

An Introduction to Homological Algebra

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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

Lei Shi



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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

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field of pure and applied mathematics *An Introduction to Homological Algebra* Douglas Geoffrey Northcott, 2003-01-01

An Introduction to Homological Algebra Charles A. Weibel, 1994 **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 $\varprojlim$ 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

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