

# Annual Reviews: *A Nonprofit Scientific Publisher*

In this brief presentation,  
you will learn how to:

- 1) Navigate to content
- 2) Search effectively using *simple* and *advanced* search techniques
- 3) Access content
- 4) Access content anytime and anywhere using a mobile device

## Annual Reviews: Navigating to Content

The screenshot shows the Annual Reviews website homepage. At the top, there is a navigation bar with the Annual Reviews logo and a welcome message for Laura Paterson. Below the navigation bar, there are three main statistics: 30,000+ Available Review Articles, 41,000+ Available Figures and Images, and 32 Top-Ranked Impact Factor Journals. A search bar is located in the top right corner. Below the statistics, there is a 'SEARCH JOURNALS' section with search terms, authors, and journals dropdown menus. The main content area is divided into 'BROWSE JOURNALS' and 'SUPPLEMENTAL MATERIALS'. The 'BROWSE JOURNALS' section is organized into three columns: Biomedical/Life Sciences, Physical Sciences, and Social Sciences. Each column contains a list of journal titles with expandable icons. A red arrow points from the 'SEARCH JOURNALS' section to the 'BROWSE JOURNALS' section, indicating the navigation path.

Our newly redesigned website allows for easy navigation to content.

From the homepage at [www.annualreviews.org](http://www.annualreviews.org)

users can:

- Search by
  - Keyword
  - Author
  - Journal
- Browse by
  - Journal
  - Collection

## Annual Reviews: Navigating to Content

Access  = from Vol. 1;  = to current or back volumes; No icon = to abstracts only

The screenshot shows the Annual Reviews website homepage. At the top, there is a navigation bar with the Annual Reviews logo and a search bar. Below the navigation bar, there are three statistics: 30,000+ available review articles, 41,000+ available figures and images, and 32 top-ranked impact factor journals. A search bar is located below these statistics. The main content area is titled 'BROWSE JOURNALS' and features a legend for access icons: a green checkmark for 'from Vol. 1', a blue checkmark for 'to current or back volumes', and no icon for 'to abstracts only'. Below the legend, there are three columns of journals categorized by field: Biomedical/Life Sciences, Physical Sciences, and Social Sciences. Each journal entry has a small icon (green or blue checkmark) indicating access options.

Access icons on the homepage identify what is currently included in your subscription:

- A green checkmark indicates complete access to all volumes from Volume 1

- A blue checkmark indicates access to either current volumes or back volumes

- No icon indicates access to abstracts only

## Annual Reviews: Navigating to Content

WELCOME Laura Paterson: My Account | Log out | Mobile | Activate | Help | Item:0

ANNUAL REVIEWS  
A NONPROFIT SCIENTIFIC PUBLISHER

Access provided by:  
Annual Reviews

Journals | General Info | advanced search

JOURNALS | SUBSCRIPTIONS | AUTHORS | LIBRARIANS & AGENTS | ABOUT

ANALYTICAL CHEMISTRY	EARTH AND PLANETARY SCIENCES	LAW AND SOCIAL SCIENCE	PHYSIOLOGY	PUBLICATION DATES
ANTHROPOLOGY	ECOLOGY, EVOLUTION, AND SYSTEMATICS	MARINE SCIENCE	PHYTOPATHOLOGY	ADDING TO YOUR COURSE READER
ASTRONOMY AND ASTROPHYSICS	ECONOMICS	MATERIALS RESEARCH	PLANT BIOLOGY	COPYRIGHT & PERMISSIONS
BIOCHEMISTRY	ENTOMOLOGY	MEDICINE	POLITICAL SCIENCE	SUPPLEMENTAL MATERIALS
BIOMEDICAL ENGINEERING	ENVIRONMENT AND RESOURCES	MICROBIOLOGY	PSYCHOLOGY	ACCESS METADATA
BIOPHYSICS	FINANCIAL ECONOMICS	NEUROSCIENCE	PUBLIC HEALTH	ARCHIVE RANKINGS
CELL AND DEVELOPMENTAL BIOLOGY	FLUID MECHANICS	NUCLEAR AND PARTICLE SCIENCE	RESOURCE ECONOMICS	ANNUAL REVIEWS AUDIO & VIDEO SERIES
CHEMICAL AND BIOMOLECULAR ENGINEERING	FOOD SCIENCE AND TECHNOLOGY	NUTRITION	SOCIOLOGY	
CLINICAL PSYCHOLOGY	GENETICS	PATHOLOGY: MECHANISMS OF DISEASE		
COMPUTER SCIENCE	GENOMICS AND HUMAN GENETICS	PHARMACOLOGY AND TOXICOLOGY		
CONDENSED MATTER PHYSICS	IMMUNOLOGY	PHYSICAL CHEMISTRY		

From every page, users can roll over or click the Journals tab to **browse journals** alphabetically.

