BMEG371 – Transport Phenomena within Cells and Tissues

2024W

Lecture 1
Sep 4

We acknowledge that UBC's Vancouver Point Grey campus is situated on the traditional, ancestral, and unceded territory of the xwməθkwəy̓ am (Musqueam) people. This site has been a place of learning for millennia.

For more information on why we acknowledge this, visit:
https://indigenous.ubc.ca/indigenous- engagement/musqueam-and-ubc/
For information on traditional territories for other locations, visit:
https://native-land.ca/

Why we study this course

Transport Phenomena within Cells and Tissues:

Provides the essential foundational knowledge for engineering or manipulating living systems

In biological systems, various physical quantities are **transported** to maintain life processes, including:

•Nutrients: Transport of glucose, amino acids, and other essential molecules to sustain metabolism.

•Oxygen supply: Delivery of oxygen to tissues and cells through blood circulation or diffusion.

•Waste removal: Elimination of metabolic waste products like carbon dioxide and urea.

•Signaling molecules and chemicals: Transmission of hormones, neurotransmitters, and other chemical signals to coordinate biological functions.

Understanding these transport processes is crucial for effectively analyzing and engineering biological phenomena, whether at the cellular or tissue level.

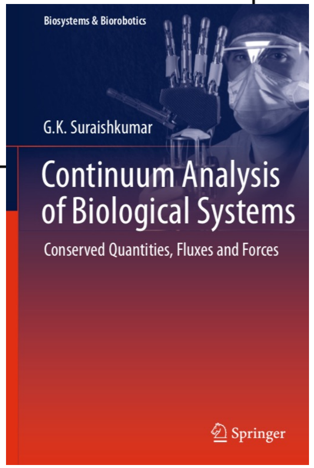
Who we are

Lecture schedule and location:
Lecture: 4 - 5 pm on Monday, Wednesday, and Fridays following the schedule (see below) **Location**: IRC-Floor B1-Room 1 (Woodward Instructional Resource Centre, 2194 Health Sciences Mall)
Instructors:

Dr. Tiam Heydari (he/him) tiam.heydari@ubc.ca **Zoom Drop-In Office hours:** Monday 12-2pm Dates: Sept 9, 16th ; Oct 7th ; Nov 4th, 11th ; Dec 2nd Zoom link will be posted in Canvas.	**Dr. Daniel Aguilar-Hidalgo** (they/he) daniel.hidalgo@ubc.ca **Zoom Drop-In Office hours:** Wednesdays from 10am-12am Dates: Sep 18th-25th, Oct 16th-23rd, Nov 20th-Dec 4th. Zoom link

Teaching Assistants and Tutorial schedule and location:
Please check your UBC course schedule to confirm which tutorial section you are enrolled in. **Ali Shahdoost** ali.shahdoost@ubc.ca **Sogand Golshahian** sogand.golshahian@ubc.ca **Tutorial BMEG371 T1A:** Tuesday 9-11am (*alternate weeks*), starting Sept 17; last day Nov 26* *We will schedule one session early December to ensure same # of sessions in both sections **Tutorial location**: MCLD-Floor 3- Room 3014 **Tutorial BMEG371 T1B:** Wednesday 9-11am (*alternate weeks*), starting Sept 11, last day Dec 4 **Tutorial location:** MCLD-Floor 3-Room 2014

Course pre-requisites:
One of MATH 253, MATH 217 and either (a) MATH 256 or (b) all of MATH 255, MATH 257 Or permission of the instructors
Course materials:
All course materials will be available through our Canvas course site. Lecture notes and slides: Lecture notes and slides will be available on Canvas. Still, each class session may involve discussions, group activities and active learning opportunities, it will be important that you still attend the class every week. Textbook: G.K. Suraishkumar, “Continuum Analysis of Biological Systems Conserved Quantities, Fluxes and Forces”, 2014. This is an excellent textbook that provides in-depth coverage of all the topics we will cover in this course. It is also free to download from the UBC Library website. Note this textbook uses gender-binary language. - **Available as an e-book from the UBC Library (Link here)**



