

An Introduction to Homological Algebra

Aaron Marcus

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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.

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

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Sze-tsen Hu



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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**

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

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web feb 22 2022 we use a series of specific numbers called quantum numbers to describe the location of an electron in an associated atom quantum numbers specify the properties of the atomic orbitals and the electrons in those orbitals an electron in an atom or ion has four quantum numbers to describe its state

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web never true in the quantum mechanical model of the atom the probability of finding an electron within a certain volume of space surrounding the nucleus can be portrayed as a fuzzy cloud always true the fourth principal energy level of an atom donations 32 electrons sometimes true

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web limit an electron s energy to certain values differences between bohr s model and quantum mechanical model of the atom q mechanical model of the atom makes no attempt to describe the electron s path around the nucleus where bohr s model does atomic orbital