

An Introduction to Homological Algebra

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September 21, 2007

1 Introduction

While it began as a tool in algebraic topology, the last fifty years have seen homological algebra grow into an indispensable tool for algebraists, topologists, and geometers.

2 Preliminaries

Before we can truly begin, we must first introduce some basic concepts. Throughout, R will denote a commutative ring (though very little actually depends on commutativity). For the sake of discussion, one may assume either that R is a field (in which case we will have chain complexes of vector spaces) or that $R = \mathbb{Z}$ (in which case we will have chain complexes of abelian groups).

2.1 Chain Complexes

Definition 2.1. A **chain complex** is a collection of $\{C_i\}_{i \in \mathbb{Z}}$ of R -modules and maps $\{d_i : C_i \rightarrow C_{i-1}\}$ called **differentials** such that $d_{i-1} \circ d_i = 0$. Similarly, a **cochain complex** is a collection of $\{C^i\}_{i \in \mathbb{Z}}$ of R -modules and maps $\{d^i : C^i \rightarrow C^{i+1}\}$ such that $d^{i+1} \circ d^i = 0$.

$$\cdots \longrightarrow C_{i+1} \xrightarrow{d_{i+1}} C_i \xrightarrow{d_i} C_{i-1} \longrightarrow \cdots$$

Remark 2.2. The only difference between a chain complex and a cochain complex is whether the maps go up in degree (are of degree 1) or go down in degree (are of degree -1). Every chain complex is canonically a cochain complex by setting $C^i = C_{-i}$ and $d^i = d_{-i}$.

Remark 2.3. While we have assumed complexes to be infinite in both directions, if a complex begins or ends with an infinite number of zeros, we can suppress these zeros and discuss finite or **bounded** complexes. Additionally, if $C_i = 0$ for all sufficiently large or sufficiently small values of i , then we say that the complex is **bounded above** or **bounded below**.

To ease notation, the subscripts and superscripts on differentials will be suppressed. For example, the condition that one has a chain complex becomes $d^2 = 0$.

Definition 2.4. Given two chain complexes $C = (C_i, d)$ and $C' = (C'_i, d')$, a **chain map** between them is a collection of maps $f = \{f_i : C_i \rightarrow C'_i\}$ such that $d' \circ f_i = f_{i-1} \circ d$, i.e., the following diagram commutes.

$$\begin{array}{ccccccc} \cdots & \longrightarrow & C_{i+1} & \xrightarrow{d_{i+1}} & C_i & \xrightarrow{d_i} & C_{i-1} \longrightarrow \cdots \\ & & \downarrow f_{i+1} & & \downarrow f_i & & \downarrow f_{i-1} \\ \cdots & \longrightarrow & C'_{i+1} & \xrightarrow{d'_{i+1}} & C'_i & \xrightarrow{d'_i} & C'_{i-1} \longrightarrow \cdots \end{array}$$

An Introduction To Homological Algebra An Introduction To Homological Algebra

Charles A. Weibel



An Introduction To Homological Algebra An Introduction To Homological Algebra:

An Introduction to Homological Algebra Joseph J. Rotman, 2008-12-10 Homological Algebra has grown in the nearly three decades since the first edition of this book appeared in 1979 Two books discussing more recent results are Weibel *An Introduction to Homological Algebra* 1994 and Gelfand Manin *Methods of Homological Algebra* 2003 In their Foreword Gelfand and Manin divide the history of Homological Algebra into three periods the first period ended in the early 1960s culminating in applications of Homological Algebra to regular local rings The second period greatly influenced by the work of A Grothendieck and J P Serre continued through the 1980s it involves abelian categories and sheaf cohomology The third period involving derived categories and triangulated categories is still ongoing Both of these newer books discuss all three periods see also Kashiwara Schapira *Categories and Sheaves* The original version of this book discussed the first period only this new edition remains at the same introductory level but it now introduces the second period as well This change makes sense pedagogically for there has been a change in the mathematics population since 1979 today virtually all mathematics graduate students have learned something about functors and categories and so I can now take the categorical viewpoint more seriously When I was a graduate student Homological Algebra was an unpopular subject The general attitude was that it was a grotesque formalism boring to learn and not very useful once one had learned it

An Introduction to Homological Algebra Charles A. Weibel, 1994 A portrait of the subject of homological algebra as it exists today *An Introduction to Homological Algebra* Joseph Rotman, 2008-11-25 Graduate mathematics students will find this book an easy to follow step by step guide to the subject Rotman's book gives a treatment of homological algebra which approaches the subject in terms of its origins in algebraic topology In this new edition the book has been updated and revised throughout and new material on sheaves and cup products has been added The author has also included material about homotopical algebra alias K theory Learning homological algebra is a two stage affair First one must learn the language of Ext and Tor Second one must be able to compute these things with spectral sequences Here is a work that combines the two

INTRODUCTION TO HOMOLOGICAL ALGEBRA. Sze-tsen Hu, 1984 *Introduction to Homological Algebra*, 85 Joseph J. Rotman, 1979-09-07 *An Introduction to Homological Algebra* discusses the origins of algebraic topology It also presents the study of homological algebra as a two stage affair First one must learn the language of Ext and Tor and what it describes Second one must be able to compute these things and often this involves yet another language spectral sequences Homological algebra is an accessible subject to those who wish to learn it and this book is the author's attempt to make it lovable This book comprises 11 chapters with an introductory chapter that focuses on line integrals and independence of path categories and functors tensor products and singular homology Succeeding chapters discuss Hom and projectives injectives and flats specific rings extensions of groups homology Ext Tor son of specific rings the return of cohomology of groups and spectral sequences such as bicomplexes Kunneth Theorems and Grothendieck Spectral Sequences This book will be of interest to practitioners in the

field of pure and applied mathematics **An Introduction to Homological Algebra** Douglas Geoffrey Northcott, 2003-01-01 [An Introduction to Homological Algebra](#) ,1979 *An Introduction to Homological Algebra* Charles A. Weibel, 1995-10-27 The landscape of homological algebra has evolved over the last half century into a fundamental tool for the working mathematician This book provides a unified account of homological algebra as it exists today The historical connection with topology regular local rings and semi simple Lie algebras are also described This book is suitable for second or third year graduate students The first half of the book takes as its subject the canonical topics in homological algebra derived functors Tor and Ext projective dimensions and spectral sequences Homology of group and Lie algebras illustrate these topics Intermingled are less canonical topics such as the derived inverse limit functor $\varprojlim^1$ local cohomology Galois cohomology and affine Lie algebras The last part of the book covers less traditional topics that are a vital part of the modern homological toolkit simplicial methods Hochschild and cyclic homology derived categories and total derived functors By making these tools more accessible the book helps to break down the technological barrier between experts and casual users of homological algebra [An Introduction to Homological Algebra](#) ,1962 **An Introduction to Homological Algebra** Douglas Geoffrey Northcott, 1962

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