COURSE-LEVEL LEARNING OUTCOMES

We designed this course with specific goals in mind. If you are willing and able to meet the requirements, by the end of this course, you will be able to:

1. **Interpret and apply the concepts of vector fields** (e.g., velocity, force, acceleration) and scalar fields (e.g., pressure, density, temperature), along with vector calculus, in different coordinate systems to analyze biological systems.
2. **Apply the principle of mass conservation** and the equation of continuity to biological systems, with examples such as metabolic flux analysis and oxygen transport in bioreactors.
3. **Analyze mass flux in biological and engineering systems**, utilizing key concepts like Fick's laws and steady- and unsteady-state diffusion to solve transport problems.
4. **Apply Newton's second law and momentum conservation** principles to fluid analysis, including biological flows such as cylindrical pipe flow, capillary flow, and pulsatile flow, using shell momentum balance techniques.
5. **Utilize system and control volume methods** based on the conservation of mass, momentum, and energy to **analyze and design transport** systems relevant to engineering and biological applications.
6. **Apply dimensional analysis and similitude** to represent data, and accurately interpret the Reynolds number and other fundamental dimensionless parameters in fluid flow problems.
7. **Solve energy conservation problems related to heat flux in biological tissues**, with a focus on temperature profiles and unsteady-state heat conduction.

STUDENT EVALUATION

Activity	Percentage of total grade	Description
Homework assignments (5) and Mini project	(30+10)%	Homeworks: 5 homework assignments will be given in total, but only the top 4 will be counted toward the final grade. Assignments will be posted on Canvas by your TA. Completed assignments should be submitted on Canvas. Mini project: Details will be provided by your TA by October 1st. All mini project submissions will be counted.
Midterm Exams (2)	25%	2 in total but only the best result will be counted
Final Exam	35%	Date TBD: Examination dates released by UBC mid-October (see Exam Schedule)
Participation in lecture, tutorial, and piazza/Canvas	Up to extra 5%	
	100%	

LECTURE SCHEDULE

Dates (Mon/Wed/Fri)	**Topic and textbook chapter**	**Instructor**
Sept. 4	Introduction to course	
Sept. 6 - 11	Mathematical foundations	*Dr. Heydari*
Sept. 13 - 16	Principles of mass conversation (Textbook chapter 1) • *Assignment 1 due 1 Oct*	*Dr. Heydari*
Sept 18 - 27 *No lecture Sept 30*	Mass Flux and Fick's laws (Textbook chapter 2.1 and 2.3)	*Dr. Aguilar-Hidalgo*
Oct 2 - 9	Application of diffusion equation in biological systems (Textbook chapter 2.4 to 2.6) • *Assignment 2 due 15 Oct*	*Dr. Heydari*
Oct 24	**Midterm Exam 1**	
Oct 11 - 23 *No lecture Oct 14*	Momentum Flux (Textbook chapter 3.1 to 3.4.1) • *Assignment 3 due 29 Oct*	*Dr. Aguilar-Hidalgo*
Oct 25-Nov 8	Equation of motion and Non-dimensional Analysis (Textbook chapter 3.4.2 to 3.4.4) • *Assignment 4 due 12 Nov*	*Dr. Heydari*
UBC midterm break (Nov 11-13) – No lectures/tutorials		
Nov 18	**Midterm Exam 2**	
Nov 18-Dec 2	Solution to Momentum Flux and Thermal Flux (Textbook chapters 3.5 to 3.7 and 4.1 to 4.2) • *Assignment 5 due 4 Dec*	*Dr. Aguilar-Hidalgo*
Dec 4-6	Course review / Lecture catch-up	
Examination period (Dec 11-21) Exam date set by UBC in mid-October		

LATE POLICY

Homework Due Dates

Success in this class depends upon your active participation and we will ask you to do only those activities that we believe will help you learn. Due dates are set to help you manage your time, and turning in work on time will help you keep on top of course topics and achieve your desired grades. For late assignments, 2**0%** will be deducted for each late day until the assignment solutions are released. However, students will be able to drop their lowest assignment grade.

