



## Perspective/Opinion

# Reactome and ORCID—fine-grained credit attribution for community curation

Guilherme Viteri<sup>1</sup>, Lisa Matthews<sup>2</sup>, Thawfeek Varusai<sup>1</sup>, Marc Gillespie<sup>3,4</sup>, Marija Milacic<sup>3</sup>, Justin Cook<sup>3</sup>, Joel Weiser<sup>3</sup>, Solomon Shorser<sup>3</sup>, Konstantinos Sidiropoulos<sup>1</sup>, Antonio Fabregat<sup>1</sup>, Robin Haw<sup>3</sup>, Guanming Wu<sup>5</sup>, Lincoln Stein<sup>3</sup>, Peter D'Eustachio<sup>2</sup> and Henning Hermjakob<sup>1,6,\*</sup>

<sup>1</sup>European Molecular Biology Laboratory, European Bioinformatics Institute (EMBL-EBI), Wellcome Trust Genome Campus, Hinxton, Cambridgeshire CB10 1SD, UK, <sup>2</sup>Department of Biochemistry, NYU School of Medicine, New York, NY 10016, USA, <sup>3</sup>Ontario Institute for Cancer Research, Toronto, ON, M5G 0A3, Canada, <sup>4</sup>College of Pharmacy and Health Sciences, St. John's University, Queens, NY 11439, USA, <sup>5</sup>Oregon Health and Science University, Portland, OR 97239, USA and <sup>6</sup>State Key Laboratory of Proteomics, Beijing Proteome Research Center, Beijing Institute of Lifeomics, National Center for Protein Sciences (The PHOENIX Center, Beijing), 102206, Beijing, China.

\*Corresponding author: Tel: +44 1223 494671; Fax: +44 1223 494468; Email: hhe@ebi.ac.uk

Citation details: Viteri,G., Matthews,L., Varusai,T. *et al.* Reactome and ORCID—fine-grained credit attribution for community curation. *Database* (2019) Vol. 2019: article ID baz123; doi:10.1093/database/baz123

Received ; Revised 10 September 2019; Accepted 17 September 2019

## Abstract

Reactome is a manually curated, open-source, open-data knowledge base of biomolecular pathways. Reactome has always provided clear credit attribution for authors, curators and reviewers through fine-grained annotation of all three roles at the reaction and pathway level. These data are visible in the web interface and provided through the various data download formats. To enhance visibility and credit attribution for the work of authors, curators and reviewers, and to provide additional opportunities for Reactome community engagement, we have implemented key changes to Reactome: contributor names are now fully searchable in the web interface, and contributors can 'claim' their contributions to their ORCID profile with a few clicks. In addition, we are reaching out to domain experts to request their help in reviewing and editing Reactome pathways through a new 'Contribution' section, highlighting pathways which are awaiting community review.

Database URL: <https://reactome.org>

## Introduction

Reactome is a manually curated, open-source, open-data knowledge base of biomolecular pathways (1,2). The cen-

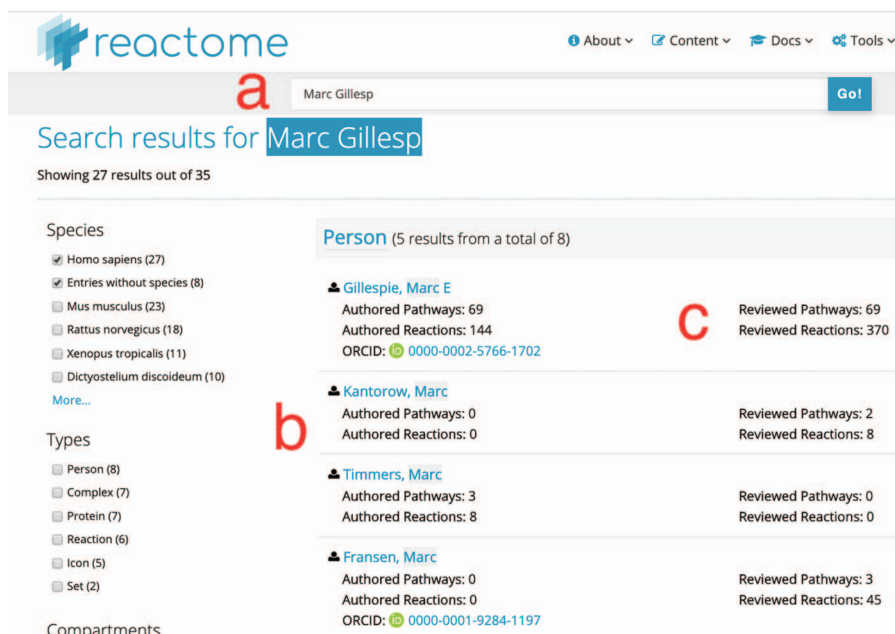
tral element of Reactome is a biochemical reaction, with multiple reaction types, for example classical enzymatic reactions, translocations, complex formation and protein

© The Author(s) 2019. Published by Oxford University Press.

