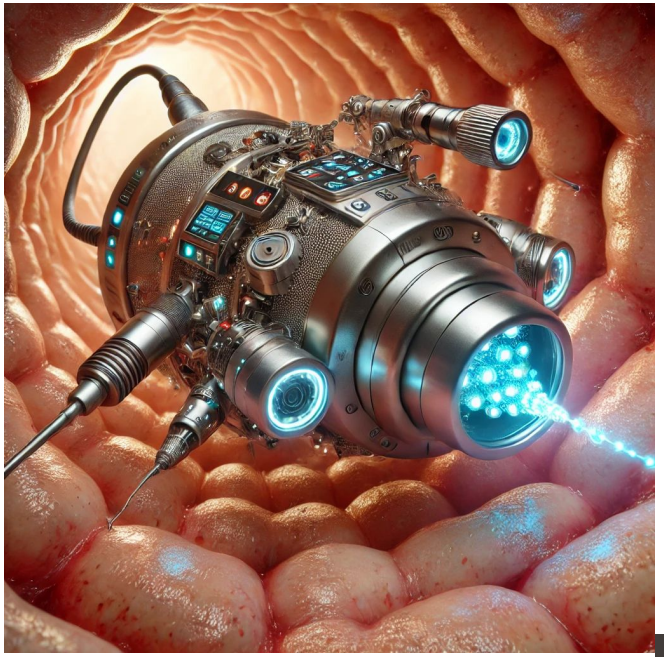

Image created with DALL-E

Capsule endoscopy

Seminar in physiology

Jennifer Joey Ayer

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Images sources:
If not mentionned, they come from papers and schemes are from BioRender.

Table of contents

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Capsule endoscopy: overview

- Aim: take pictures of interior of gut and send them wirelessly
- Size: vitamin pill

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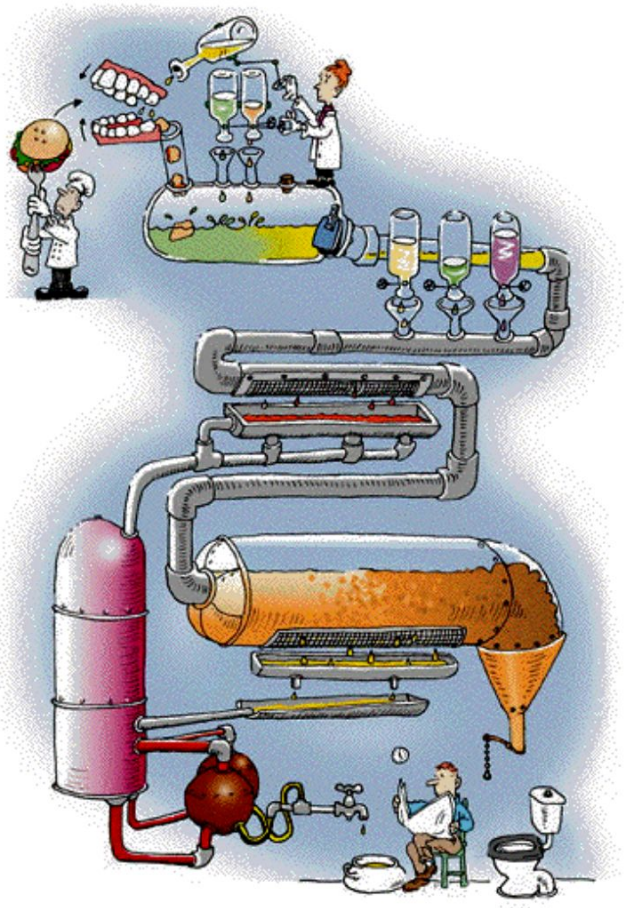

Gastrointestinal tract (GI)

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Aim:

