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Database issue

Generic Diagramming Platform (GDP): a comprehensive database of high-quality biomedical graphics

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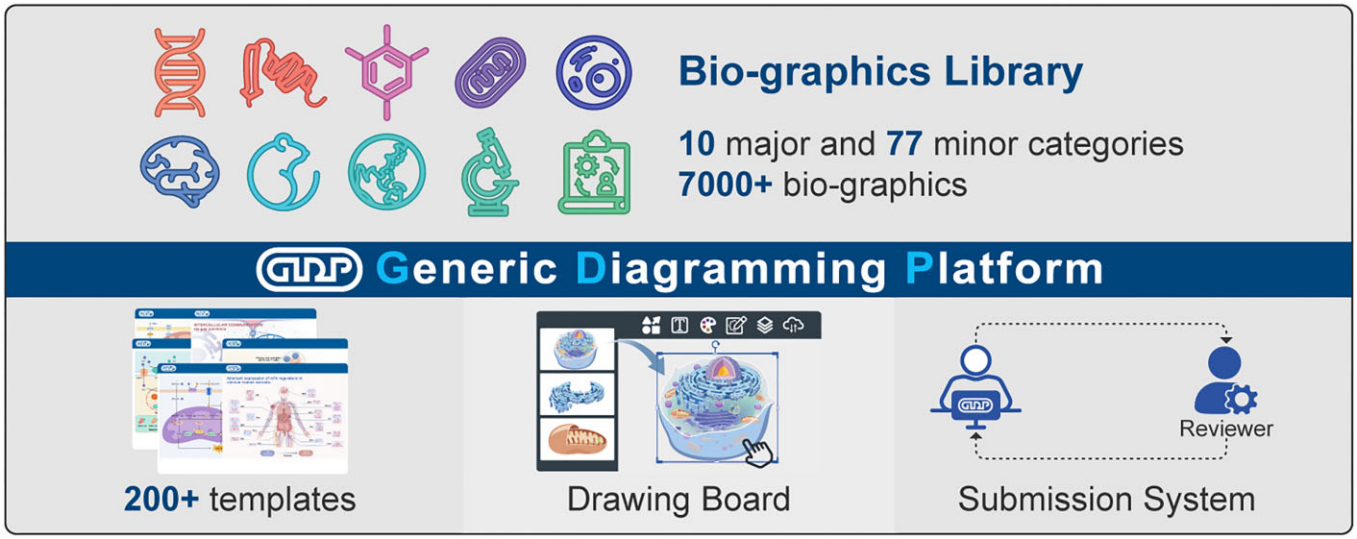
Abstract

High-quality schematic illustrations are fundamental to the publication of scientific achievements in biomedical research, which are crucial for effectively conveying complex biomedical concepts. However, creating such illustrations remains challenging for many researchers due to the need to devote a significant amount of time and effort to accomplish it. To address this need, we present the Generic Diagramming Platform (GDP, https://BioGDP.com), a comprehensive database of professionally crafted biomedical graphics (bio-graphics). Currently, GDP houses 7 562 high-quality bio-graphics, meticulously categorized into 10 major and 77 minor categories. To increase the design efficiency, GDP provides 204 customizable templates derived from an extensive review of over 2000 literature and 7 textbooks. With the interactive drawing platform and user-friendly web interface implemented in GDP, these resources can facilitate the efficient generation of publication-ready illustrations for the biomedical community. Additionally, GDP incorporates a collaborative submission system, allowing researchers to contribute their artwork, fostering a growing diagramming ecosystem, and ensuring continuous database expansion. Overall, we believe that GDP will serve as an invaluable platform, significantly enhancing the efficiency and quality of scientific illustration for biomedical researchers.

Graphical abstract



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Introduction

High-quality schematic illustrations play a crucial role in biomedical research, serving as essential tools for conveying complex scientific concepts across various platforms, including academic papers, posters and conferences. These well-structured illustrations offer a great advantage over textual descriptions alone, providing a more intuitive and concise means of conveying novel discoveries and facilitating more effective scientific knowledge exchange. However, drawing high-quality biomedical illustrations presents a significant challenge for many researchers. These illustrations often require various bio-graphics, such as schematic diagrams of proteins, organelles, cells, and model organisms. Manually drawing these components is time-consuming and laborious, particularly for researchers lacking artistic skills. These limitations highlight the need for a more efficient and standardized approach to bio-graphics production and curation.

