The ecological footprint of liver transplantation

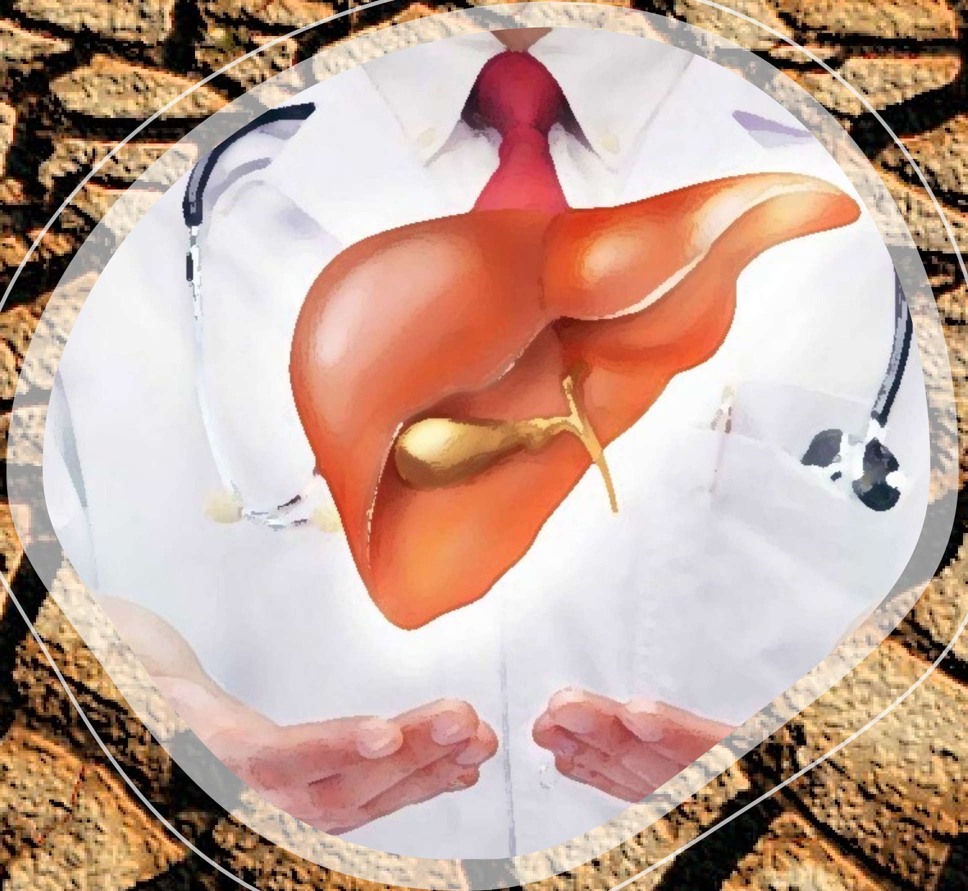
Paolo De Simone, MD PhD

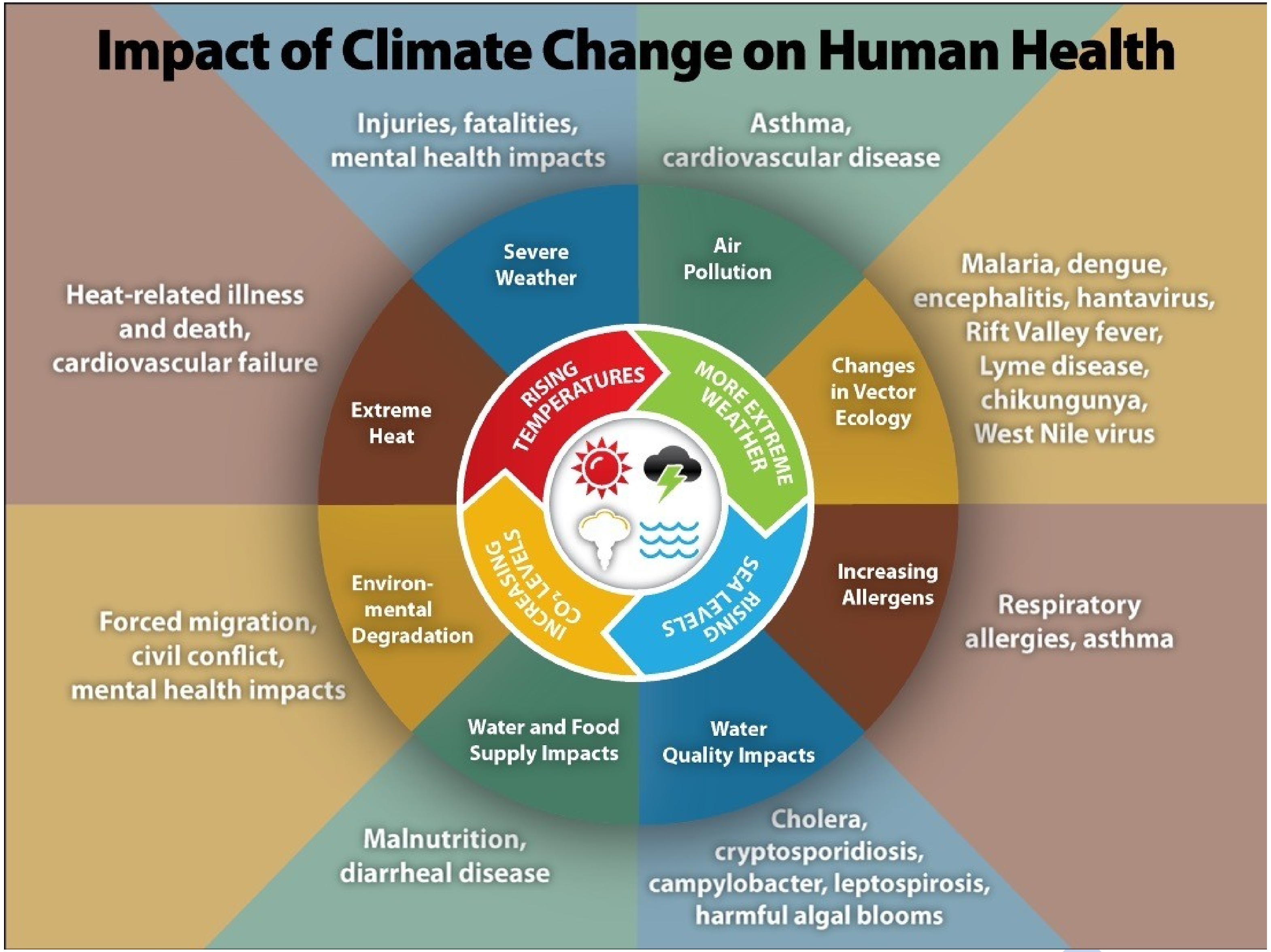
Hepatobiliary surgery and liver transplantation