This is an Open Access article distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/4.0/>), which permits unrestricted reuse, distribution, and reproduction in any medium, provided the original work is properly cited.

Page 1 of 5

(page number not for citation purposes)



**Figure 1.** Search results for partial author name ‘Marc Gillesp’. Direct access URL <https://reactome.org/content/query?q=Marc+Gillesp&species=Homo+sapiens&species=Entries+without+species&cluster=true>, accessed 2019/08/15. Within the figure, label ‘a’ marks the mis-spelt contributor name, label ‘b’ marks the list of other contributor names matching the search terms and label ‘c’ marks the fine-grained ‘contribution matrix’, distinguishing between pathways and reactions in one dimension and authoring/reviewing in the other dimension.

modifications. Reactions are linked by shared molecular entities into pathways, which in turn are grouped into a pathway hierarchy that is co-ordinated with the ‘Biological Process’ branch of the Gene Ontology (3).

The Reactome curation process is similar to the writing of a pathway review for a scientific journal. Typically, we recruit an external domain expert for the target pathway, the pathway author. This expert collaborates with the professional Reactome curator in creating a representation of the pathway in the Reactome database, potentially in several iterations. While this work often starts from reviews, as a key requirement, we trace back and link assertions to the underlying primary literature. In cases where published information needed to annotate a reaction fully is not available, the resulting event is clearly marked as a ‘Black box’ reaction. The resulting pathway representation is then reviewed internally by a senior curator. Next, we recruit a second external domain expert, from a different group, as a reviewer, who provides major or minor comments and corrections, triggering an update of the pathway representation. Once all three key people (author, curator, and reviewer (contributors)) are satisfied, the pathway is released in the next Reactome quarterly release. While this process is slow and labour-intensive, it assures a high quality of Reactome content.

A Reactome curator can assume the role of the expert author or reviewer, typically when they have worked in the target domain previously. However, the recruitment of

authors and reviewers is currently the major bottleneck in the Reactome curation process: on average, we are contacting 10 domain experts for one actual contributor. This is not really surprising; domain experts are providing their expertise and time voluntarily, without payment. Sometimes, we achieve a scientific publication with the authors/reviewers as co-authors (4), but often this is not possible. Then, the only recognition of their work is credit attribution through the Reactome records they have authored or reviewed. Even for professional (paid) curators, their scientific contribution is mainly visible through Reactome records, their productivity in terms of scientific publications is typically only visible in the Reactome consortium database publications like (1,5). Recognising this challenge, recently there are significant efforts to improve citability and scientific credit attribution for non-publication objects like datasets (6,7).

Reactome has always provided clear credit attribution for authors, curators and reviewers through fine-grained annotation of all three roles at the reaction and pathway levels. These data are visible in the web interface and provided through the various data download formats. Starting in 2008 and retroactively implemented for earlier releases, on author/reviewer request, we also provide DOIs (8) for pathways to make them citable in scientific publications or on contributor’s CVs and similar documents. However, DOIs are only created at the pathway level. In addition, Reactome is a dynamic knowledge base, and changing science or content reorganisations require relatively frequent changes of existing pathways, which is

reactome About Content Docs Tools Community Download

e.g. C95631, NTN1, signaling by EGFR, glucose **Go!**

**Marc E Gillespie** **Expand All**

ORCID <https://orcid.org/0000-0002-5766-1702> Are you Marc E Gillespie? Register or Connect your ORCID

Affiliation Cold Spring Harbor Laboratory, St. John's University, NYU School of Medicine, Department of Biochemistry

Authored Pathways (15/69)