In recent years, several tools have been developed to meet this demand. BioRender (https://www.biorender.com) is one of the most widely used tools in the scientific community, which offers a comprehensive library of pre-made illustrations and an intuitive drag-and-drop interface. However, BioRender is a purely commercial tool and its subscription-based model can be cost-prohibitive for many academic users and research labs. Another notable resource is PhyloPic (http://phylopic.org), which provides a database of silhouette images of various species. While PhyloPic is an excellent resource for taxonomic illustrations, its scope is limited to black-and-white silhouettes and does not cover the broader range of biomedical graphics needed in many research contexts.

Despite these existing resources, there remains a significant gap in the availability of comprehensive, high-quality and freely accessible bio-graphics for academic purposes. To better understand this need, we conducted an extensive literature survey of over 1000 published articles to analyze the bio-graphics commonly used in biomedical illustrations. Our findings revealed that these components could be categorized into 10 major classes with several subclasses. This classification suggested a potential for standardization and reusability, opening up possibilities for more efficient diagram creation.

We have previously developed several widely adopted tools for biological sequence visualization, including the Domain Graph (DOG) for protein domain visualization (1), the Illustrator for Biological Sequences (IBS) (2) and its upgraded version, IBS 2.0 (3). These tools have demonstrated significant utility in generating graphical representations of protein and nucleic acid sequences, gaining widespread adoption within the scientific community. However, these tools require users to create each element from scratch rather than provide a comprehensive library of pre-existing, reusable components. Therefore, developing a database housing a wide range of high-quality, editable bio-graphics is urgently needed.

In this study, we present the Generic Diagramming Platform (GDP, https://BioGDP.com), a comprehensive database of high-quality biomedical graphics (Figure 1). GDP encompasses an ever-increasing, well-categorized, and vast bio-graphics library, housing over 7000 high-quality bio-graphics meticulously crafted by professional artists. By investigating over 2000 current publications and classic textbooks, we have collected and re-illustrated 204 illustrations, allowing researchers to generate their schematic diagrams efficiently based on these templates. In addition, GDP provides a user-friendly interface enabling the efficient creation of publication-ready illustrations. To establish a robust diagramming ecosystem, GDP has implemented a collaborative submission system that allows researchers to contribute their artworks. By integrating these advanced features, we expect GDP to be an invaluable resource for researchers, enhancing the efficiency and quality of scientific illustration in biomedical research.

Materials and methods

Data sources

All bio-graphics in GDP are entirely original creations with completely copyright ownership. These graphics are meticulously crafted to maintain a consistent style across all images while ensuring both accuracy and clarity. The creation process begins with a comprehensive review of real-world images, classic textbook illustrations, and figures from scientific literature. Following this review, professional artists of our team, under the guidance of biomedical experts, designs and illustrates each graphic from scratch. The classic textbooks referenced include *Molecular Cell Biology* (4), *Molecular Biology of the Cell* (5), *Lewin's Genes XII* (6), *Prescott's Microbiology* (7), *Sherris Medical Microbiology* (8), *Biochemistry* (9) and *Neuroscience* (10). Besides, the literature figures referenced from high-impact scientific journals, such as *Nature*, *Cell*, *Nature Plants*, *Molecular Cell*, *Signal Transduction and Targeted Therapy* etc., were also included.

The templates available in GDP were created by referencing illustrations from these authoritative sources (Supplementary Table S1), followed by careful and manual re-illustrating using the elements within the bio-graphics library. These templates originate from two primary sources (Supplementary Figure S1C). On the one hand, professional artists of our team, guided by biomedical experts, creates templates by referencing illustrations from the aforementioned authoritative sources. On the other hand, we leverage community contributions. Users can create templates using GDP's bio-graphics and drawing tools, and then submit them to the platform. These user-submitted templates undergo rigorous review before inclusion in the public template library. This dual approach allows us to maintain a diverse, high-quality template collection while fostering community engagement and continuous expansion of our resources.

Upload and download

Users can upload local resources to the GDP platform and download high-resolution finalized images in multiple formats. The platform utilizes HTTPS for secure data transfer, distributed storage, and backup to ensure data integrity and security during transmission and storage. Advanced authentication mechanisms restrict image access and retrieval only to authorized users, robustly preventing unauthorized access and protecting user data privacy and security.