- Transform what is ingested
- Transport to blood

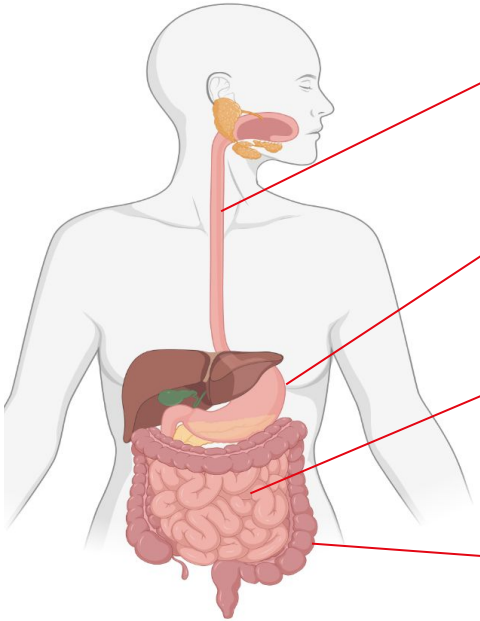
Structure:

- Segmented and compartmentalised piping
- Each with its own physico-chemical conditions
- Open system
- One direction

Challenges:

- No light inside
- Curved

GI in details



Oesophagus:
- Transit canal
- 1-2cm diameter

Stomach :
- Acidic environment : pH 0.1-5
- 0.8-1.5l
- 2-4h
- Absorption of proteins

Small intestine
- Alkalin environment : pH 7-8.5
- 3-5m
- 3-5h
- 2.5-3cm diameter
- Absorption of carbohydrates, peptides, fat,Na+, calcium, iron, folate, vitamins
- gastric extractions

Large intestine :
- pH 5.7-7
- 150cm
- 15-30h
- 4-9cm diameter
- Absorption of H20, electrolyte

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GI movements

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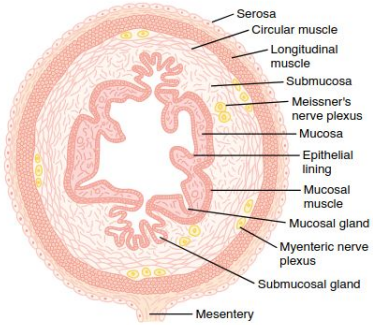
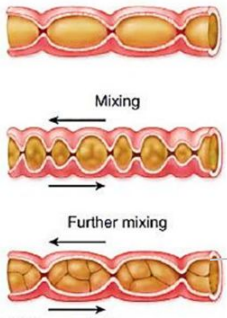
Two types of muscle:

- Circular muscles (mixing)
- Oblique muscles (mixing)
- longitudinal muscles (propel)

Movements:

- Mixing
  - malaxation (stomach)
    - mixing, mechanical destruction
  - segmentation (small bowel)
    - mixing, less vigorous than malaxation, more localised
- Propel
  - peristatilsm
    - waves movements





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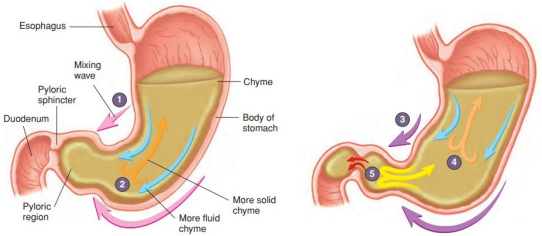

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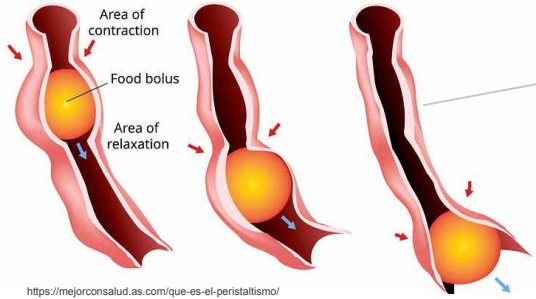
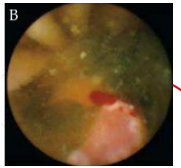


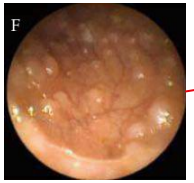
https://mejorconsalud.as.com/que-es-el-peristaltismo/