Date	Identifier	Pathway	Reference
2019-05-10	R-HSA-168898	Toll-like Receptor Cascades	BibTex
2019-05-10	R-HSA-73886	Chromosome Maintenance	BibTex
2015-01-13	R-HSA-162906	HIV Infection	BibTex
2015-01-13	R-HSA-162587	HIV Life Cycle	BibTex
2014-03-03	R-HSA-5423599	Diseases of Mismatch Repair (MMR)	BibTex
2013-11-21	R-HSA-5205647	Mitophagy	BibTex
2013-11-21	R-HSA-8934903	Receptor Mediated Mitophagy	BibTex
2013-11-21	R-HSA-5205685	Pink/Parkin Mediated Mitophagy	BibTex
2013-11-18	R-HSA-168253	Host Interactions with Influenza Factors	BibTex
2013-11-18	R-HSA-168277	Influenza Virus Induced Apoptosis	BibTex
2013-11-18	R-HSA-168276	NS1 Mediated Effects on Host Pathways	BibTex
2013-11-18	R-HSA-169131	Inhibition of PKR	BibTex
2013-11-18	R-HSA-168315	Inhibition of Host mRNA Processing and RNA Silencing	BibTex
2013-11-18	R-HSA-168305	Inhibition of Interferon Synthesis	BibTex
2013-11-18	R-HSA-168888	Inhibition of IFN-beta	BibTex

Show all authored pathways...

Authored Reactions (15/144)

Date	Identifier	Reaction	Reference
2017-01-27	R-HSA-8959573	Phosphorylated FUNDC1 links damaged mitochondria to LC3	BibTex
2016-11-11	R-HSA-8948039	FUNDC1 is phosphorylated by CK2	BibTex
2016-11-02	R-HSA-8948146	FUNDC1 is phosphorylated by ULK1 at Ser17	BibTex
2016-11-02	R-HSA-8948143	p-S13, FUNDC1 is phosphorylated by CK2 at Tyr18	BibTex
2016-11-02	R-HSA-8948139	p-S13-FUNDC1 is dephosphorylated by PGAM5	BibTex
2016-11-02	R-HSA-8948136	ULK1 Translocates to the mitochondria	BibTex
2014-05-30	R-HSA-5632970	MSH6 variant:MSH2-defective DNA mismatch repair	BibTex
2014-05-30	R-HSA-5578663	MSH3 variant:MSH2-defective DNA mismatch repair	BibTex
2014-05-24	R-HSA-5577259	MSH2 variant:MSH3-defective DNA mismatch repair	BibTex

**Figure 2.** Detailed list of contributions for 'Marc E Gillespie'. Unique identifiers in the 'Identifier' column directly link to the relevant pathway/reaction. BibTex records can be downloaded for each data object if desired. After ORCID authentication at the top of the page, all contributions can be claimed to the contributor's ORCID record with a single click, or individual data object can be claimed for finer granularity.

not fully compatible with the DOI concept of immutability for objects referenced by a DOI.

## Results

To enhance visibility and credit attribution for the work of authors, curators and reviewers, and to provide additional opportunities for Reactome community engagement, we have implemented three key changes to the Reactome web interface:

(i) Searchability: contributor names are now fully searchable in the standard Reactome web interface, with the same advanced features as other data objects, including auto-completion and approximate search. As illustrated in Figure 1, label a, the search for a unique name returns a result, even if the name is incomplete, here 'Marc Gillesp' instead of 'Marc Gillespie'. In case of multiple matching

contributors, all are listed and presented as part of the faceted search results as a separate facet, similar to other data objects (Figure 1, label b). This search functionality is distinct from the search for authors of publications cited by Reactome. If a user searches for the name of an author of a publication cited in Reactome, the web interface will return the data objects, for example pathways, which cite the publication(s) of the author. In contrast, contributor names are explicitly listed as separate data objects. For each contributor, their contribution is listed in a fine-grained matrix, distinguishing between pathways and reactions as well as between author and reviewer roles (Figure 1, label c). Clicking on the contributor name returns a new page with a detailed view of the work attributed to the Reactome contributor (Figure 2). Importantly, if the contributor has provided their ORCID identifier, the identifier is clearly shown as part of the record and linked to their ORCID

reactome

About Content Docs Tools Community Download

e.g. O95631, NTN1, signaling by EGFR, glucose Go!

Icon Library

Outreach

Events

Training

Publications

Partners

Papers Citing Us

Resources Guide

Collaboration

### External Contribution

Become a Reactome contributor! You will be credited with authorship or reviewership for all of your contributions. Each pathway is associated with a DOI and can be cited as a publication. You can quickly and easily claim your Reactome contributions in ORCID using our new ORCID claiming feature when you search for your name in Reactome.

We are currently seeking reviewers for the following pathways. If you'd like to contribute a pathway that is not on this list, please contact us. We would be happy to work with you!