Interactive drawing

By integrating pixi.js v7.2.4 (https://pixijs.com), GDP delivers an interactive drawing feature. Within this platform, GDP enhances user interaction with graphical elements via mouse clicks, dragging, rotation and scaling, ensuring a smooth and real-time responsive drawing experience. Furthermore, lever-

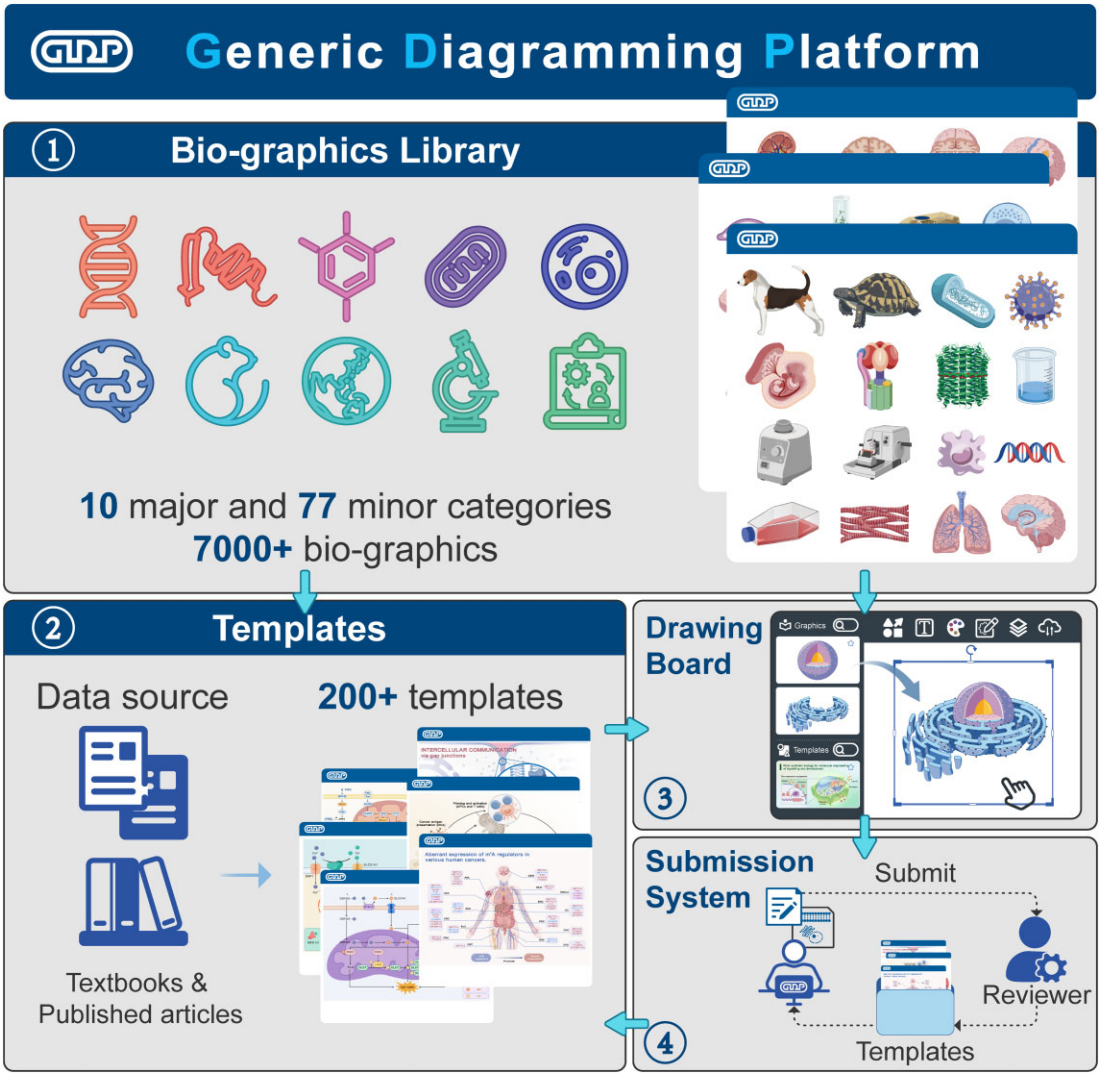

Figure 1. Overall design and construction of GDP. GDP consists of four main parts: (1) A comprehensive bio-graphics library containing over 7000 high-quality biomedical images crafted by professional artists, forming the foundation of GDP. (2) A template library featuring more than 200 classic illustrations derived from extensive literature review. (3) An integrated online drawing module that allows users to create publication-ready illustrations using these bio-graphics and pre-designed templates. (4) A submission system that enables users to contribute their artworks to GDP's public template library, fostering a collaborative diagramming ecosystem.