USE OF GENERATIVE AI TOOLS

At the School of Biomedical Engineering, we believe that academic integrity is core to our educational mission, and are committed to upholding these values and skills. This is in line with UBC's stance on academic integrity, which you can learn more about here. As part of our educational mission, SBME is also committed to equipping our students with the competencies and tools needed to address complex and evolving challenges.

As Generative Artificial Intelligence (GenAI) technologies become more developed, it is crucial that you understand both the capabilities and limitations of these tools, so that – like any tool or technology – you may use them in a responsible and ethical manner. You are encouraged to review UBC's principles for the use of GenAI tools. The following was adapted from draft principles and guidelines prepared by UBC's Generative AI in Teaching and Learning Advisory Committee.

Key ethical considerations that you should be aware of as a learner:

- GenAI can be used in a way to support inclusion and accessibility
- GenAI outputs reflect social and cultural biases, which can reproduce systemic inequities, causing harm to individuals and communities
- GenAI outputs may be false, and therefore require critical evaluation by the user. This is also important to be aware of when GenAI tools are used for studying purposes.
- Different individuals have different levels of access to GenAI tools

UBC POLICY ON ACADEMIC INTEGRITY

The academic enterprise is founded on honesty, civility, and integrity. As members of this enterprise, all students are expected to know, understand, and follow the codes of conduct regarding academic integrity. At the most basic level, this means submitting only original work done by you and acknowledging all sources of information or ideas and attributing them to others as required. This also means you should not cheat, copy, or mislead others about what is your work. Violations of academic integrity (i.e., misconduct) lead to the breakdown of the academic enterprise, and therefore serious consequences arise and harsh sanctions are imposed. For example, incidences of plagiarism or cheating may result in a mark of zero on the assignment or exam and more serious consequences may apply if the matter is referred to the President's Advisory Committee on Student Discipline. Careful records are kept in order to monitor and prevent recurrences.

For more information, see: http://www.calendar.ubc.ca/vancouver/index.cfm?tree=3,286,0,0

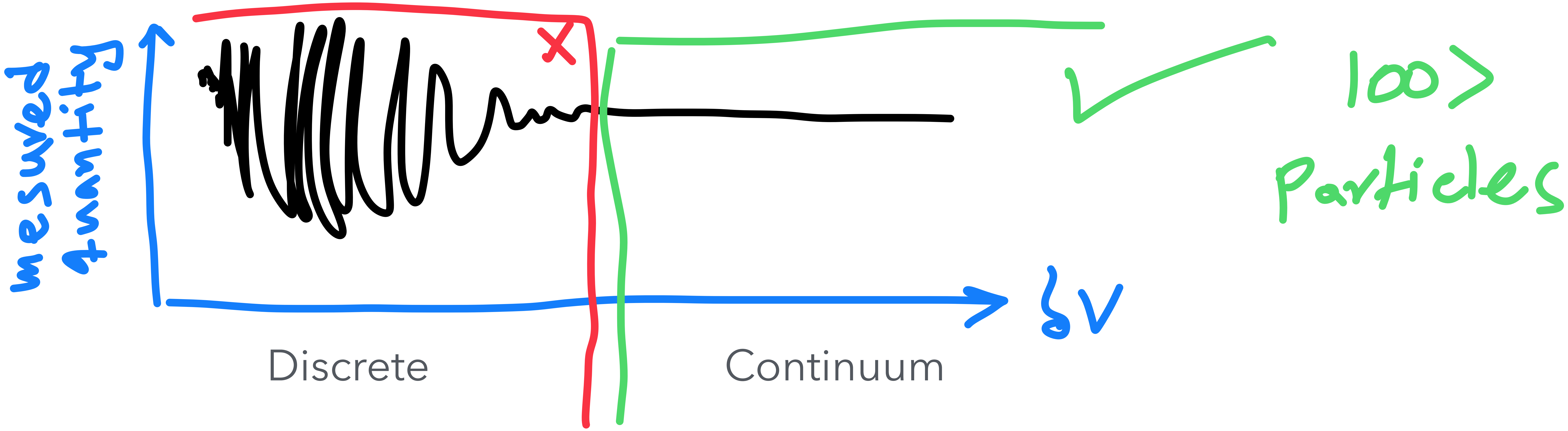
Lecture 1 Part II:

Background and Motivation: Explaining What We Will Teach, Why We Will Teach It, and How It All Connects

Tiam Heydari

We will study biological systems at this course at continuums.

