exchange provides a publicly accessible venue for a community of users to share their innovative 3D models with the global community, and to learn and discuss new ways to design and utilize bioscientific 3D prints.

The Exchange began a public "beta" at the USA Science and Engineering Festival, held in Washington, DC, on April 26–28, 2014. The official release was announced on June 18 in conjunction with the White House Maker Faire, where the Exchange was a featured exhibit. Within one month, over 11,000 unique visitors had viewed the site.

Addressing the Need for Bioscientific 3D Prints

Tangible models built by 3D printers are highly valuable in biomedical research and communication as well as education,[1–3] and 3D visualization and printing has facilitated scientific insights and changed the direction of biomedical research (Figure 2). In medicine, 3D prints are being used in surgical planning and in creating custom implants and

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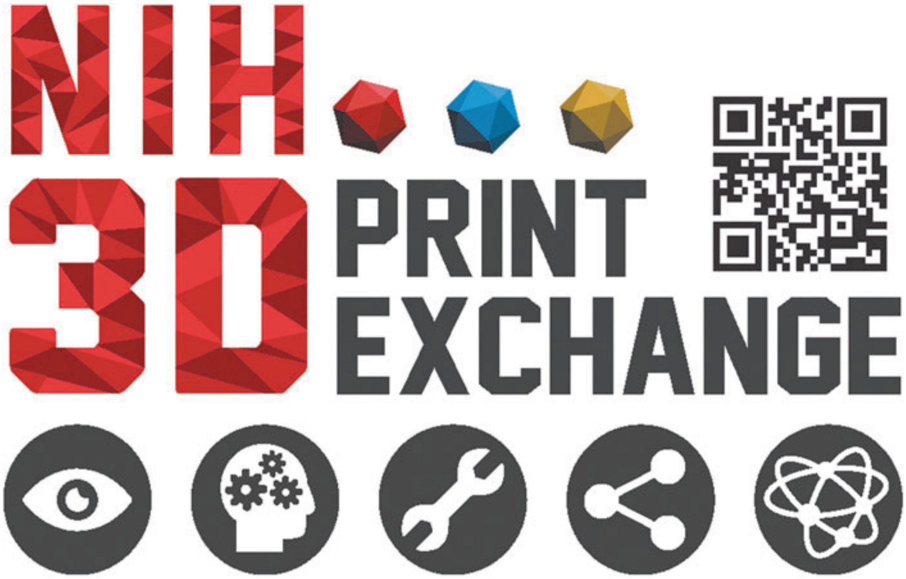

Figure 1. The NIH 3D Print Exchange is a virtual collection of bioscientific 3D models and tutorials for 3D printing, sponsored by the National Institutes of Health. Scan the QR code to visit the web site