WELCOME Laura Paterson: My Account | Log out | Mobile | Activate | Help | Item:0

ANNUAL REVIEWS  
A NONPROFIT SCIENTIFIC PUBLISHER

Access provided by:  
Annual Reviews

JOURNALS | SUBSCRIPTIONS | AUTHORS | LIBRARIANS & AGENTS | ABOUT

Home / Journals / Browse journals

JOURNALS

BROWSE JOURNALS

EXPECTED PUBLICATION DATES

IMPACT FACTOR RANKINGS

COPYRIGHT & PERMISSIONS

SUPPLEMENTAL MATERIALS

ALL AUDIO & VIDEO SERIES

GET MORE FROM ANNUAL REVIEWS!

LIBRARY & PERMALINK

RENAME YOUR ALERTS

RECOMMEND TO A FRIEND

Explore the New Annual Reviews Website

CLICK HERE FOR A TUTORIAL

ANNUAL REVIEWS AUDIO SERIES

Find a Journal

BIOMEDICAL LIFE SCIENCES

PHYSICAL SCIENCES

SOCIAL SCIENCES

ANALYTICAL CHEMISTRY

The Annual Review of Analytical Chemistry, first published in 2008, provides a perspective on the field of analytical chemistry.  
Latest Volume: Volume 39 (2016)

ANTHROPOLOGY

The Annual Review of Anthropology, in publication since 1972, covers significant developments in the subfields of Anthropology.  
Latest Volume: Volume 39 (2016)

ASTRONOMY AND ASTROPHYSICS

The Annual Review of Astronomy and Astrophysics, in publication since 1963, covers the significant developments in the field of Astronomy and Astrophysics.  
Latest Volume: Volume 49 (2016)

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

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## Annual Reviews: Navigating to Content – Journal Homepage

The screenshot shows the Annual Reviews journal homepage for Biochemistry. The header includes the Annual Reviews logo, navigation links (Journals, Subscriptions, Authors, Librarians & Agents, About), and a search bar. The main content area is divided into three columns: 'ABOUT THIS JOURNAL' with a bubble graphic, 'FEATURED REVIEWS' with a review on 'MECHANISMS OF ENDOCYTOSIS', and 'NEWS' with a congratulatory message. Below this is a 'JOURNAL CONTENT' sidebar with links like 'FORTHCOMING', 'LATEST VOLUME', and 'VOLUME SELECTOR'. The main content area also features a 'MOST RECENT' section with a list of reviews, including 'Bacterial Nitric Oxide Synthases', 'Protein Sorting Receptors in the Early Secretory Pathway', and 'High-Throughput Metabolic Engineering: Advances in Small-Molecule Screening and Selection'. A 'FIND A JOURNAL' section is visible on the right side of the content area.

Browsing will take users to a journal's homepage. From here users can view:

- Current Volume's Table of Contents
- Forthcoming Content
- Volume Selector for back volumes
- Most Downloaded Reviews
- Most Cited Reviews
- General information about the journal, including the current editorial committee, featured reviews, and news.



## Annual Reviews: Navigating to Content – Abstract

The screenshot shows the Annual Reviews website interface. At the top, there is a navigation bar with the Annual Reviews logo and a search bar. Below the navigation bar, there are tabs for JOURNALS, SUBSCRIPTIONS, AUTHORS, LIBRARIANS & AGENTS, and ABOUT. The main content area is titled 'MEDICINE' and 'VOLUME 51, 2000'. The article title is 'Adjuvant Therapy for Breast Cancer' by G. Hortobagyi. The abstract text is visible, along with a 'Go to full-text...' link. On the left side, there are links for 'FULL-TEXT HTML' (marked with a red '1') and 'FULL-TEXT PDF'. Below the abstract, there are sections for 'BROWSE RELATED REVIEWS', 'USERS ALSO READ', 'THIS ARTICLE IS CITED BY', and 'FIND RELATED REVIEWS' (marked with a red '3'). The 'FIND RELATED REVIEWS' section includes a search bar and a list of authors and key words. At the bottom left, there is a 'MANAGE YOUR ALERTS' button (marked with a red '2') and a 'SUBSCRIBE AND PURCHASE' button. The page also features a 'GET MORE FROM ANNUAL REVIEWS!' section with a 'SUBSCRIBE AND PURCHASE' button.

On the **abstract page** users can:

1. Navigate to full-text HTML and PDFs
2. Sign up for Email Alerts
3. View Related Review
4. Link to cited articles in CrossRef, Medline®, and ISI's Web of Science®
5. Download article information to citation manager
6. Sign up for article citation alerts

## Annual Reviews: Navigating to Content – Journal Homepage

Here is a preview of the Thumbnail figures as shown on the journal homepage.

Users can scroll through thumbnail images of all figures from an article directly from the Table of Contents page.