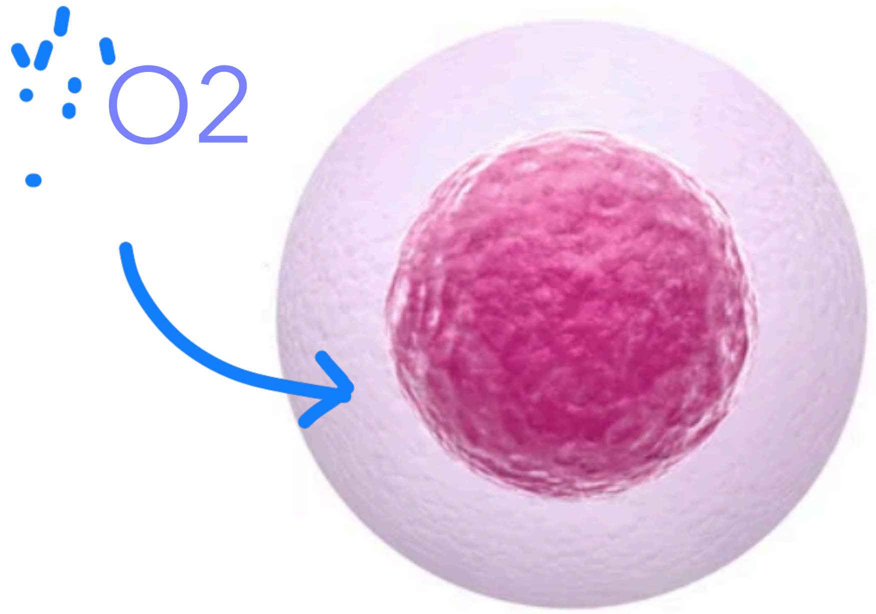
What is the continuum approximation and when it is valid?



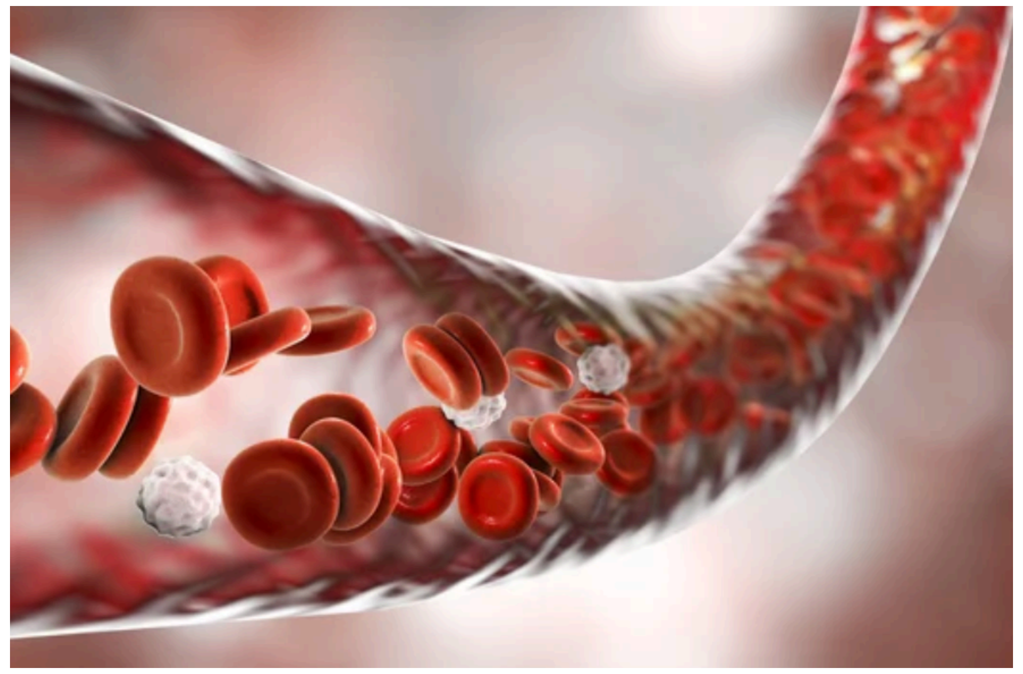
- This is the scope of this course
- we assume we have enough particles in our system to be in continuum limit and should not be worried about stochastic fluctuations