aging the capabilities of WebGL rendering technology, GDP enables the efficient and flexible rendering of complex diagrams directly within the web browser's canvas element.

Web interface implementation

All metadata and original bio-graphics in GDP were stored and managed in MySQL tables and the Alibaba Cloud Object Storage Service, respectively. The server-backend development was based on Java, and the web-frontend interfaces were implemented in Hyper Text Markup Language (HTML), Cascading Style Sheets (CSS) and JavaScript (JS).

Results

Bio-graphics library

The bio-graphics library of GDP serves as a foundational feature, offering researchers a diverse array of high-quality, prefabricated biomedical imagery. Housing 7562 bio-graphics meticulously crafted by professional artists, the library spans multiple dimensions of biomedical research, from the microscopic to the macroscopic, including nucleic acids, proteins, subcellular structures, tissues and organs, species and ecosystems. These bio-graphics are not only aesthetically professional but also proprietary, ensuring legal and unique usage for academic publication and result demonstration. GDP categorizes these resources into 10 major and 77 minor categories based on biological significance and application context (Figure 2A and Supplementary Figure S2), providing an intuitive and efficient means for researchers to effortlessly locate and utilize the necessary imagery, thereby significantly enhancing the efficiency and quality of scientific illustration.

Templates

In addition to its extensive bio-graphics library, GDP offers a curated collection of 204 high-quality templates (Figure 2B), meticulously selected and professionally enhanced from textbooks and published scholarly papers. The template library encompasses a wide range of biomedical re-