University of Pisa Medical School Hospital

Pisa

Is there any link between liver transplantation and drought?




Impact of Climate Change on Human Health
Injuries, fatalities, mental health impacts
Asthma, cardiovascular disease
Heat-related illness and death, cardiovascular failure
Severe Weather
Air Pollution
Malaria, dengue, encephalitis, hantavirus, Rift Valley fever, Lyme disease, chikungunya, West Nile virus
Extreme Heat
RISING TEMPERATURES
MORE EXTREME WEATHER
Changes in Vector Ecology
INCREASING CO2 LEVELS
RISING SEA LEVELS
Environ-mental Degradation
Increasing Allergens
Forced migration, civil conflict, mental health impacts
Respiratory allergies, asthma
Water and Food Supply Impacts
Water Quality Impacts
Malnutrition, diarrheal disease
Cholera, cryptosporidiosis, campylobacter, leptospirosis, harmful algal blooms

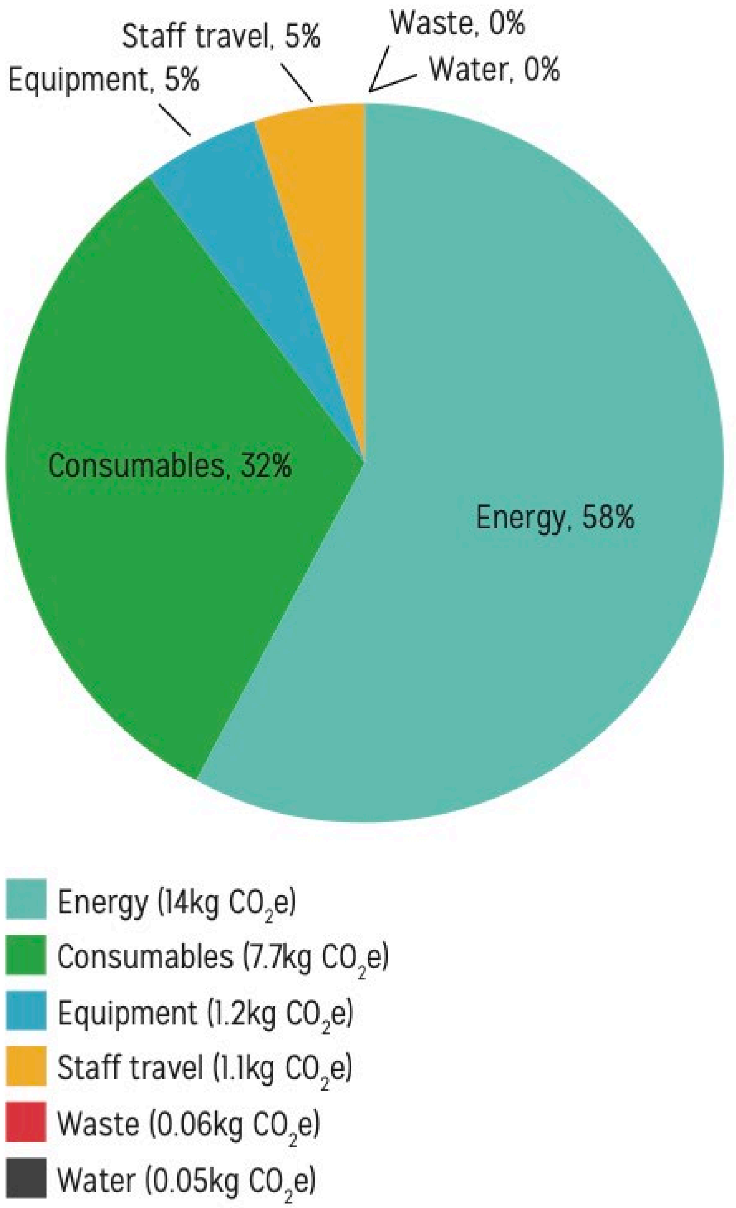
- On a global average basis, healthcare systems account for over 4% of global CO2 emissions
- For most industrialized nations, that figure is closer to 10% of national emissions
- That is more than the aviation or shipping sectors
- Hospitals have the highest energy intensity of all publicly funded buildings and emit 2.5 times more greenhouse gases than commercial buildings