GI diseases

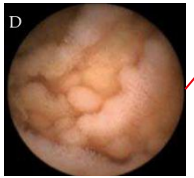
- Obscure GI bleeding
  bleeding of unknown origin
- SB polyps
  abnormal growth
- SB tumors
- Small bowel (SB) inflammatory disorders
  - Celiac diseases
    inappropriate immune response to gluten
  - Crohn's disease
    chronic inflammatory condition that can affect full GI tract



Jejunal mass with active bleeding

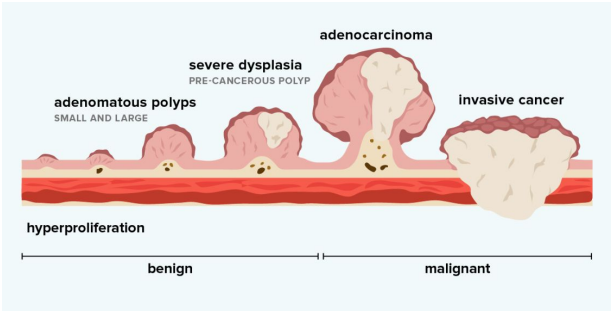


Multiple small polyps in the ileum



Benign lymphoid hyperplasia located diffusely through the GI tract

An ileal ulcer in a patient with newly diagnosed Crohn's disease



Historical timeline

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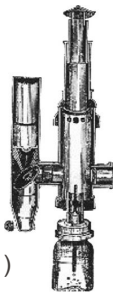
1806

1st endoscope



Lichtleiter, Bozzini

1957

1st endoscope with fiber optic

Basil Hirschowitz

2001

1st CE FDA and EMA approved
Given Imaging (Israel)

2004

1st esophageal CE FDA approved

2014

1st colon CE FDA approved

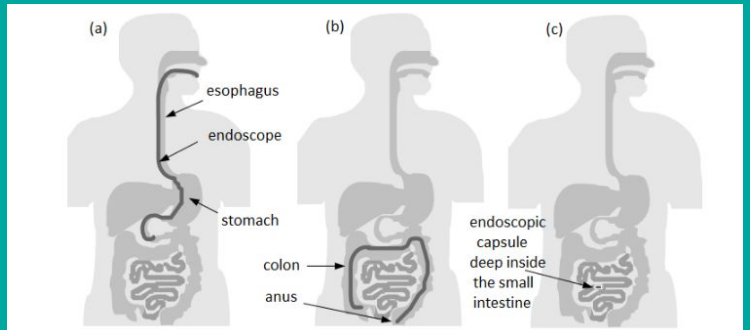
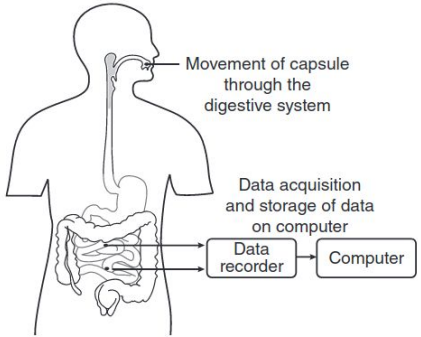
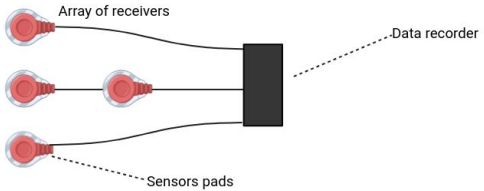
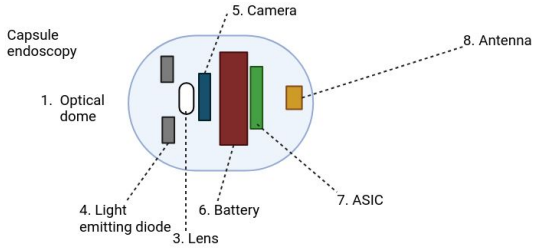


Image resources:
(1) https://www.researchgate.net/figure/n-1806-Philip-Bozzini-developed-the-fi-rst-endoscope-with-a-light-source-His-instrument_fig1_290163874
(2) https://www.conrad.com/en/p/voltcraft-bs-300xrsd-endoscope-probe-diameter-8-mm-probe-length-183-cm-1209851.html







https://www.researchgate.net/figure/Components-of-the-capsule-endoscope-Courtesy-of-Given-Imaging-Inc_fig5_50195844