Pathway name and link to website	Topic	Contact Reactome about this pathway	Link to editable text document
<a href="#">ERCC6 (CSB) and EHM2 (G9a) positively regulate rRNA expression</a>	Gene Expression	<a href="mailto:help@reactome.org">help@reactome.org</a>	<a href="https://docs.google.com/document">https://docs.google.com/document</a>
<a href="#">ERCC6 and KAT2B positively regulate rRNA expression</a>	Gene Expression	<a href="mailto:help@reactome.org">help@reactome.org</a>	<a href="https://docs.google.com/document">https://docs.google.com/document</a>
<a href="#">Regulation and Function of NBPF Genes</a>	Gene Expression	<a href="mailto:help@reactome.org">help@reactome.org</a>	<a href="https://docs.google.com/document">https://docs.google.com/document</a>
<a href="#">Transcriptional Regulation by VENTX</a>	Gene Expression	<a href="mailto:help@reactome.org">help@reactome.org</a>	<a href="https://docs.google.com/document">https://docs.google.com/document</a>
<a href="#">Interleukin-17 signaling</a>	Immune System	<a href="mailto:help@reactome.org">help@reactome.org</a>	<a href="https://docs.google.com/document">https://docs.google.com/document</a>
<a href="#">Interleukin-18</a>	Immune System	<a href="mailto:help@reactome.org">help@reactome.org</a>	<a href="https://docs.google.com/document">https://docs.google.com/document</a>
<a href="#">Interleukin-33</a>	Immune System	<a href="mailto:help@reactome.org">help@reactome.org</a>	<a href="https://docs.google.com/document">https://docs.google.com/document</a>
<a href="#">PI3P Regulates T-cell Receptor Signaling</a>	Immune System	<a href="mailto:help@reactome.org">help@reactome.org</a>	<a href="https://docs.google.com/document">https://docs.google.com/document</a>
<a href="#">ATF8 (ATF8-beta) activates chaperones</a>	Metabolism of Proteins	<a href="mailto:help@reactome.org">help@reactome.org</a>	<a href="https://docs.google.com/document">https://docs.google.com/document</a>
<a href="#">Protein hydroxylation</a>	Metabolism of Proteins	<a href="mailto:help@reactome.org">help@reactome.org</a>	<a href="https://docs.google.com/document">https://docs.google.com/document</a>
<a href="#">EGR2 and SOX10-mediated initiation of Schwann cell myelination</a>	Signal transduction	<a href="mailto:help@reactome.org">help@reactome.org</a>	<a href="https://docs.google.com/document">https://docs.google.com/document</a>

Ready\_for\_externalReview

**Figure 3.** Reactome ‘External Contribution’ page. Direct access URL <https://reactome.org/community/collaboration>, accessed 2019/08/15. This page lists pathways which have passed internal validation, and for which we are eager to find an external reviewer. The links in the leftmost column show the preliminary pathway in the Reactome ‘reviewer view’, which is slightly simpler than the final web view. The links in the rightmost column lead to text documents which can be copied for local editing. We would like to encourage any domain experts to contribute to the correct representation of ‘their’ pathways by contributing to these pending reviews.

profile. ORCID provides unique identifiers for scientists, allowing to disambiguate names and aggregate scientific contributions like publications and datasets to a central ORCID profile.

(ii) ORCID claiming: where the contributor has provided an ORCID identifier, the top of the detailed contribution page (Figure 2) shows a link that allows the contributor to validate themselves using the ORCID API. After validation, the details page provides additional buttons to claim, at a single click, all their Reactome contributions to their ORCID profile, or provide a more fine-grained selection of the Reactome contributions they would like to claim to their ORCID profile. In coordination with ORCID, the type of contribution for Reactome content is ‘data-set’. As of August 2019, 1473 Reactome pathways (64% of 2287 pathways in Reactome) and 6217 reactions (49% of 12 608 reactions in Reactome) have been claimed in ORCID. The lower claim rate for reactions is probably due to the fact that some large-scale contributors only claim pathways, to avoid filling their ORCID profile with many claims for individual reactions.

(iii) Community outreach for reviewer recruitment: By now, Reactome has reached a fairly good coverage of human pathway space. Although Reactome curation is as open-ended as research on human biology, we now typically add or update smaller pathway subsections, rather than entire new pathways. This exacerbates the problem

of recruiting reviewers, as we need relatively more reviewers to review relatively smaller entities. In an experiment to increase Reactome user engagement and contribution, we have added a specific ‘Collaboration’ section to the Reactome ‘Community’ web pages (Figure 3). Here, we list pathways which have passed the internal review, but still require an external review to be ready for release. We expect that this opportunity might encourage Reactome users to become contributors and hopefully will also develop into a forum for larger-scale community contributions and both suggestions of future pathway curation projects and offers of pathway authorship.