Surgery is one of the clinical activities contributing to the carbon footprint and the contribution made is not limited solely to energy use in the operating theatre

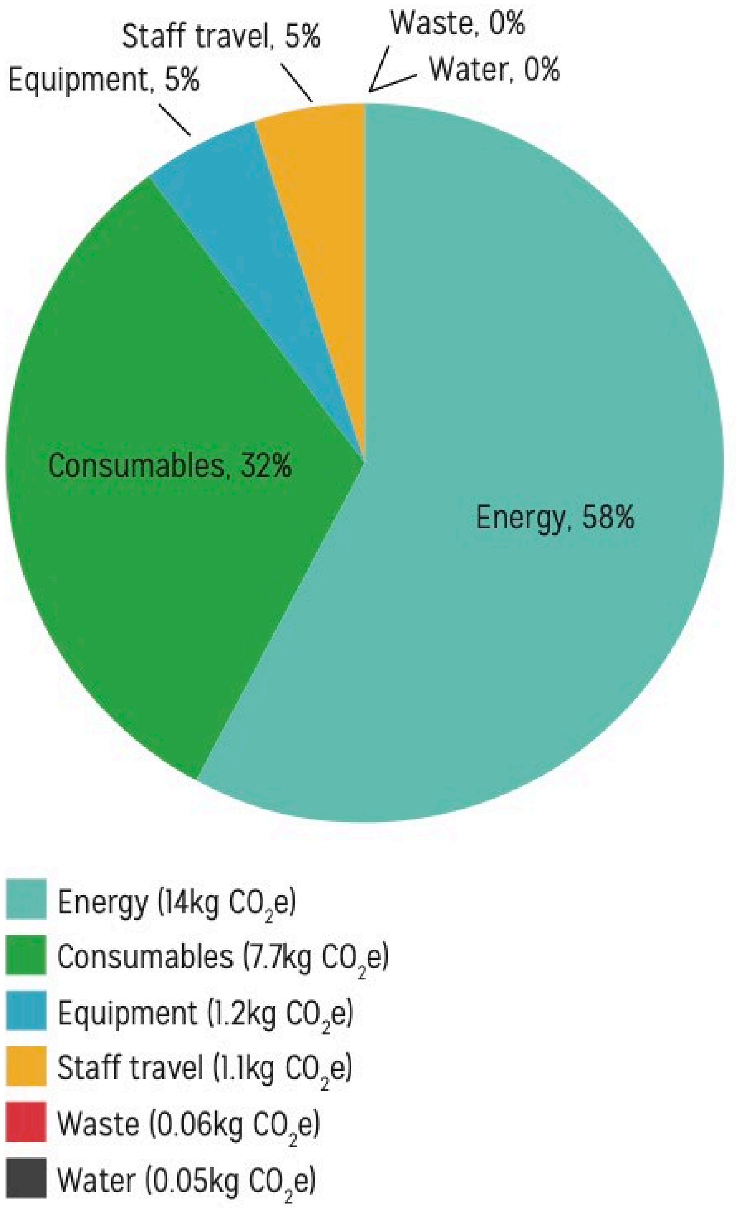
Surgery and CO2 footprint

- Healthcare makes a major contribution to climate change through the procurement, use and disposal of products,
- through the running of facilities and
- through the means by which treatment or care pathways are accessed by patients
- Without intervention, contributions to greenhouse gas (GHG) emissions from healthcare are anticipated to rise owing to
    - increasing access to healthcare
    - advances in medicine
    - a growing population
    - and the increasing number of people living with multiple long-term conditions

Surgical procedure module carbon footprint results (per hour of
surgery), excluding anaesthetic gases