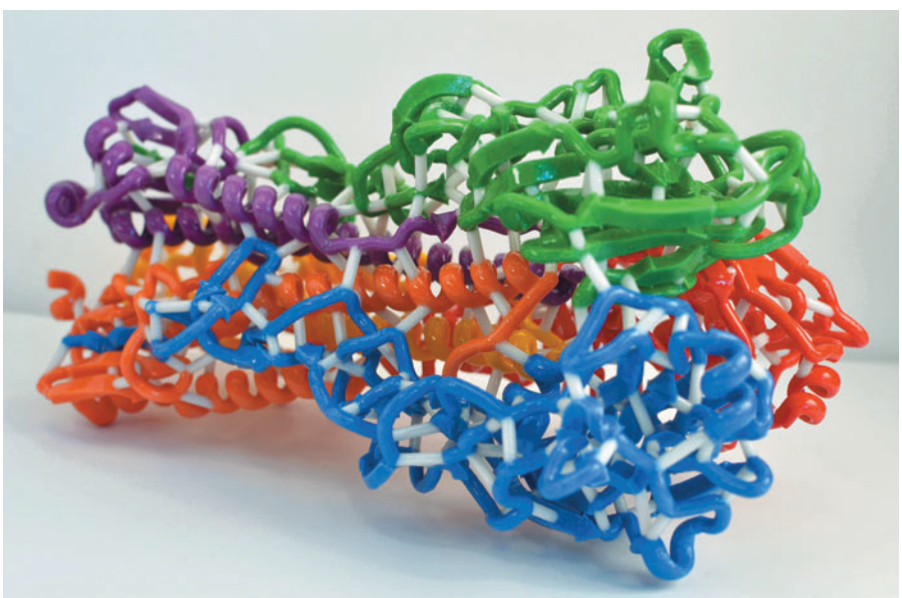

Figure 2. Physical representations of complex structures can provide valuable insights into otherwise unseen features. A 3D print of hemagglutinin (3DPX-000027), a receptor on the influenza virus, helped change the direction of research toward a universal flu vaccine (print by Darrell Hurt, photo by Jeremy Swan).

prosthetics.[4] Bioprinting and tissue fabrication methods are rapidly advancing, and the potential is vast.[5–7] At the NIH, 3D printing has saved hundreds of research animals and precious samples in some of the most advanced labs in the country; we estimate that tens of thousands of dollars in research funding have been saved by streamlining laboratory processes and avoiding downtime, as well as saving researchers' time and speeding the path to discovery.

Despite the fast-growing applications for 3D printing, it is not widely used in the biosciences at present. With the exception of well-trained modeling specialists and 3D printing enthusiasts, most researchers and lay people have little to no experience using the software required to create digital models. 3D printers are affordable and readily accessible, and hundreds of thousands of printable models can be found online. However, in an online sea of gadgets, toys, and accessories numbering into the thousands, there were few models relevant to scientific research, medical practice, or STEM (science, technology, engineering, and mathematics) education.

The Exchange thus fills an important, latent need: to provide scientifically accurate, high-quality 3D models in a ready-to-print format, bridging the knowledge gap between a novice user and the 3D modeling specialist. The site's novel, open source tools generate 3D printable models of molecular, microscopy, and medical imaging data through automated pipelines (Figure 3). What used to take hours for a skilled user is now possible in only minutes by even the most naïve user. By democratizing access to bioscientific 3D models on demand, the Exchange enables users of all levels to focus their time less on tedious tasks and more on research and discovery, while at the same time vastly increasing the number of 3D printable models available to the bioscientific research community.

Bringing Added Value

In addition to 3D models and free tools, the Exchange brings added value by providing video tutorials for 3D modeling software, with a focus on converting medical and scientific data. These are intended to empower users with the skills to customize their own models, beyond the basic offerings in the automated pipelines. The site also hosts a discussion forum to cultivate a community of users and to facilitate idea sharing and collaboration among them.

The Exchange provides both researchers and educators with a trusted source to discover accurate and informative models. Because models can be generated from data derived directly from scientific databases (the Protein Data Bank[8] and the Electron Microscopy Data Bank[9]), users can expect a higher level of confidence in scientific accuracy. All models are given a unique ID number (e.g., 3DPX-123456),