The screenshot displays the Annual Reviews journal homepage. At the top, there is a navigation bar with the journal logo, a search bar, and user account options. Below this, a main navigation menu includes 'JOURNALS', 'SUBSCRIPTIONS', 'AUTHORS', 'LIBRARIANS & AGENTS', and 'ABOUT'. The main content area is divided into sections: 'ABOUT THIS JOURNAL', 'FEATURED REVIEWS', and 'NEWS'. A 'JOURNAL CONTENT' sidebar on the left lists various categories like 'FORTHCOMING', 'LATEST VOLUME', and 'MOST CITED REVIEWS'. The 'MOST RECENT' section highlights a featured article: 'Associational Resistance and Associational Susceptibility: Having Right or Wrong Neighbors'. This article's thumbnail figure is shown in a larger view on the right, which includes a 'THUMBNAILS' tab and a scrollable list of figure thumbnails. The first thumbnail is labeled 'Figure 1' and is circled in red. The caption for Figure 1 reads: 'Figure 1 The distribution of effect sizes across all studies measuring...'. Navigation arrows are visible below the figure thumbnails.

## Annual Reviews: Navigating to Content – Journal Homepage

From the journal homepage, users can also view Related Content for each article, which includes

- similar articles read
- articles by the same authors
- keywords that have been chosen by the authors

The screenshot displays the Annual Reviews journal homepage. At the top, there is a navigation bar with the journal logo and a search bar. Below this, a main navigation menu includes 'JOURNALS', 'SUBSCRIPTIONS', 'AUTHORS', 'LIBRARIANS & AGENTS', and 'ABOUT'. The main content area is divided into sections: 'ABOUT THIS JOURNAL', 'FEATURED REVIEWS', and 'NEWS'. A sidebar on the left provides 'JOURNAL CONTENT' options like 'FORTHCOMING', 'LATEST VOLUME', and 'VOLUME SELECTOR'. The central 'MOST RECENT' section lists several articles, with one article highlighted in a red box. This article is 'Associational Resistance and Associational Susceptibility: Having Right or Wrong Neighbors' by Pedro Barbosa, Jessica Hines, Ian Kaplan, Holly Martinson, Adrianna Szczepaniec, and Zsófia Szendrei. A red circle highlights the 'RELATED CONTENT' link in the article's navigation tabs. A callout box on the right provides a detailed view of this article, showing its title, authors, volume information, and navigation options (ABSTRACT, THUMBNAILS, RELATED CONTENT, SUPPLEMENTAL MATERIALS). Below the article title, there are sections for 'Users Who Read This Article Also Read:' and 'More by Author:', both listing related articles and authors. A 'More by Keyword:' section lists keywords like 'apparent competition', 'associational defense', 'defense against herbivory', 'intercropping', 'monoculture', and 'polyculture'.

# Annual Reviews: Navigating to Content – Journal Homepage

Users can read the full-text PDF or HTML versions of the article directly from the journal homepage and Table of Contents page.

The screenshot shows the journal homepage for Ecology, Evolution, and Systematics. At the top, there is a navigation bar with options for Journals, Subscriptions, Authors, Librarians & Agents, and About. Below this, the main content area is divided into sections. On the left, there is a 'Further' section with a play button icon. The central part features a large image of green, circular biological structures. To the right of this image is the 'ABOUT THIS JOURNAL' section, which states that the journal has been published since 1970 and covers significant developments in the fields of Ecology, Evolutionary Biology, and Systematics. Below this is a 'FEATURED REVIEWS' section with the title 'ECOLOGICAL AND EVOLUTIONARY RESPONSES TO RECENT CLIMATE CHANGE'. On the far right, there is a 'NEWS' section with a link to a featured review by Edward C. Holmes. At the bottom of the page, there is a 'VISIT ANNUAL REVIEWS AT THE ACS FALL NATIONAL MEETING!' banner. A red box highlights the 'Full-Text HTML' and 'PDF (311K)' options for the article 'Associational Resistance and Associational Susceptibility: Having Right or Wrong Neighbors'.

## Annual Reviews: Searching Content

The screenshot shows the Annual Reviews website homepage. At the top right, there is a search bar with a 'SEARCH' button, circled in red. Below the search bar, there are navigation tabs for 'JOURNALS', 'SUBSCRIPTIONS', 'AUTHORS', 'LIBRARIANS & AGENTS', and 'ABOUT'. The main content area features three statistics: '30,000+ AVAILABLE REVIEW ARTICLES', '41,000+ AVAILABLE FIGURES AND IMAGES', and '32 TOP-RANKED IMPACT FACTOR JOURNALS'. Below these statistics, there is a 'SEARCH JOURNALS' section with a search bar and a 'SEARCH' button, also circled in red. The 'SEARCH JOURNALS' section includes a 'SEARCH BY' dropdown menu and a 'JOURNALS' dropdown menu. Below the search bar, there is a 'BROWSE JOURNALS' section with a grid of journal categories, including 'BIOMEDICAL/LIFE SCIENCES', 'PHYSICAL SCIENCES', and 'SOCIAL SCIENCES'. The 'BROWSE JOURNALS' section also includes a 'SUPPLEMENTAL MATERIALS' and 'SPECIAL COMPILATIONS' section. The 'BROWSE JOURNALS' section is also circled in red.

Users can **Search** by keyword, author, or journal directly from the [www.annualreviews.org](http://www.annualreviews.org) homepage.

There is also a **Quick Search** box at the top right corner of every page.