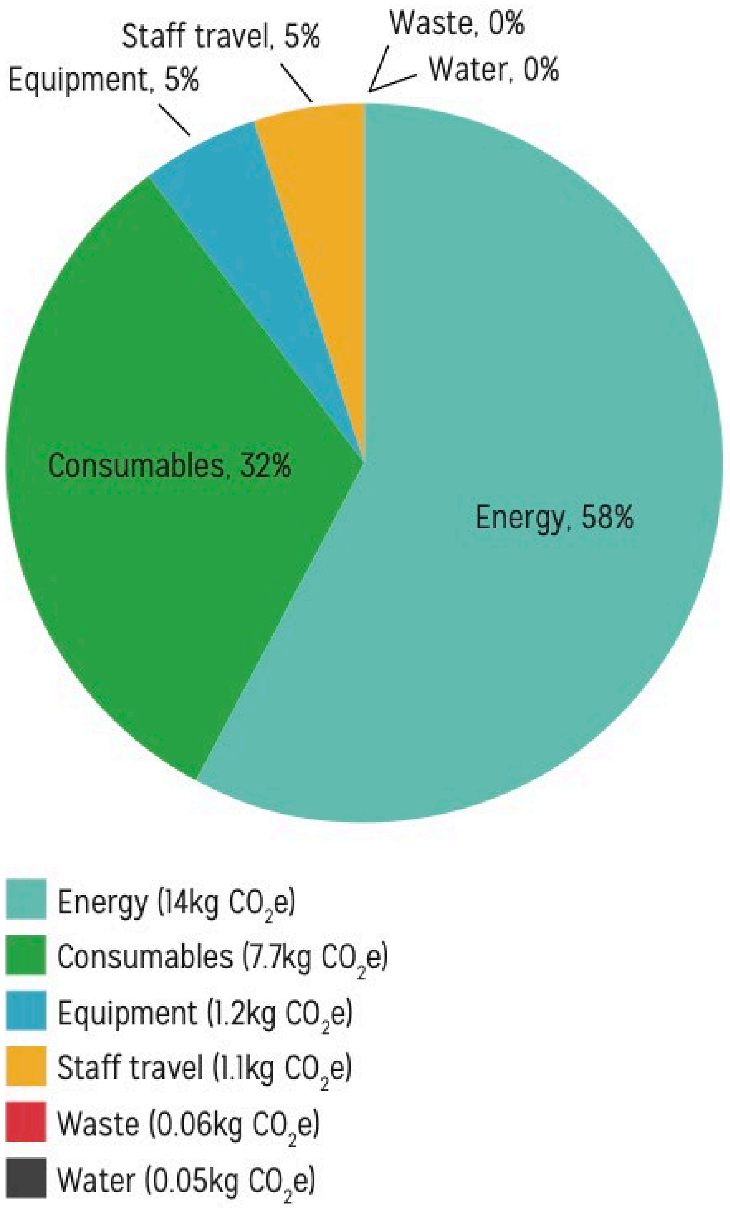


Surgical procedure module carbon footprint results (per hour of surgery), excluding anaesthetic gases



Category	Emissions	Contribution
Anaesthetic gases, excluding nitrous oxide	105kt CO_2e	22.2%
Nitrous oxide	95kt CO_2e	20.1%
*Anaesthetic gases total**	*200kt CO_2e*	*42.3%*
Surgical procedures (excluding anaesthetic gases), from Figure 1	109kt CO_2e	23.0%
Patient travel	26kt CO_2e	5.5%
Surgical inpatient bed days	138kt CO_2e	29.2%
Surgical procedures total, excluding anaesthetic gases	*273kt CO_2e*	*57.7%*
Total	**473kt CO_2e**	**100%**

Surgical procedure module carbon footprint results (per hour of
surgery), excluding anaesthetic gases



Anaesthetic gases are likely, without intervention, to become an even more dominant contributor to the climate change impact of surgery

REVIEW PAPER

The Carbon Footprint of Surgical Operations

A Systematic Review

Chantelle Rizan, MRCS (ENT),[*,†,‡,§] ✉ *Ingeborg Steinbach, MA,*[§] *Rosamond Nicholson, MBChB,*[¶]
Rob Lillywhite, PhD,[||] *Malcolm Reed, FRCS,*[†] *and Mahmood F. Bhutta, FRCS*[*,†,**]

TABLE 1. Study Characteristics and Scope of Product Inventory

Study Characteristics

Study (yr)	Study Setting; *Country*	Focus of Study; *Surgical Specialty*	Carbon Footprinting Approach; *Guideline*		
Berner et al (2017)[26]	1 airforce teaching hospital; *Chile*	(a) Abdominoplasty versus (b) bilateral breast augmentation versus (c) rhinoplasty; *Plastic surgery*	Process-based *Nil*	1	
Campion et al (2012)[31]	1 university hospital; *USA*	Childbirth: (a) cesarean section versus (b) natural delivery; *O&G*	Process-based *ISO 14040 and 14044*	Bi	
Gatenby (2011)[32]	21 hospitals; *UK*	GORD: (a) surgical versus (b) medical management; *GI*	EEIO *Nil*	1 reflux patient; *Start of secondary care for reflux-end of life*	CO_2 *Nil*
Morris et al (2013) [27]	1 university hospital; *UK*	Cataract surgery; *Ophthalmology*	Hybrid *PAS2050*	Cataract surgery 1 eye; *Referral to secondary care- discharge*	6 GH *Kyoto*
Thiel et al (2015)[7]	1 university hospital; *USA**	Hysterectomy: (a) abdominal versus (b) vaginal versus (c) laparoscopic versus (d) robotic; *O&G*	Hybrid *ISO 14040 and 14044*	1 hysterectomy; *Patient enter theatre-leave*	(91 G *TRAC*
Thiel et al (2017)[34]	2 tertiary care hospitals; *India*	Cataract surgery; *Ophthalmology*	Hybrid *ISO 14040*	Cataract surgery 1 eye; *Patient enter theatre-leave*	(91 G *TRAC*
Thiel et al (2018)[33]	1 university hospital; *USA**	Hysterectomy: model interventions (a) anesthesia (b) surgical materials and equipment (c) energy for HVAC; *O&G*	Hybrid *ISO 14040 and 14044*	1 hysterectomy *Patient enter theatre-leave*	(91 G *TRAC*
Woods et al (2014)[35]	Not specified; *USA*	Endometrial cancer staging: (a) laparoscopy versus (b) laparotomy versus (c) robotic; *O&G*	Process-based *PAS2050, GGP*	1 endometrial staging procedure; *Patient enter theatre-leave*	(6 GH *GGP*

*Inter-related studies.