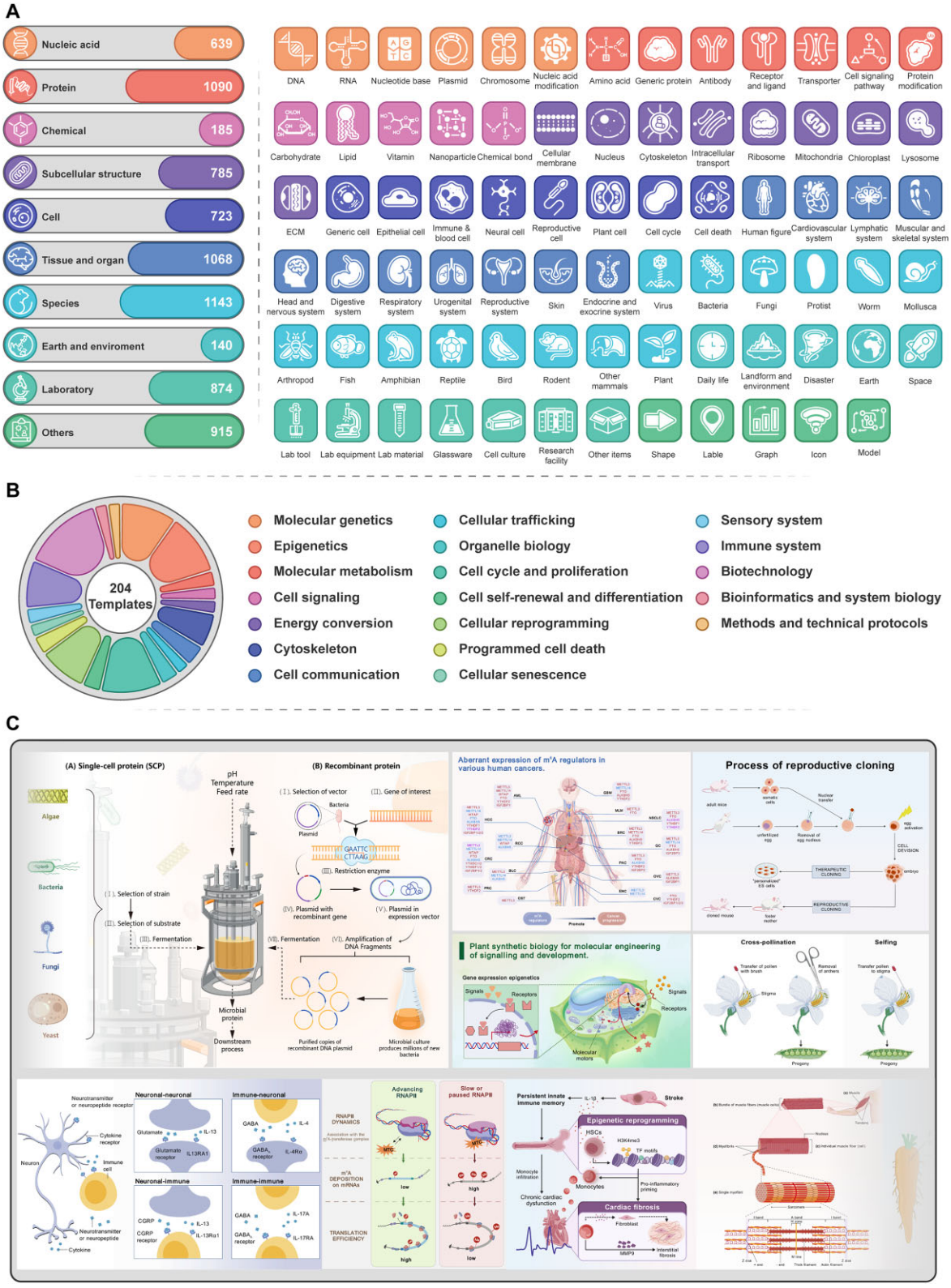

Figure 2. Classification and statistics of GDP's bio-graphics library and templates. (**A**) The bio-graphics library is categorized into 10 major and 77 minor categories. The bar chart (left) shows the number of bio-graphics in each major category, while the matrix (right) displays the subcategories within each major category. (**B**) The pie chart illustrates the distribution of templates across different categories. (**C**) Some representative examples of the template library.

search fields, including molecular genetics, epigenetics, molecular metabolism, cell signaling, and energy conversion. As shown in Figure 2C, we present a selection of classic illustrations redrawn using GDP, demonstrating the platform's capability to reproduce and enhance complex biomedical concepts across these diverse fields. These templates are not only ready for direct use but also customizable for redrawing and modification, catering to the specific and personalized research needs of scientists. Consequently, GDP provides a potent resource that enables researchers to efficiently create professional and research-specific biomedical illustrations with minimal time and effort investment.

Community engagement

Since its public beta launch in October 2023, GDP has experienced significant growth and adoption within the biomedical research community. As of 31 August 2024, GDP has attracted 31 795 users from 45 countries (Supplementary Figure S1A), with continued rapid growth. These users have collectively created 36 820 illustrations using the platform (Supplementary Figure S1B). Additionally, 26.96% of the templates available in GDP originate from user contributions (Supplementary Figure S1C).

Web interface and usage

GDP provides a user-friendly web interface that facilitates the efficient creation of research illustrations through easy browsing, searching and interaction with bio-graphics and templates in the database (Figure 3).

Drawing Board, the primary interface of GDP, features a well-organized bio-graphics library on the left side (Figure 3A). Users can explore bio-graphics of interest by category or keywords, and then drag selected items onto the canvas. Meanwhile, GDP offers a comprehensive set of editing tools, including options to move, resize, rotate, and adjust colors. For precise editing, various fine-tuning methods are available, such as numerical adjustments, color palettes, and direct color code input. Notably, an advanced feature of GDP is the personal 'My library', where users can save any edited elements from the canvas. This function facilitates efficient editing and reuse of previously refined graphics. Additionally, users can upload local image resources to their private library, enabling the creation of highly customized illustrations. Upon completion, GDP supports the export of publication-quality, high-resolution images (300 DPI PNG/JPG/TIFF/PDF) along with publication permission license for scholarly publication purposes.

Workspace, serving as a management hub for users' illustrations and personal private library (Figure 3B). Implementing a tree-like folder management platform similar to computer file structures, allows users to categorize and manage their drawings and private image resources based on research topics. Users can easily rename, move, and copy items within this system. Furthermore, the 'Workspace' page integrates a submission system, encouraging users to contribute their completed illustrations to GDP. All user-submitted illustrations undergo strict review by biomedical experts. Approved submissions are incorporated into GDP's public template library, becoming available for all users to view and edit. This collaborative approach aims to build a growing diagramming ecosystem that benefits a wide range of researchers.