**Quick Search** allows searching by keywords or authors across all Annual Reviews content.

## Annual Reviews: Searching Content

A link to the **Advanced Search** page is also available in the top right corner on every page.

Home / Advanced Search

**SEARCH**

**SEARCH CRITERIA** [NEW SEARCH](#)

JOURNAL CONTENT | GENERAL INFO | CITATION

SEARCH FOR IN

All Fields

AND  Author

AND  Article Title

in all journals  in selected journals

**PUBLICATION DATES**

Between 1930 and 2010

[CLEAR](#) [SEARCH](#)

**SAVED SEARCHES**

[SAVE THIS SEARCH](#) [VIEW SAVED SEARCHES](#)

Saving this search allows you to execute the same search later without having to reenter the criteria each time. Simply give this search a name and press save.

**GIVE THIS SEARCH A NAME**

[SAVE](#)

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## Annual Reviews: Search Results

The screenshot displays the Annual Reviews search interface. The search criteria section, highlighted with a red circle, includes options for searching in 'JOURNAL CONTENT', 'GENERAL INFO', and 'CITATION'. The search for field is set to 'All Fields'. The search criteria are 'chemotherapy' AND 'Author' AND 'Article Title'. The publication dates are set to 'Between 1930 and 2010'. The refine your search section includes 'MOST FREQUENT AUTHOR NAMES', 'MOST FREQUENT KEYWORDS', 'MOST FREQUENT JOURNALS', and 'SAVED SEARCHES'. The search results section shows a list of articles with titles, authors, and options for PDF and Full Text.

Quick Search bring users to a results page that offers additional options for narrowing the search:

- **Advanced Search by**
  - Author
  - Article title
  - Abstract
  - Full text
  - Keywords
  - Cited Authors
- **Refine Your Search**
- **Saved Searches**

## Annual Reviews: Refine Your Search Results and Save Your Searches

The screenshot shows the Annual Reviews website search interface. The search term "chemotherapy" is entered in the top search bar. The search results page displays a list of articles with checkboxes for selection. Three red boxes highlight key features: "REFINE YOUR SEARCH" (top left), "SAVED SEARCHES" (bottom left), and a "SAVE THIS SEARCH" button (bottom right).

**REFINE YOUR SEARCH**

**MOST FREQUENT AUTHOR NAMES**

- Leake, C D (14)
- Englund, P T (4)
- Horsfall, J G (4)
- Jawetz, E (4)
- Storb, R (4)
- Way, E L (4)
- Benacerraf, Baruj (3)
- Dale, Henry H. (3)
- de Boer, A.G. (3)
- Dimond, A E (3)

**MOST FREQUENT KEYWORDS**

**MOST FREQUENT JOURNALS**

**SAVED SEARCHES**

**SAVE THIS SEARCH** **VIEW SAVED SEARCHES**

Saving this search allows you to execute the same search later without having to reenter the criteria each time. Simply give this search a name and press save.

**GIVE THIS SEARCH A NAME**

**SAVE**

Note: Users must be logged in to their Annual Reviews account to view Saved Searches.

# Annual Reviews: Accessing Articles

The screenshot displays the Annual Reviews website interface. At the top, there is a navigation bar with the Annual Reviews logo and a search bar. Below this, there are tabs for 'JOURNALS', 'SUBSCRIPTIONS', 'AUTHORS', 'LIBRARIANS & AGENTS', and 'ABOUT'. The main content area is titled 'CELL AND DEVELOPMENTAL BIOLOGY' and features a 'FULL-TEXT HTML' section. The article title is 'Mechanisms of Lipid Transport Involved in Organelle Biogenesis in Plant Cells'. Below the title, there is an abstract and a figure. The figure is a diagram showing the interaction of components involved in lipid transport and galactoglycerolipid assembly in Arabidopsis thaliana, specifically focusing on the endoplasmic reticulum (ER) and the outer and inner envelope membranes of the chloroplast. The diagram shows the flow of lipids from the ER through the outer envelope membrane to the inner envelope membrane, involving various enzymes and transporters like PLD, PtdCho, TGD4, DGD1, DGGG, PAP, and DAG. A red starburst graphic with the text 'New feature!' is overlaid on the figure caption area.

Full-text HTML article pages are designed to keep readers in context while navigating the content.

New features in the right column allow easy access to **Figures, References, Related Reviews, and Keyword Searches** related to the article.

# Annual Reviews: Accessing Articles

Users can also click to view the **full-text PDF** version of the article from the full-text HTML page.

The screenshot shows the Annual Reviews website interface. At the top, there is a navigation bar with the Annual Reviews logo and a search bar. Below the navigation bar, the article title "CELL AND DEVELOPMENTAL BIOLOGY" is displayed. The article title is "Mechanisms of Lipid Transport Involved in Organelle Biogenesis in Plant Cells". The author is Christoph Benning, Department of Biochemistry and Molecular Biology, Michigan State University, East Lansing, Michigan. A red box highlights the "PDF (652 KB)" link. Below the article title, there is an abstract and a figure caption. The abstract discusses the role of lipid transport in the biogenesis of the photosynthetic apparatus in developing chloroplasts. The figure caption is "Figure 4. Interaction of coat galactylglycerolipids (CG) and the outer and inner envelope membranes." The figure shows a diagram of a chloroplast with the outer envelope membrane and the inner envelope membrane. The diagram is labeled "Outer envelope membrane" and "Inner envelope membrane". The figure is credited to Benning C. 2009, Annu. Rev. Cell Dev. Biol. 25:71-91.