CO_2, indicates carbon dioxide; EEIO, Environmentally extended input output; GGP, greenhouse gas protocol; GHG, greenhouse gas; GI, gastrointestinal; GORD, gastro-oesophageal reflux disease; H and air conditioning; ISO, international standards organisation; O&G, obstetrics and gynecology; PAS, publicly available specification; SUD, single-use device.

REVIEW PAPER

The Carbon Footprint of Surgical Operations

A Systematic Review

Chantelle Rizan, MRCS (ENT),†‡§✉ Ingeborg Steinbach, MA,§ Rosamond Nicholson, MBChB,¶ Rob Lillywhite, PhD,|| Malcolm Reed, FRCS,† and Mahmood F. Bhutta, FRCS*†***

TABLE 2. Comparison of Inventory Boundaries

Phase	Process/ Item		Berner et al[26]	Campion et al[31]	Gatenby[32]	Morris et al[27]	Thiel et al[7]	Th… et…
Pre-op	Investigations				X			
	Outpatient appointments				X			
	Outpatient building energy use				?	X		
Operation	Patient/staff travel on day of surgery		X			X		
	Capital goods manufacture				?			
	Electronic equipment energy		X	X	?	?	X	
	Heating			X	?	?	X	
	Ventilation, air conditioning, lighting			X	?	?	X	
	(Building energy use)		X			X		
	Water	Treatment before/after use			?	?		
		Heating			?	?		
		(Water)				X		
	Anaesthetic gases	Production			?	?		
		Direct emissions			?	?		
	Intravenous anaesthetics	Production			?	?		
		Direct emissions			?	?		
	Gas insufflation	Production			?			
		Direct emissions			?			
	(Operation time)				X			
	Linen	Manufacture			?			
		Washing & drying			?	X		
		Transport to linen facility	X		?	X		
	Consumables production	Raw material extraction		X	?	X		
		Manufacturing		X	?	X		
		Transport in procurement		X	?	X		
	Disposables EOL	Incineration		X	?	?		
		Landfill	?	X	?	?		
		Autoclave/ sterilisation		X	?			
		Recycling			?			
	Reusables processing	Sterilisation		X	?			
		Repair			?			
	Reusables EOL	Landfill & incineration	?		?	?		
		Recycling			?			
	(Unspecified theatre waste)	Incineration			?	X		
		Landfill	X		?	X		
		Autoclave			?			
	Transport of (any measured) waste			X	?		X	
Peri/post-op	Recovery building energy & landfill waste		X		?			
	Postoperative inpatient care				X	X		
	Inpatient pharmaceuticals				X	X		
	IT, patient food & drink, stationary				?	X		
	Medical equipment				?	X		
	Outpatient follow up				X	X		
	Outpatient pharmaceuticals				X	X		

? indicates ambiguous; (), where likely includes other listed factors; EOL, end of life; IT, information technology; op, operative.