## Discussion

Community contribution is a major or minor component of most biomolecular database resources. Sometimes, it is seen as an approach to replace expensive manual curation, though this is unlikely to be practical. Even resources with a strong emphasis on community curation like WikiPathways (9) or Pfam (10) strongly rely on professional curators to ensure database consistency and to provide major parts of the contents. However, in our experience, community contribution is essential to ensuring the quality and coverage of a complex knowledge base like Reactome. Unfortunately, the voluntary contribution of domain experts, as well as the work of curators, is often not realised or appreciated



by the community. The strong community contribution to Reactome is, in our experience, not very well known, and yet Reactome critically depends on such contributions. Since 2002, 817 individuals have contributed to Reactome, but less than 30 of these are current or former paid curators, all the others are voluntary contributors whom we would like to strongly credit for their work. Reactome has always provided the names of content contributors at both reaction and pathway levels and since 2008 has provided DOIs for pathways.

ORCID offers scientists the possibility to claim a broad range of scientific outputs to their ORCID profile, and several data resources, for example Pfam and OmicsDI, now offer their users the possibility to claim annotations and datasets, respectively, to their ORCID profiles in a user-friendly manner (10,11). Here, we have presented a set of improvements to the Reactome web interface, including use of the ORCID API, to facilitate searching for an individual's contribution to Reactome content, as well as claiming such content to an individual's public ORCID profile, in an easy and fine-grained manner. With these measures, we aim to facilitate and improve credit attribution for Reactome content contributions. We also encourage more community contribution to Reactome content through a new section providing concrete requests from Reactome for external review.

In the context of the development of community standards for data citation (6), as well as nascent credit attribution and impact metrics for non-manuscript scientific output like datasets (12), we hope to contribute a small step towards a more multidimensional view of scientific productivity, where a scientist is more than their h-index.

### Author contributions

G.V., K.S. and A.F. developed the improvements to the Reactome web interface. T.V. and L.M. developed the Community Collaboration section. R.H., H.H., P.D. and L.S. conceived the project. P.D. coordinated the Reactome curation. R.H. and M.G. managed the Reactome DOI integration. H.H. coordinated this project and wrote the manuscript. All authors read and approved the manuscript.

### Acknowledgements

We appreciate the opportunity to have contributed to the ORCID Adoption and Integration Program, and received financial support, through ORCID, from the Alfred P. Sloan Foundation. The development of Reactome is supported by grants from the US National Institutes of Health (P41 HG003751 and 1U54GM114833-01), CFREF Medicine by Design and the European Molecular Biology Laboratory.

*Conflict of interest.* None declared.

### References

1. Fabregat,A., Jupe,S., Matthews,L. *et al.* (2018) The Reactome pathway knowledgebase. *Nucleic Acids Res.*, **46**, D649–D655.
2. Fabregat,A., Sidiropoulos,K., Viteri,G. *et al.* (2017) Reactome pathway analysis: a high-performance in-memory approach. *BMC Bioinformatics*, **18**, 142.
3. The Gene Ontology Consortium (2019) The gene ontology resource: 20 years and still GOing strong. *Nucleic Acids Res.*, **47**, D330–D338.
4. Jupe,S., Ray,K., Roca,C.D. *et al.* (2018) Interleukins and their signaling pathways in the Reactome biological pathway database. *J. Allergy Clin. Immunol.*, **141**, 1411–1416.
5. Fabregat,A., Sidiropoulos,K., Garapati,P. *et al.* (2016) The Reactome pathway knowledgebase. *Nucleic Acids Res.*, **44**, D481–D487.
6. Fenner,M., Crosas,M., Grethe,J.S. *et al.* (2019) A data citation roadmap for scholarly data repositories. *Sci Data*, **6**, 28.
7. Wimalaratne,S.M., Juty,N., Kunze,J. *et al.* (2018) Uniform resolution of compact identifiers for biomedical data. *Sci Data*, **5**, 180029.
8. Paskin,N. (2010) Digital Object Identifier (DOI®) System. In: *Encyclopedia of Library and Information Sciences*, Vol. 3, pp. 1586–1592
9. Slenter,D.N., Kutmon,M., Hanspers,K. *et al.* (2018) WikiPathways: a multifaceted pathway database bridging metabolomics to other omics research. *Nucleic Acids Res.*, **46**, D661–D667.
10. El-Gebali,S., Mistry,J., Bateman,A. *et al.* (2019) The Pfam protein families database in 2019. *Nucleic Acids Res.*, **47**, D427–D432.
11. Perez-Riverol,Y. *et al.* (2019) Quantifying the impact of public omics data. *Nat Commun.*, **10**, 3512.
12. Perez-Riverol,Y., Bai,M., da Veiga Leprevost,F. *et al.* (2017) Discovering and linking public omics data sets using the Omics Discovery Index. *Nat. Biotechnol.*, **35**, 406–409.