MARY ANN LIEBERT, INC. • VOL. 1 NO. 3 • 2014 • DOI: 10.1089/3dp.2014.1503

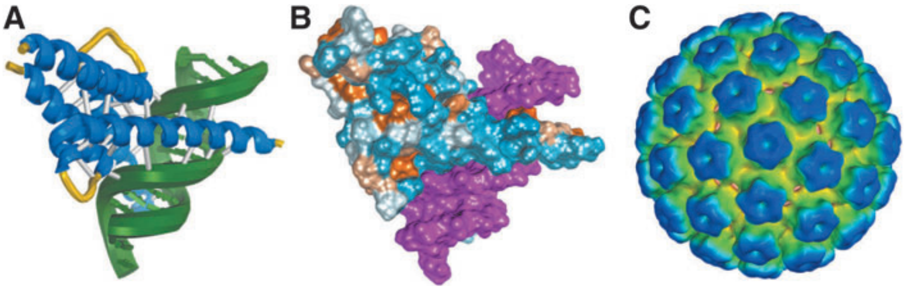

Figure 3. Novel web-based tools generate STL and VRML files, each with a corresponding PNG image and X3D version. Molecular structures are output in seven variants; examples from entry 3DPX-000479 show **(A)** ribbon secondary structure and **(B)** hydrophobic surface of a protein in complex with DNA **(A,** green; **B,** pink**)**.[10] Isosurfaces derived from microscopy data and image stacks are rendered in monochrome and with radial coloring, **(C)** the latter shown for Human Papilloma Virus (EMDB-5839),[11] 3DPX-000406.

so they can be cited in scientific publications and referenced across the web and in social media.

Moving Forward

Next steps for the Exchange are to optimize the automated tools that convert scientific and medical data to ready-to-print stereolithography (STL) and virtual reality modeling language (VRML) file formats, as well as extensible 3D graphics (X3D) files that are utilized in the in-browser X3DOM[12] viewer (Figure 4). Improvements to these pipelines will focus on increasing model quality, improving data compression to facilitate faster downloads, and accommodating more data types, such as magnetic resonance imaging (MRI) or positron emission tomography (PET) scans for medical images. Because open source development and the principles of open data are part of the overarching mission of the Exchange, the code to these tools will be placed in the public domain, and web services will be implemented.

Figure 4. A screenshot of the X3DOM viewer. An X3D was autogenerated from an STL (3DPX-000404) uploaded by Dr. Bruno B. Gobbato (username *bgobbato*), shoulder and elbow specialist, Instituto de Ortopedia e Traumatologia de Jaraguá do Sul, SC, Brazil. Model based on computed tomography scan data of the lower cranium and cervical vertebrae.

The Exchange is built on Drupal, an open source content management system facilitating free and easy transfer of the site framework to other federal agencies. In this way, the Exchange supports the government movement to make scientific collections, including digital 3D data, freely available to the public.[11] The system could be adopted to enable other exchanges, for example, 3Dprint.*agency*.gov or 3Dprint.*university*.edu.

The community-driven aspect of the Exchange is critical to its success, and we invite users to share models related to medicine and biosciences. To that end, we are continuing to enhance the user interface and user experience, primarily through feedback from the ever-growing user community. We will also be implementing specially curated “collections” and encouraging the use of 3D prints in science education by soliciting users to upload their own supplemental materials to be used in the classroom alongside 3D-printed models.

Conclusions

3D printing technology is advancing rapidly, with the expectation that within the next decade, 3D-printed human tissues and organs will regularly be used in medical treatment.[13] The Exchange is thus a well-positioned resource for supporting this significant medical development, and puts the NIH and the U.S. Department of Health and Human Services ahead of this emerging technology, which aligns with their interests to promote research leading to new and improved treatments for patient care. Furthermore, the Exchange supports government initiatives in the Maker Movement and STEM education.[14] Ultimately, we hope that the NIH 3D Print Exchange will help to bolster the use of 3D printing in medical and bioscientific research, education, and communication.

Acknowledgments

The Exchange is owned and operated by the National Institute of Allergy and Infectious Diseases under guidance from Mr. Mike Tartakovsky, chief information officer. The Exchange is funded in part by HHS Ignite and HHS Ventures, initiatives sponsored by the HHS IDEA Lab of the Office of Technology, U.S. Department of Health and Human Services. The Exchange gratefully acknowledges the time and feedback from members of our Advisory Team. Special recognition goes to Tom Ferrin, PhD, and the Chimera Team at the University of California San Francisco for help in optimizing 3D modeling workflows, and Nicholas Polys, PhD, Virginia Tech, for X3D and WebGL development support. For valuable feedback and special contributions, we also thank the NIH Library Office of Research Services, Eric Jones and Sam Michael of the National Center for Advancing Translational Sciences, the White House Office of Science and Technology Policy, and Jordan Miller, PhD, Rice University.

Author Disclosure Statement

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