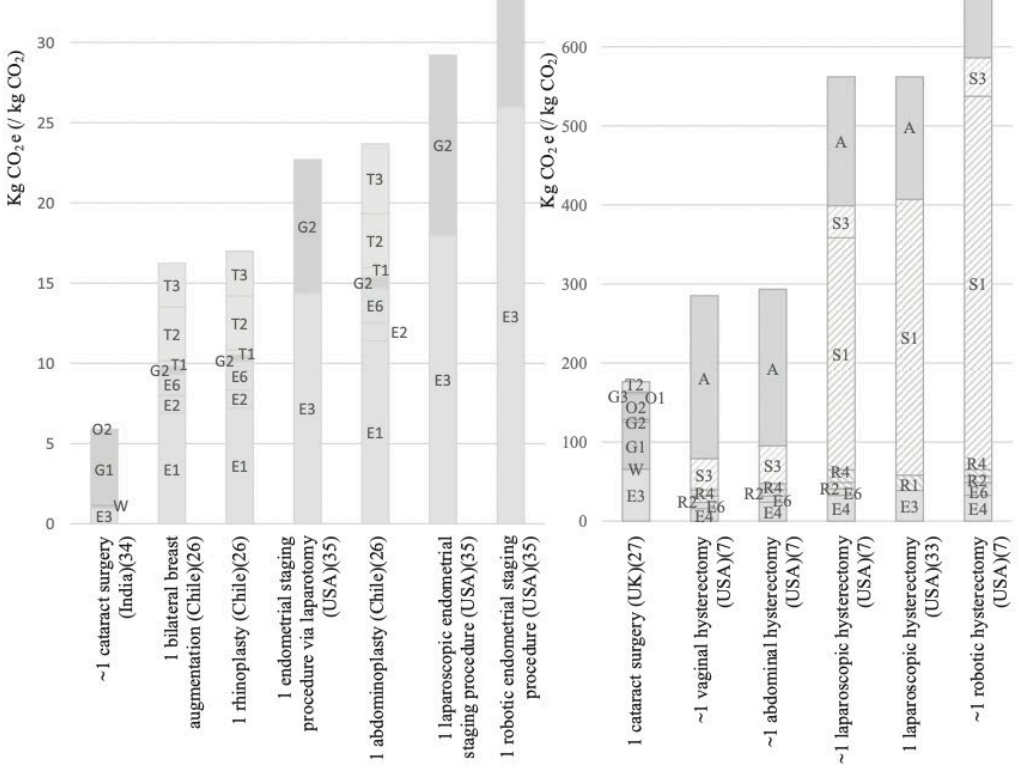
REVIEW PAPER

The Carbon Footprint of Surgical Operations

A Systematic Review

Chantelle Rizan, MRCS (ENT),†‡§✉ Ingeborg Steinbach, MA,§ Rosamond Nicholson, MBChB,¶ Rob Lillywhite, PhD,|| Malcolm Reed, FRCS,† and Mahmood F. Bhutta, FRCS*†***

- Inventory boundaries of CO2 footprint are largely variable as per
  - Anesthesia
  - Type of surgery
  - OR setting
  - Outpatient/inpatient clinic
  - Patient follow-up
  - …….
  - …….



Legend for figures 2-4.

Bar colour	Category	Sub-category	
	Electricity	E1=Building energy (theatre) E3=Electricity use E5=Lighting E7=Operation time	E2=Building energy (recovery) E4=HVAC E6=Medical equipment energy
	Water	W=Water	
	Consumables (General)	G1= Consumables procurement G3= Laundry	G2 = Waste
	Consumables (Other)	O1=Other procurement O3= Pharmaceuticals (ongoing)	O2 =Pharmaceuticals
	Reusables	R1=Reusable instruments R3=Reusables production & sterilisation	R2=Reusables production R4=Reusables treatment & sterilisation
	Single-use items	S1=Single-use items production S3=Single-use materials (gowns, gloves etc)	S2=Single-use instruments production
	Travel	T1=Patient travel T3=Waste transport	T2=Staff travel
	Anaesthetics	A=Anaesthetics	
	Beyond operation	B1=Day case B3=Outpatient appointment	B2=Inpatient care B4=Outpatient tests

FIGURE 2. Carbon footprint results of single operations. ~ = approximated from descriptive or graphical data, Thiel *et al.* (2015)[7] cross referenced in Thiel *et al.* (2018)[33].

Review Paper

The Carbon Footprint of Surgical Operations

A Systematic Review

Chantelle Rizan, MRCS (ENT),†‡§✉ Ingeborg Steinbach, MA,§ Rosamond Nicholson, MBChB,¶ Rob Lillywhite, PhD,|| Malcolm Reed, FRCS,† and Mahmood F. Bhutta, FRCS*†***

- Robotic procedures (hysterectomy) have the highest carbon footprint
- Electricity and single-use items account for most of the carbon footprint of surgical procedures

The ecological footprint

The Earth Overshoot Day

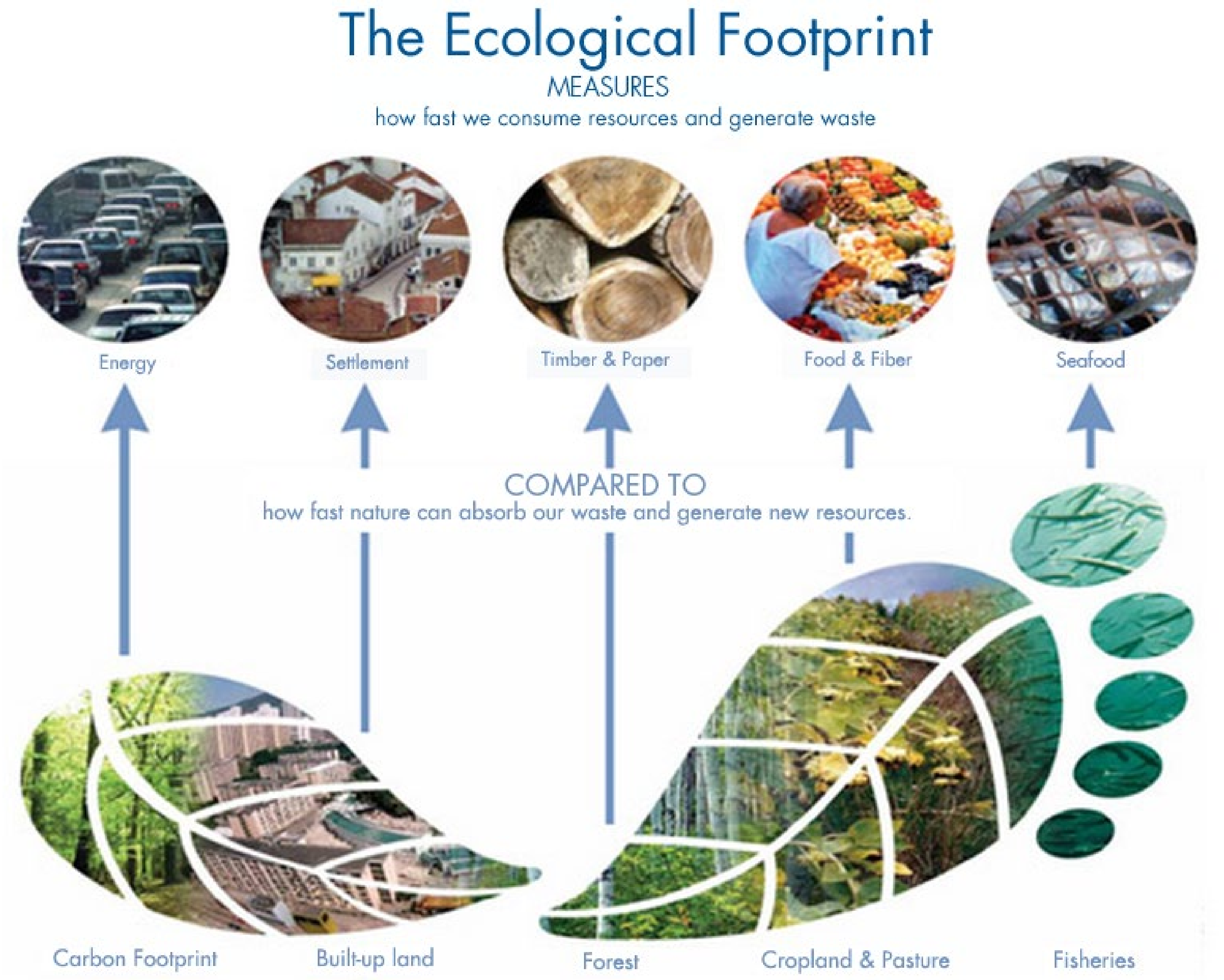
Did you know that if everyone lived the lifestyle of the average American we would need **five** planets?