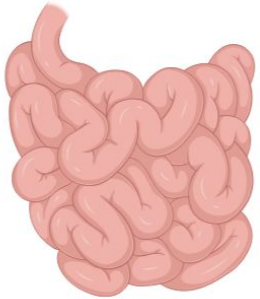
General components

Two parts:

- Capsule
  1. Optical dome (biodegradable and biocompatible plastic)
  2. Lens holder
  3. Lens
  4. Illuminating LED (light-emitting electrode)
  5. CMOS (Complementary metal oxide semiconductor) imager
  6. Battery
  7. ASIC : Application Specific Integrated Circuit transmitter
  8. Antenna
     - No motor !

- Sensors arrays
  - Each contain antenna to pick up signal
  - Connected to data recorder

Type of capsules



Small Bowel

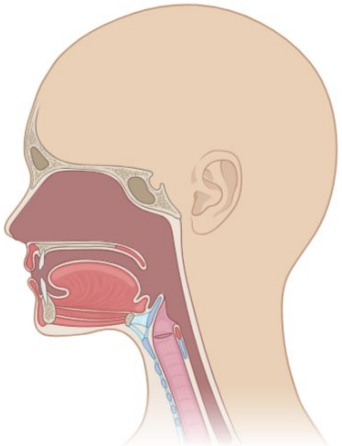
eg. PillCam (2001, Medtronics)

- 11mm diam, 26 mm height
- 1 optical dome
- 156° field of view
- Min. detection 0.007mm
- Leds
- CMOS camera
- Silver oxide battery (8h)
- 2Hz transmission rate

3rd generation :

- Adaptive frame rate :
  Dynamically adjusts the image capture rate of the capsule endoscope based on its movement speed through the GI

Type of capsules



Oesophagus

eg. PillCam UGI capsule (Medtronics)

- 32 by 11mm
- 35 frames/s during 10’ then 18 frames/s during last 80’

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Type of capsules

Colon

eg. PillCam Colon 2 (Medtronics)

- Shuts down 3’ after ingestion and wakes up 1h45 later
- 10h battery
- Requires more bowel preparation

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Type of capsules

- AdvanCE system
  (US Endoscopy, Ohio, USA)
  - Capsule delivery
  - Front-loaded onto endoscope
  - Standard endoscopic approach
  - Light to identify deployment
- PillCam Patency capsule
  (Given Imaging, Israël)
  - Dissolvable capsule
  - Similar in size as PillCam CE
  - RFID : radio frequency tag to allow its detection
  - Enable to test for capsule retention

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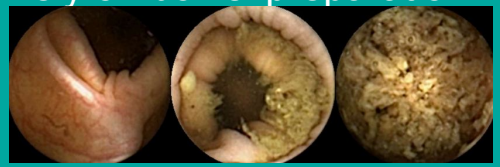
Comparison with endoscopes

Endoscopes

- Advantages
  - More accurate
  - Manoeuvrable
  - Cleaning possible
  - Surgery possible
  - No issue of battery
- Disadvantages
  - Highly invasive

Capsule endoscopy

- Advantages
  - Non-invasive
  - No sedative (colon)
  - Without radiation
  - Painless
  - Disposable (avoid in-hospital infection)
- Disadvantages
  - No mechanism of clearing visual field (secretions, bubbles, coating of the capsules by intestinal residues)
  - Inability to take biopsies
  - Unable to control location
  - Variability in lightning
  - Rely on bowel preparation



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Clinical relevance of capsule endoscopy

- Obscure GI bleeding
- SB polyps
- SB tumors
- Celiac disease
- Crohn's diseases

Narrow spectrum of indications

- Around 76.8%, best technique to diagnose it
- highest yield when ongoing bleeding, recently bled : 92.3%