Templates, users can explore a wide range of public, predesigned, reusable diagrams on this page (Figure 3C). Details of each template include title, keywords, detailed description, reference, and acknowledged contributors. By clicking the 'Use template' button on any template card, users are seamlessly directed to the 'Drawing Board' page, followed by modifying and customizing the selected illustration to suit their specific needs.

Detailed guidance on GDP usage is available on the 'Help' page.

Example of GDP

To showcase GDP's comprehensive capabilities and reliable visualization for biological schematic diagrams, we re-illustrated the classic animal cloning process using GDP, as shown in Figure 3A. Dolly was the first cloned sheep, brought into existence through the somatic cell nuclear transfer (SCNT) technique (11). The key steps involved extracting a somatic cell nucleus from an adult sheep and transferring this nucleus into an enucleated ovine egg cell to form a reconstituted embryo, which was then implanted into a surrogate mother's uterus for gestation (11,12). The SCNT process enabled the creation of a genetic clone by transferring the genetic material from a somatic cell into an enucleated egg, which developed into an offspring with an identical nuclear genome as the somatic cell donor (13–16).

Utilizing GDP's comprehensive bio-graphics library and user-friendly drawing tools, the complex process of cloning Dolly the Sheep can be rendered into a concise, clear, and visually appealing illustration. The platform's diverse graphical elements effectively depict the sequential cloning stages, from cell culture and fusion to embryonic development. The line insertion functionality in GDP facilitates a systematic representation of the experimental sequence through strategically positioned guiding lines. In addition, precise textual annotations elucidate each procedural step.

This example demonstrates how GDP can be utilized to create professional-quality scientific illustrations, making complex biological processes more accessible and understandable to a broad scientific audience.

Discussion

GDP mitigates the technical and time constraints faced by biomedical researchers in producing high-quality illustrations, enhancing the dissemination of scientific knowledge. By simplifying access to professional bio-graphics and templates, GDP empowers researchers without design expertise to create publication-standard illustrations, thus expediting scientific communication.

Compared to existing tools, GDP offers distinct advantages. Unlike BioRender's subscription-based model or PhyloPic's limited scope, GDP is dedicated to establishing an open biomedical diagramming ecosystem. It provides free access for most academic users, offering a comprehensive collection of colorful bio-graphics across various biomedical fields, paired with an integrated drawing platform. This collaborative community environment encourages researchers to create and share high-quality illustrations to enhance scientific communication.

Crucially, GDP fosters interdisciplinary collaboration in biomedical research, where accurate and accessible visual rep-

Figure 3. Basic functions of GDP web interface. (**A**) The Drawing Board interface of GDP is composed of five key modules: (1) the bio-graphics library panel on the left, allowing users to explore and select graphical elements; (2) the interactive canvas where users can draw illustrations, demonstrated by an example of the cloned sheep Dolly; (3) the component list panel showing all elements on the canvas with their layers; (4) a toolbox that contains buttons for common drawing functions, such as undo, redo, insert, crop, group, ungroup, align and zoom; (5) preview, save and export buttons. (**B**) The Workspace page, serving as the user management center, includes My illustrations, My library, and My submission sections. (**C**) The Templates interface of GDP.

resentations are paramount. It facilitates the articulation of complex scientific concepts, fostering cross-disciplinary understanding and cooperation.

In response to escalating global research competition and rapid technological advancements, GDP must continually innovate and improve its services. This entails ongoingly refining the platform's functions, optimizing user experience, and offering personalized, user-centric solutions. Expanding its resource libraries to cater to global research demands further underscores the necessity for GDP to enhance international collaboration.

In conclusion, GDP, as an innovative biomedical illustration tool, not only increases research efficiency but also promotes global scientific collaboration and communication. To sustain its competitive edge and impact, GDP must evolve in alignment with the shifting research landscape, addressing the global scientific community's emerging needs and challenges.

Data availability

GDP is a comprehensive online database available at https://BioGDP.com.

Supplementary data

Supplementary Data are available at NAR Online.

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Conflict of interest statement

None declared.

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