Simply put, we are using more than the Earth can provide

Today, it takes the Earth one year and six months to regenerate what we use in a year

The ***Global Footprint Network*** has created a topflight instrument that measures the amount of environment (in terms of planets) needed to support a particular lifestyle

Its ***Ecological Footprint Calculator*** looks at the balance between biocapacity, which represents Earth's biologically productive land areas, such as forests, cropland, and pastures, and our ecological footprint, or the demand that humans put on nature


The Ecological Footprint
MEASURES
how fast we consume resources and generate waste
Energy
Settlement
Timber & Paper
Food & Fiber
Seafood
COMPARED TO
how fast nature can absorb our waste and generate new resources.
Carbon Footprint
Built-up land
Forest
Cropland & Pasture
Fisheries

Global Footprint Network®

Earth Overshoot Day 2022 is July 28

WHAT IS YOUR

Ecological Footprint?

How many planets do we need if everybody lives like you?

When is your personal Overshoot Day?

TAKE THE FIRST STEP

RESULTS

Your personal Earth Overshoot Day is:

21. Mar

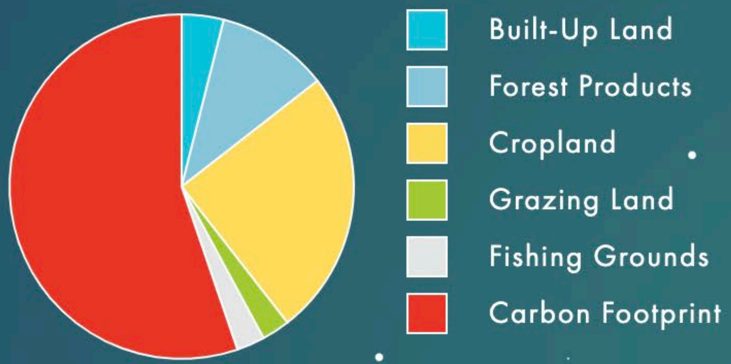
If everyone lived like you, we would need

4.6 Earths

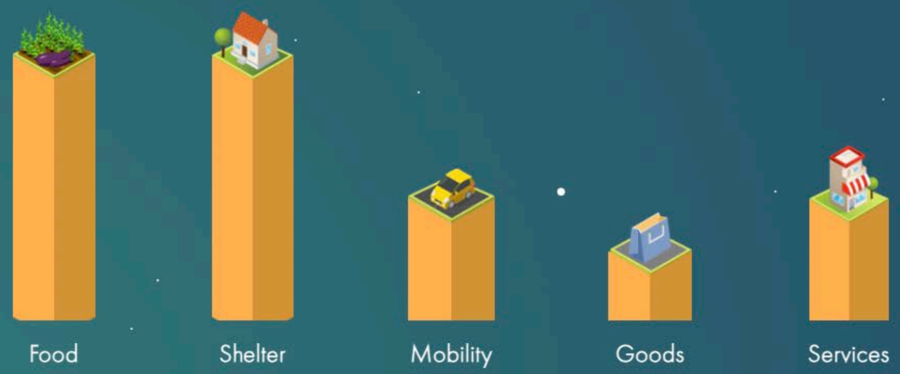
Why can't I get my Footprint score within the means of one planet?