# Annual Reviews: Accessing Articles

The screenshot shows the Annual Reviews website interface. At the top, there is a navigation bar with the logo and the text 'ANNUAL REVIEWS A NONPROFIT SCIENTIFIC PUBLISHER'. Below this is a search bar and a menu with options like 'JOURNALS', 'SUBSCRIPTIONS', 'AUTHORS', 'LIBRARIANS & AGENTS', and 'ABOUT'. The main content area displays the article title 'Mechanisms of Lipid Transport Involved in Organelle Biogenesis in Plant Cells' and its author 'Christoph Benning'. A red box highlights the 'ABSTRACT' section, which is expanded to show a list of article sections.

Expanding the **drop down feature on the article headings** allows users to quickly navigate to different sections of the article.

## ABSTRACT

### TOP OF PAGE

- INTRODUCTION: LIPID DIVERSITY AND BIOGENIC MEMBRANES
- THE DYNAMIC NATURE OF LIPID METABOLISM
- FATTY ACID EXPORT FROM PLASTIDS
- TWO PATHWAYS FOR THE ASSEMBLY OF THYLAKOID LIPIDS
- LIPID TRANSFER BETWEEN THE ER AND PLASTID ENVELOPES
- LIPID TRANSFER FROM THE ENVELOPES TO THE THYLAKOIDS
- ANSWERS TO EMERGING QUESTIONS
- SUMMARY POINTS
- FUTURE ISSUES
- DISCLOSURE STATEMENT
- ACKNOWLEDGMENTS



# Annual Reviews: Accessing Articles

When a user navigates to a new section of the article, **tag-along navigation** allows the right-side content box to follow alongside as they scroll down the article page.

**CELL AND DEVELOPMENTAL BIOLOGY**  
FULL-TEXT HTML

**Mechanisms of Lipid Transport Involved in Organelle Biogenesis in Plant Cells**  
Annual Review of Cell and Developmental Biology  
Vol. 25, 71-91 (Volume publication date November 2009)  
First published online as a Review in Advance on July 2, 2009  
Christoph Benning  
Department of Biochemistry and Molecular Biology, Michigan State University,  
East Lansing, Michigan 48824; email: benning@msu.edu

**ABSTRACT**  
TOP OF PAGE  
INTRODUCTION: LIPID DIVERSITY AND BIOGENIC MEMBRANES  
THE DYNAMIC NATURE OF LIPID METABOLISM  
FATTY ACID EXPORT FROM PLASTIDS

**LIPID TRANSFER BETWEEN THE ER AND PLASTID ENVELOPES**  
LIPID TRANSFER FROM THE ENVELOPES TO THE THYLAKOIDS  
ANSWERS TO EMERGING QUESTIONS  
SUMMARY POINTS  
FUTURE ISSUES  
DISCLOSURE STATEMENT  
ACKNOWLEDGMENTS

**LIPID TRANSFER BETWEEN THE ER AND PLASTID ENVELOPES**  
The complexity and redundancy of thylakoid lipid biosynthesis as depicted in Figure 3b clearly invokes lipid transport processes that must shuttle lipid precursors and products between the three involved biogenic membranes and the thylakoids. In recent years, *Arabidopsis* genetics provided identification of some of the genes and proteins involved in the process, and a current model depicting the location and possible function of these proteins is shown in Figure 4. In addition to the already mentioned *ats1* mutant disrupted in the *plastid* pathway of galactolipid biosynthesis, mutants of *Arabidopsis* were identified that clearly meet phenotypic criteria for a disruption in the ER pathway of thylakoid lipid biosynthesis. These are the *ltp2* mutants named after oligogalactolipid precursors, for example, trigalactosyldiacylglycerol (TGDG; see Figure 1), accumulating in their tissues (Awai et al. 2006; Lu et al. 2007; Xu et al. 2003, 2005, 2008a). The oligogalactolipids produced in the *ltp2* mutants are structurally different from the typical galactoglycerolipids found in leaves, such that they are not likely the product of the nonprocessive UDP-Gal-dependent MGD1 or DGD1 galactosyltransferases or their MGD2/3 and DGD2 paralog (Xu et al. 2003). Instead, these oligogalactolipids appear to be produced by a processive UDP-Gal-independent galactosyltransferase associated with the outer envelope membrane. This activity was also previously observed in plastid preparations by Wierlemans and colleagues (Wierlemans et al. 1988; van Bilsouw & Wierlemans 1978). The respective enzyme transfers galactosyl residues repeatedly from MGDG onto an acceptor lipid, for example a second MGDG, thereby releasing diacylglycerol (DAG) (Benning & Ohno 2003).