The two primary modes of transport in transport phenomena are:

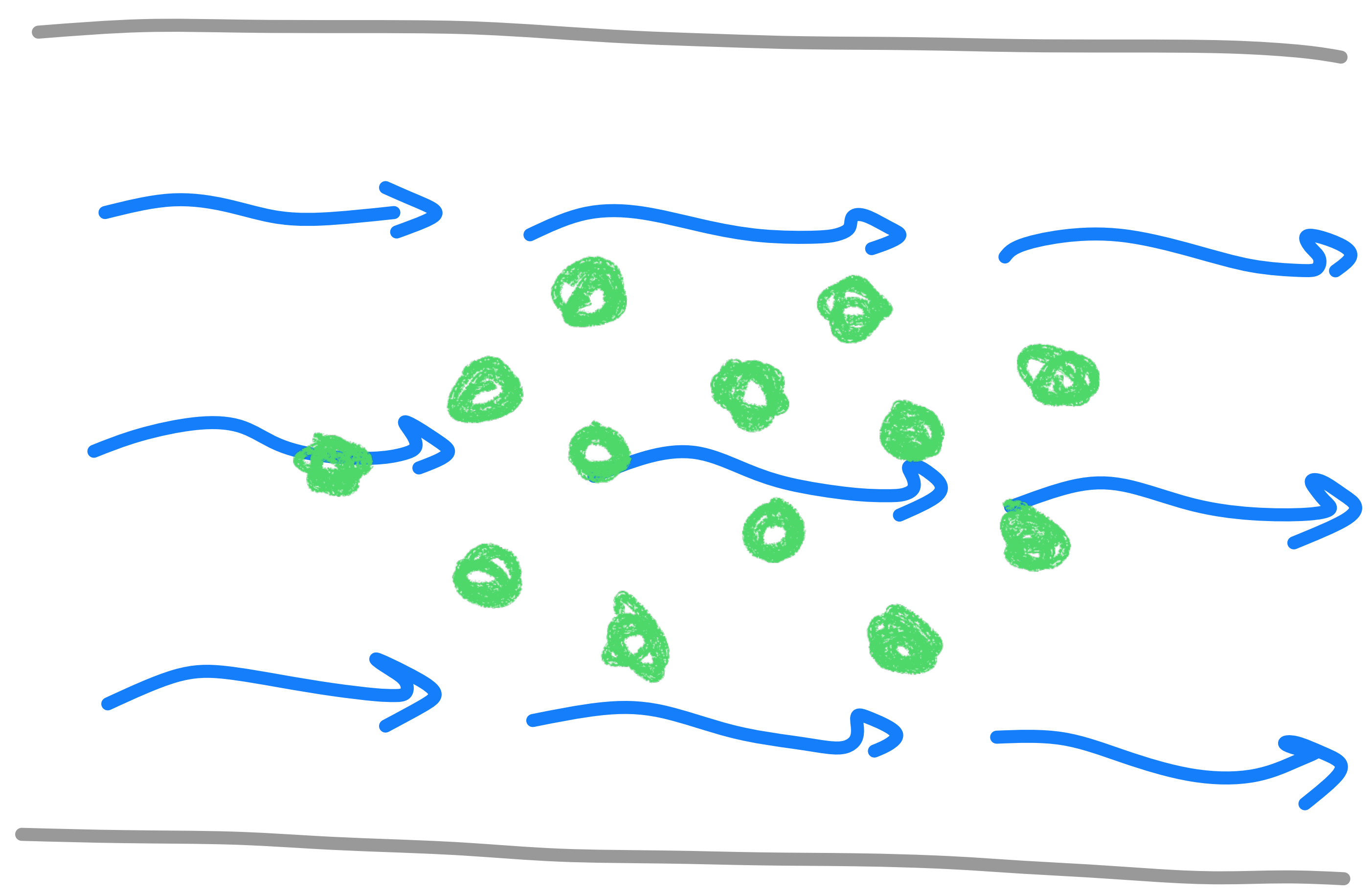
A) Diffusive Transport (Molecular Transport)