- Mixed results
- Seems appropriate to detect early polyps but not larger ones

- Not possible to detect the type of tumors based on CE pictures only

- Recognise the extent of the disease and may be a tool of follow-up

- No single test to diagnose CD completely
- Enable to identify mucosal changes before other technologies

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Patient side

- To ensure:
  - Capable of swallowing a pill
  - Thorough history
  - Bowel preparation : pretest fasting and consumption of clear liquids
    “The latter, the better”
    - No consensus on which exact protocol
- Risks:
  - Missed lesions
  - Capsule retentions : rate differ upon indications
- Contre-indications:
  - SB obstructions strictures, fistulas
  - Pacemakers

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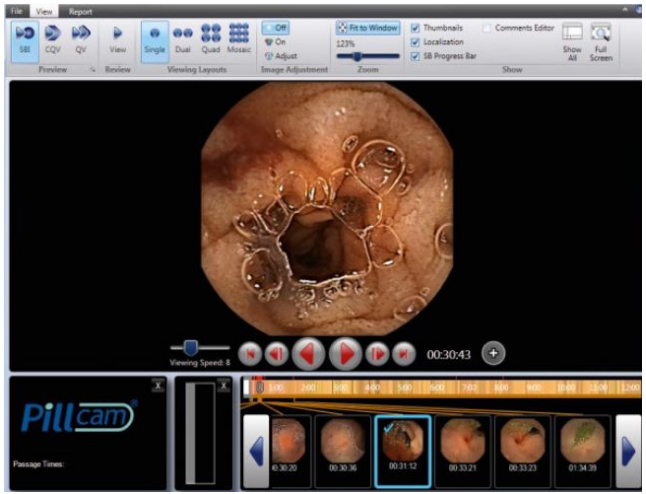
Gastroenterologist side



Example of interface for images visualisation, here suspected blood indicator

- Little if any technical competence -> high interpretive competence
- Lengthy reading time
- Challenging since abnormality can appear on single frame only
- No consensus in scoring system for SB changes
  - Attempt : Gralnek et al. , quantify mucosal changes associated with inflammatory processes (eg. villous oedema)
- No universally agreed-upon benchmarks for competence to read CE study

Key figures

- Cost: between 500-800 $
- Market value: $400 million
- Market size: 10% of the global gastrointestinal endoscopic market
- Key companies:

1. Medtronic (Dublin, Ireland)
2. Olympus Corporation (Tokyo, Japan)
3. IntroMedic Co., Ltd. (Seoul, Korea)
4. CapsoVision (Californie, USA)

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Additional informations

- Specific ISO norms : **ISO 8600-8:2021**
- Medical device of Class II
- EMA initiatives:
  - NEMO Project
    Nao-base capsule-Endoscopy with Molecular Imaging and Optical biopsy
  - VECTOR Project
    Versatile Endoscopic Capsule for gastrointestinal Tumor Recognition therapy

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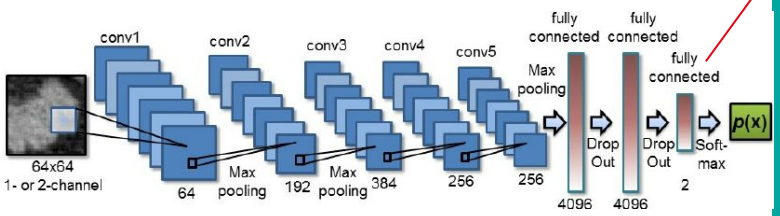
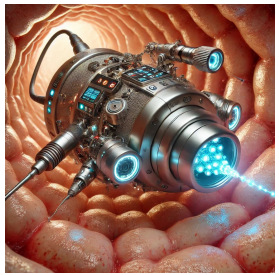
Future perspectives





- Motion
  - Magnetically controlled capsule
  - Self-propelled miniaturized robotic pill
- AI
  - High heterogeneity even within same patients
  - Rely on bowel preparation
    - Automated bowel cleansing classification
    - Automated classification with explanations eg. Gilbert P. et al., colon CE, CNN that gives a probability score per image + heatmap explaining the prediction
- Drug delivery
- Zooming/magnification
- Aspiration
- Biopsy
- Surgery

Time for questions !