The function of this enzyme in the wild type is not clear at this time. However, a candidate gene and a mutant of *Arabidopsis* deficient in this activity were recently isolated and provide the basis for a functional analysis in the near future (B. Muthan, E.R. Moelinger, C. Xu, and C. Benning, unpublished work). It is possible that this enzyme is activated by PtdOH, which according to the current model shown in Figure 4 is produced at the outer plastid envelope membrane. Incidentally, PtdOH levels were found to be elevated in the *gpf2* mutant (Xu et al. 2003), but the extent of its increase was dependent on the growth conditions with older plants grown on agar plates showing the highest PtdOH levels (C. Xu and C. Benning, unpublished work). The mutants also accumulate triacylglycerols in their leaf tissue, and triacylglycerol biosynthesis could be stimulated at the ER to remove PtdOH backing up in *ltp2* mutants. Therefore, the buildup of unusual lipids, although highly diagnostic for this mutant class, appears to be a secondary phenotype.

The primary biochemical phenotype of the *ltp2* mutants is a disruption of lipid transfer from the ER to the plastid apparent in an altered molecular species composition—increased 16-carbon fatty acids in the sn-2 position of the glycerol backbone—of the thylakoid lipids consistent with a relatively higher fraction of lipids derived from the *plastid* pathway and a

**Figure 4**  
Interaction of components involved in ER-to-plastid lipid transport and galactoglycerolipid assembly in *Arabidopsis*. The endoplasmic reticulum (ER) and the outer and inner envelope membranes of the plastid are shown. The two layers of the membranes are indicated. Proteins for which the identity is known are shaded purple; those for which the identity is unclear or are shown in blue. TGD4 is associated with the ER but its exact role is not yet known. A phospholipase D (PLD) is proposed to convert phosphatidylcholine (PtdCho) to phosphatidic acid (PtdOH), which is the proposed substrate of the TGD1,2,3 transporter complex in the inner envelope membrane. Phosphatidic acid phosphatase (PAP) at the inside of the inner envelope converts PtdOH to diacylglycerol (DAG). DAG is made available for the biosynthesis of monogalactosyldiacylglycerol (MGDG) by MGD1 located at the intermembrane face of the inner plastid envelope membrane. MGDG is converted to digalactosyldiacylglycerol (DGDG) by DGD1 located at the stromal face of the outer envelope membrane. These proteins could be organized in a supercomplex involving the three membranes and allowing substrate channeling between the components.

Benning C. 2009.  
Annu. Rev. Cell Dev. Biol. 25:71-91

## Annual Reviews: Accessing Figures

Figures and illustrations can be viewed in multiple sizes and downloaded for use in PowerPoint slides.

Figures can also be viewed directly within the full-text HTML by clicking on the "Figure Locations" tab.

The screenshot shows the Annual Reviews website interface. At the top, there are navigation tabs: FIGURES, REFERENCES, RELATED REVIEWS, and KEYWORD SEARCH. Below this is a large diagram of the ER-to-plastid lipid transport pathway. The diagram shows the Endoplasmic reticulum (ER) at the top, the Outer envelope membrane in the middle, and the Inner envelope membrane at the bottom. Key components and their interactions are labeled: PLD (phospholipase D) converts PtdCho to PtdOH; TGD4 is associated with the ER; TGD1,2,3 is a transporter complex in the inner envelope membrane; PAP (phosphatidic acid phosphatase) converts PtdOH to DAG; MGD1 is located at the intermembrane face of the inner plastid envelope membrane; and DGD1 is located at the cytosolic face of the outer envelope membrane. The pathway shows the conversion of PtdCho to PtdOH, then to DAG, and finally to MGDG and DGDG.

Benning C. 2009.  
Annu. Rev. Cell Dev. Biol. 25:71-91

FIGURE CAPTION    FIGURE LOCATIONS    Enlarge    PowerPoint

**Figure 4** Interaction of components involved in ER-to-plastid lipid transport and galactoglycerolipid assembly in Arabidopsis. The endoplasmic reticulum (ER) and the outer and inner envelope membranes of the plastid are shown. The two layers of the membranes are indicated. Proteins for which the identity is known are shaded purple; those for which the identity is unclear are shown in blue. TGD4 is associated with the ER but its exact role is not yet known. A phospholipase D (PLD) is proposed to convert phosphatidylcholine (PtdCho) to phosphatidic acid (PtdOH), which is the proposed substrate of the TGD1,2,3 transporter complex in the inner envelope membrane. TGD2 is proposed to accept PtdOH from the outer envelope. Phosphatidic acid phosphatase (PAP) at the inside of the inner envelope converts PtdOH to diacylglycerol (DAG). DAG is made available for the biosynthesis of monogalactosyl diacylglycerol (MGDG) by MGD1 located at the intermembrane face of the inner plastid envelope membrane. MGDG is converted to digalactosyl diacylglycerol (DGDG) by DGD1 located at the cytosolic face of the outer envelope membrane. All these proteins could be organized in a supercomplex involving the three membranes and allowing substrate channeling between the components.