B) Convective Transport (Bulk Transport) by the medium movement



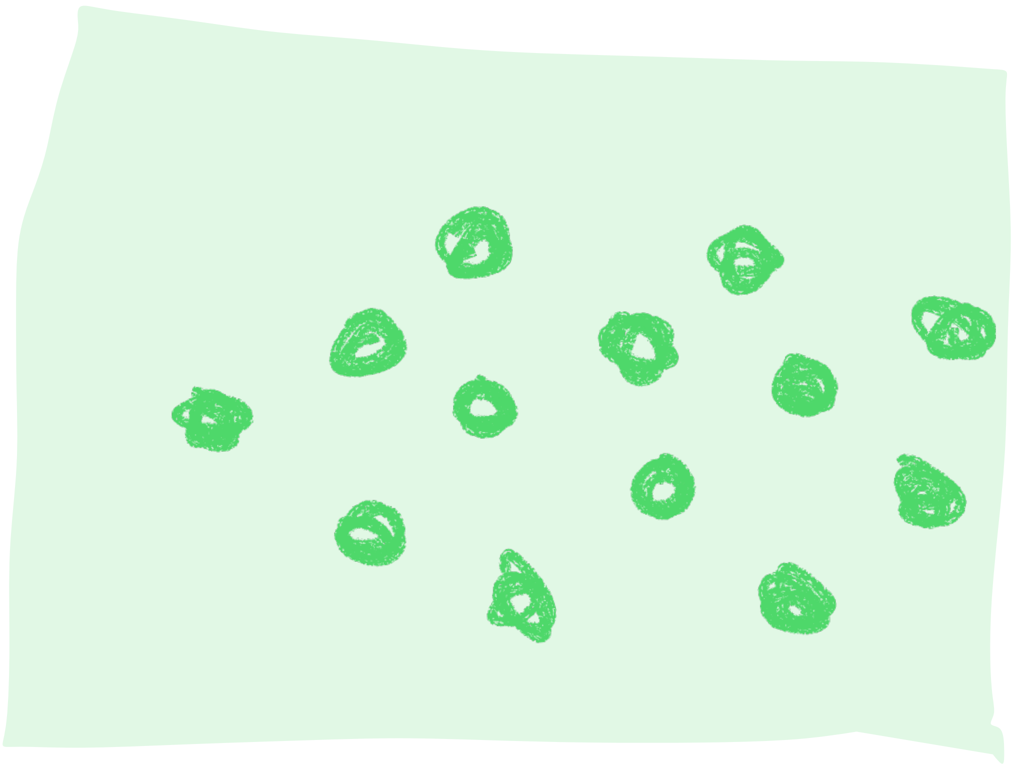
Consider that a solution of a physical quantity (green dots) in a media (blue).
How can we study a problem like this?



Let’s first focus on on the carried molecules:

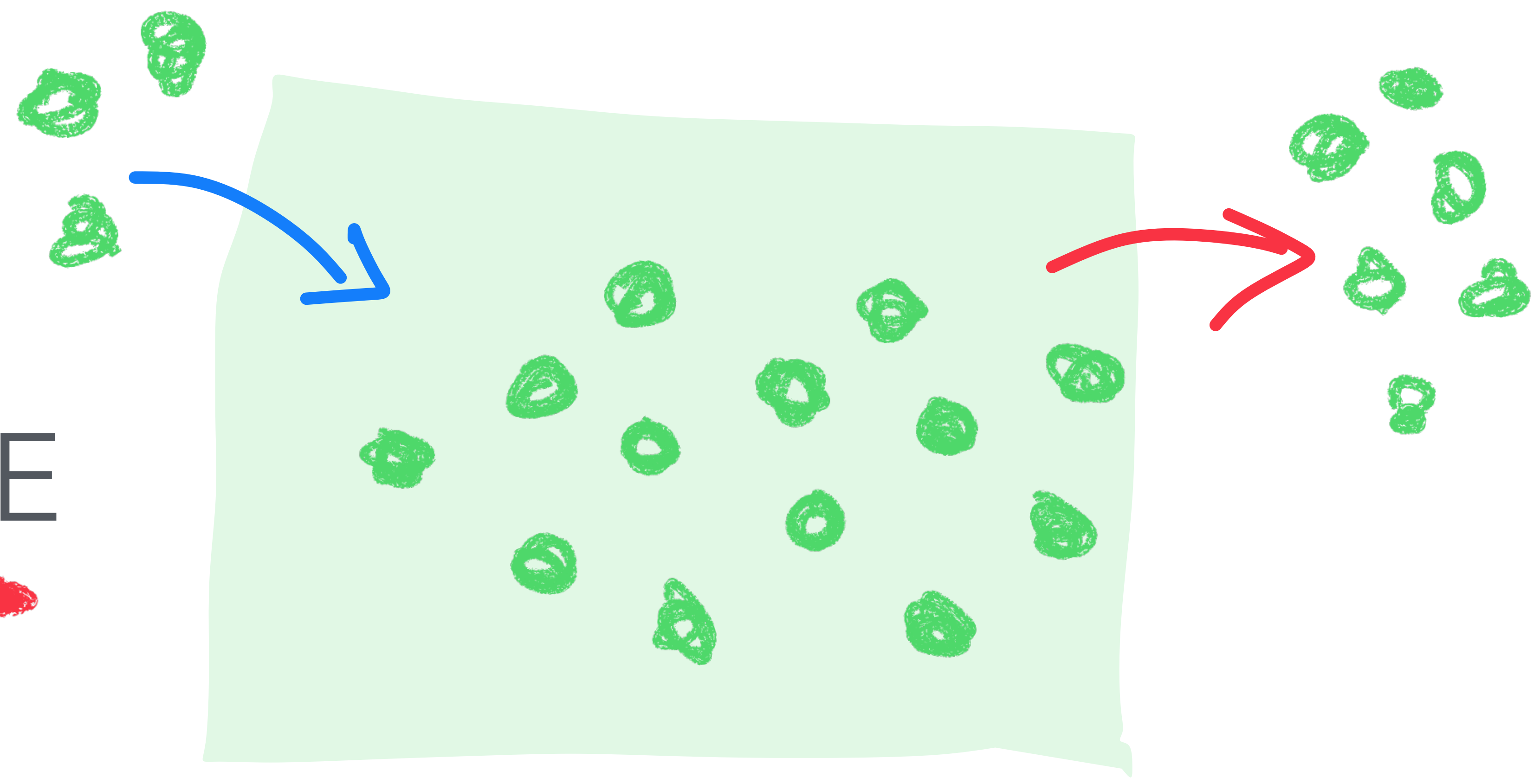
A) regardless of it’s spatial distribution and shape:

It’s total mass is conserved,



Chapter 1

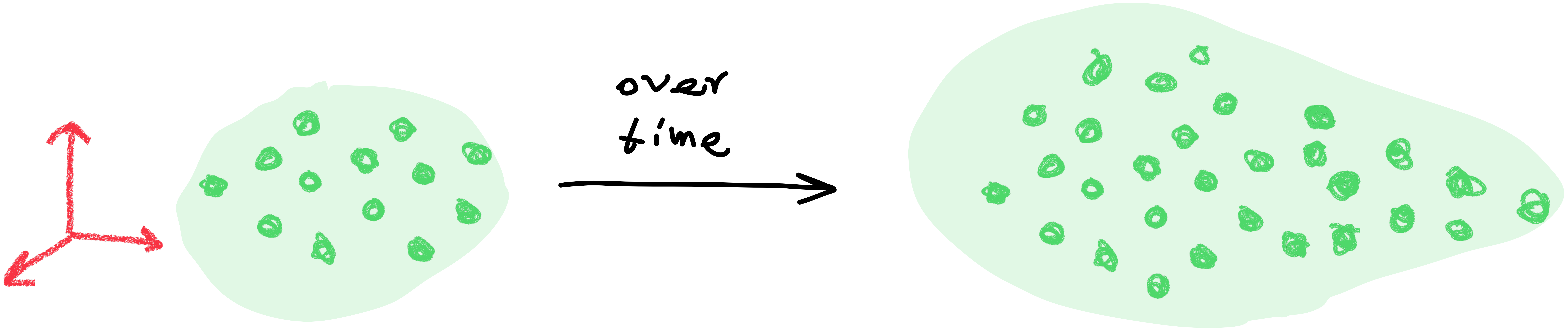
If some the total mass is chasing, it should come from somewhere? We can write ODE for it.



