1 Introduction

The biological production of renewable fuels, chemicals, medicines, and proteins is not possible without a properly functioning bioreactor. Bioreactors are expected to meet several basic requirements and create conditions favorable to the biological matter such that the desired production is maximized. The basic requirements may include minimal damage to the biological matter, maximum bioreactor volume utilization, maximum gas–liquid mass transfer, and/or maximum mass transfer from the liquid to the biological species (Bliem and Katinger, 1988a). Even though gas–liquid mass transfer is often the limiting reaction process, the biological species may incur additional limitations. For example, biological species can be very sensitive to shear while others may not grow well in laminar flow conditions but thrive in very turbulent conditions (Bliem and Katinger, 1988a; Hoffmann et al., 2008). In other words, the bioreactor has to accommodate very specific environmental conditions, and the operator has to be mindful of those when choosing bioreactor design and operating conditions.

Once the broadness of the problem is absorbed, it becomes clear that one bioreactor design or design ideology is insufficient to meet the operational requirements for all bioreactor operations (Bliem and Katinger, 1988a). Therefore, each bioreactor design tries to produce a very specific set of conditions applicable to a certain cell or bacteria line. In order to help with this decision process, this book provides a survey of relevant gas–liquid and gas–liquid–solid bioreactors; defines the respective bioreactor pros, cons, hydrodynamic considerations, and gas–liquid mass transfer correlations; and identifies research needs and figures of merit that have yet to be addressed. Since a large portion of the bioreactor designs have been ported over from the chemical and petrochemical industries, a significant portion of the basic bioreactor knowledge has originated from those areas. Hence, bioreactors will often be referred to as simple reactors in order to signal that some of the research used for the discussion and conclusion have been adapted from nonbiological research areas.

The remainder of this book is organized as follows. All bioreactors have common modes of operation, which are described in Chapter 2. General gas–liquid mass transfer considerations are then summarized in Chapter 3. Various hydrodynamic and gas–liquid mass transfer measure techniques are then outlined in Chapter 4, followed by a summary of multiphase flow modeling

An Introduction to Bioreactor Hydrodynamics and Gas-Liquid Mass Transfer, First Edition.
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methods in Chapter 5. Chapters 6–8 then cover the three common bioreactor types, including stirred-tank bioreactors, bubble column bioreactors, and airlift bioreactors, respectively. Chapters 9 and 10 then cover less common bioreactor types, including fixed bed bioreactors and novel bioreactor designs. Some general figures of merit are then described in Chapter 11, followed by general conclusions.