The screenshot shows the full-text HTML view of the figure on the Annual Reviews website. The page title is "CELL AND DEVELOPMENTAL BIOLOGY". The article title is "Mechanisms of Lipid Transport Involved in Organelle Biogenesis in Plant Cells". The author is Benning C. 2009. The journal is Annu. Rev. Cell Dev. Biol. 25:71-91. The abstract is visible, and the figure is shown in a smaller size within the text. The figure caption and "Figure Locations" tab are also visible.

Benning C. 2009.  
Annu. Rev. Cell Dev. Biol. 25:71-91

FIGURE CAPTION    FIGURE LOCATIONS    Enlarge    PowerPoint

**Figure 4** Interaction of components involved in ER-to-plastid lipid transport and galactoglycerolipid assembly in Arabidopsis. The endoplasmic reticulum (ER) and the outer and inner envelope membranes of the plastid are shown.

## Annual Reviews: Accessing Literature Cited

The screenshot displays the Annual Reviews website interface. At the top, there is a navigation bar with the Annual Reviews logo and a search bar. Below this, a breadcrumb trail indicates the current page: Home / Journals / Cell and Developmental Biology / Volume 25, 2009 / Benning, pp. 71-91. The main content area is titled 'CELL AND DEVELOPMENTAL BIOLOGY' and shows the 'FULL-TEXT HTML' view of an article. The article title is 'Mechanisms of Lipid Transport Involved in Organelle Biogenesis in Plant Cells'. The 'REFERENCES' section is highlighted with a red circle and contains a list of seven references, each with a plus icon for expansion. The references are:

1. Andersson MX, Goksoor M, Sandelius AS. 2007. Optical manipulation reveals strong attracting forces at membrane contact sites between endoplasmic reticulum and chloroplasts. *J. Biol. Chem.* 282(2):1170-74. First detailed characterization of ER plastid outer envelope contact sites. [[CrossRef](#)] [[Medline](#)] [[ISI](#)]
2. Andersson MX, Kjellberg JM, Sandelius AS. 2001. Chloroplast biogenesis. Regulation of lipid transport to the thylakoid in chloroplasts isolated from expanding and fully expanded leaves of pea. *Plant Physiol.* 127(1):184-93 [[CrossRef](#)] [[Medline](#)] [[ISI](#)]
3. Andersson MX, Larsson KE, Tjellstrom H, Lijenberg C, Sandelius AS. 2005. Phosphate-limited oat. The plasma membrane and the tonoplast as major targets for phospholipid-to-glycolipid replacement and stimulation of phospholipases in the plasma membrane. *J. Biol. Chem.* 280(30):27578-86 [[CrossRef](#)] [[Medline](#)] [[ISI](#)]
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The tag-along navigation allows users to scroll and read the full-text HTML, while viewing all references.

# Annual Reviews: Accessing Literature Cited

OpenURL linking allows users to view references via CrossRef, Medline®, and ISI's Web of Science®.

The image displays a list of three references from an annual review. The first reference is highlighted with a red box, and three arrows point from its citation links to three separate screenshots showing how to access the full article:

- Reference 1:** Andersson MX, Goksor M, Sandelius AS. 2007. Optical manipulation reveals strong attracting forces at membrane contact sites between endoplasmic reticulum and chloroplasts. *Chem.* 282(2):1170-74. First detailed characterization of ER plastid outer envelope sites. [CrossRef] [Medline] [ISI]
- Reference 2:** Andersson MX, Kjellberg JM, Sandelius AS. 2001. Chloroplast biogenesis. Regulation of lipid transport to the thylakoid in chloroplasts isolated from expanding and fully expanded leaves pea. *Plant Physiol.* 127(1):184-93. [CrossRef] [Medline] [ISI]
- Reference 3:** Andersson MX, Larsson KE, Tjellstrom H, Liljenberg C, Sandelius AS. 2005. Phosphate-limited oat. The plasma membrane and tonoplast as major targets for phospholipid-to-glycolipid replacement and stimulation of phospholipases in the plasma membrane. *J. Biol. Chem.* 280(30):27578-86. [CrossRef] [Medline] [ISI]

The three screenshots show the following access paths:

- Journal Website:** A screenshot of the *Journal of Biological Chemistry* website showing the article page for "Optical Manipulation Reveals Strong Attracting Forces at Membrane Contact Sites between Endoplasmic Reticulum and Chloroplasts" by Mats X. Andersson, Mattias Goksor, and Anna Stina Sandelius.
- PubMed:** A screenshot of the PubMed.gov website showing the abstract for the same article, with a "Full Text" link available.
- ISI Web of Knowledge:** A screenshot of the ISI Web of Knowledge interface showing the article's citation information, including the journal name, volume, issue, and page numbers, along with a "Full Text" link.