intro to math

Let's first focus on on the carried molecules:

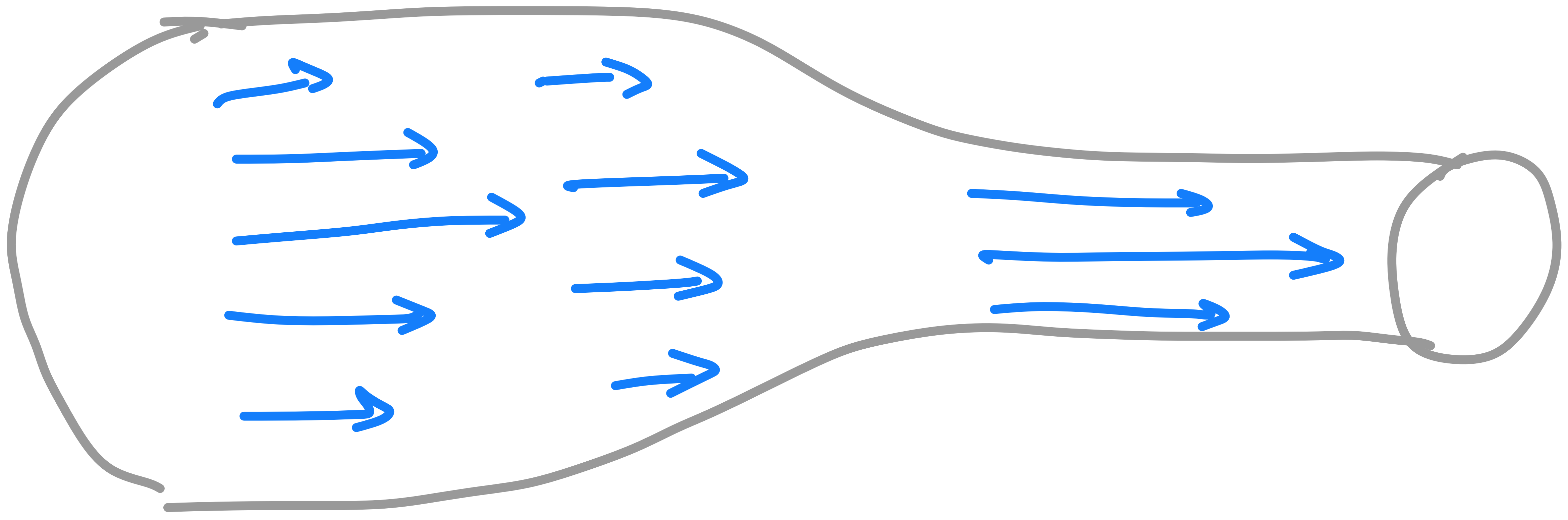
B) Now what if the spatial distribution and shape is changing by diffusion (and not much by convective flow)**?**



First we should be able to describe the shape and movement in space, in different coordinate systems. intro to math

Then we will be able to derive and solve equations that govern these types of processes. chapter 2

C) Now what if the spatial distribution and shape is changing by Convective Transport (and not much by diffusion)**?**



chapter 3

How to determine if diffusion is dominant or convection?

Péclet Number (Pe)

If Pe ≪ 1: Diffusion dominates.

If Pe ≫ 1: Convection dominates

If Pe ~ 1: both

How can we formulate transport phenomena problems?

Conservation of physical quantities are the fundamental principle in this course:

Mass: total Mass of an enclosed system is conserved

Momentum: total Momentum of an enclosed system is conserved

Energy: total Energy of an enclosed system is conserved (chapter 4)

And we will use these to derive equations that govern transport phenomena

Questions?