## Annual Reviews: Contextual Snippets and Shared Citation Links

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is also visible in a mutant deficient in which extraplastidic lipids are less (al. 1986a). Thus, the interaction between the and assembly is complex—involving intricate processes. Indeed, distinguishing lipid assembly and transport processes, the and the plastid outer envelope membrane have become conceptually more difficult with the discovery of ER-plastid contact sites (Figure 3a,b) that give rise to a plastid-associated microsome fraction (PLAM) with classically ER-associated enzymatic activities (Kjellberg et al. 2000). These contact sites have recently been visualized, and the strength of interaction between the two membrane systems has been determined using optical tweezers (Andersson et al. 2007).

### LIPID TRANSFER BETWEEN THE ER AND PLASTID ENVELOPES

The complexity and redundancy of thylakoid lipid biosynthesis as depicted in Figure 3b clearly invokes lipid transport processes that must shuttle lipid precursors and products between the three involved biogenic membranes and the thylakoids. In recent years, *Arabidopsis* genetics provided identification of some of the genes and proteins involved in the process, and a current model depicting the location and possible function of these proteins is shown in Figure 4. In addition to the already mentioned *ats1* mutant disrupted in the plastid pathway of galactolipid biosynthesis, mutants of *Arabidopsis* were identified that clearly meet phenotypic criteria for a disruption in the ER pathway of thylakoid lipid biosynthesis. These are the *tgf* mutants named after oligogalactolipids, for example, trigalactosyl-diacylglycerol (TGDG; see Figure 1), accumulating in their tissues (Awad et al. 2006; Lu et al. 2007; Xu et al. 2003, 2005, 2008a). The oligogalactolipids produced in the *tgf* mutants are structurally different from the typical galactolipids found in leaves, such that they are not likely the product of the nonprocessive UDP-Gal-dependent MGD1 or DGD1 galactosyltransferases or their MGD2/3 and DGD2 paralogs (Xu et al. 2003). Instead, these oligogalactolipids appear to be produced by a processive UDP-Gal-independent galactosyltransferase associated with the outer envelope membrane. This activity was also previously observed in plastid preparations by Wintermans and colleagues (Heemskerk et al.

FIGURES REFERENCES RELATED REVIEWS KEYWORD SEARCH

1. Andersson MX, Goksoy M, Sandelius AS. 2007. Optical manipulation reveals strong attracting forces at membrane contact sites between endoplasmic reticulum and chloroplasts. *J. Biol. Chem.* 282(2):1170–74. First detailed characterization of ER plastid outer envelope contact sites. [[CrossRef](#)] [[Medline](#)] [[ISI](#)]

and the strength of interaction between the two membrane systems has been determined using optical tweezers (Andersson et al. 2007).

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- The Origin and Establishment of the Plastid in Algae and Plants  
Adrian Reyes-Prieto, Andreas P.M. Weber, Debashish Bhattacharya  
Annual Review of Genetics Vol. 41: 147 - 168

2. Andersson MX, Kjellberg JM, Sandelius AS. 2001. Chloroplast biogenesis. Regulation of lipid transport to the thylakoid in chloroplasts isolated from expanding and fully expanded leaves of pea. *Plant Physiol.* 127(1):184–93 [[CrossRef](#)] [[Medline](#)] [[ISI](#)]
3. Andersson MX, Larsson KE, Tjellstrom H, Liljenberg C, Sandelius AS. 2005. Phosphate-limited oat. The plasma membrane and the tonoplast as major targets for phospholipid-to-glycolipid replacement and stimulation of phospholipases in the plasma membrane. *J. Biol. Chem.* 280(30):27578–86 [[CrossRef](#)] [[Medline](#)] [[ISI](#)]
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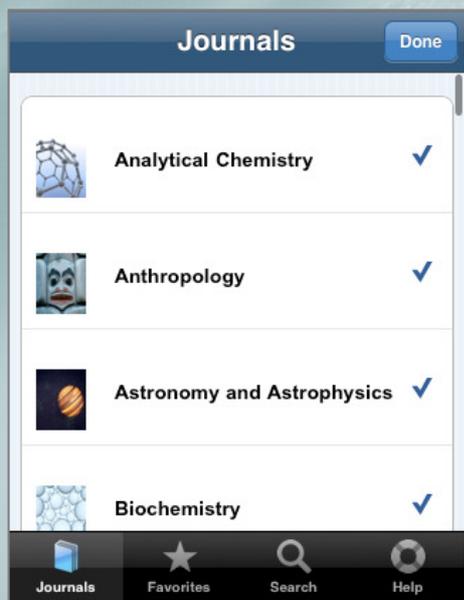
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The screenshot displays the 'KEYWORD SEARCH' section of the Annual Reviews website. It features a search bar with a dropdown menu set to 'Annual Reviews'. Below the search bar, there is a list of keywords with checkboxes: 'chloroplast' (checked), 'photosynthetic membrane', 'endoplasmic reticulum', 'lipid assembly', 'lipid transport', and 'galactolipid'. A 'SEARCH' button is located at the bottom of the list. The background shows the article page for 'Mechanisms of Lipid Transport Involved in Organelle Biogenesis in Plant Cells' by Christoph Benning.

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