See Details

By Land Type



By Consumption Category



7.5 Your Ecological Footprint (global hectares or gha)

12.2 Your Carbon Footprint (CO_2 emissions in tonnes per year)

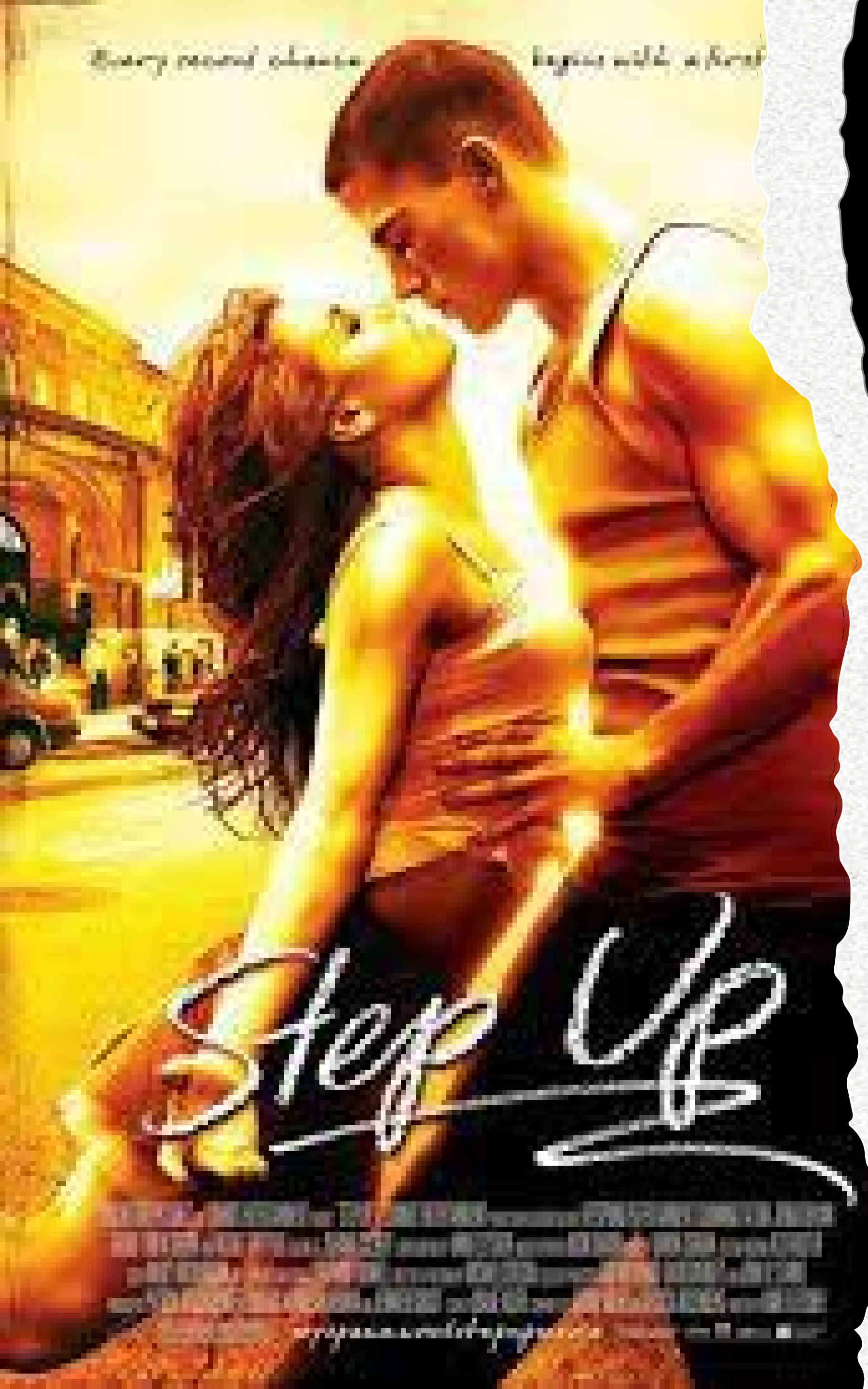
56 Your Carbon Footprint (% of your total Ecological Footprint)

How Do You Feel?

#movethedate

INITIATIVES

- Reduce direct power consumption and improve energy efficiency
- Reduce indirect emissions through sustainable use of materials and circular economy
- Digital tools and software support “dematerialization” by enabling the creation of virtual resources that deliver maximum value with minimum resources
- Drive a shift from resource-intensive clinical facilities to networked lower-cost settings and the home, thereby giving more people access to care
- Support preventive care and telehealth, or virtual care, by enabling remote interaction between patients and care givers, thus avoiding the related travel and CO2 emissions
- Radically optimize care along care pathways



INITIATIVES

Step up our action together

Liver transplantation in Jehovah's Witnesses

Case 1

- OS, male, 57 years
- HCV-RNA+ cirrhosis
- Severe portal hypertension with refractory ascites
- The patient was referred to bridging TIPS prior to LT
- Did not declare his faith prior to TIPS
- TIPS was performed uneventfully

Case 1

- 3 months after TIPS, the patient declared his faith
- He underwent LT with no RBC utilization
- The patient died 7 years after LT due to chronic graft rejection (immunosuppressive drug non-adherence)

Case 2

- MM, male, 54 years
- HCV-RNA+ cirrhosis
- The patient consented to LT
- At surgery, hypertensive pneumothorax with cardiogenic shock
- 50 RBC/FFP/PLT transfused
- The patient survived surgery and died to Enterococci infection on day 40

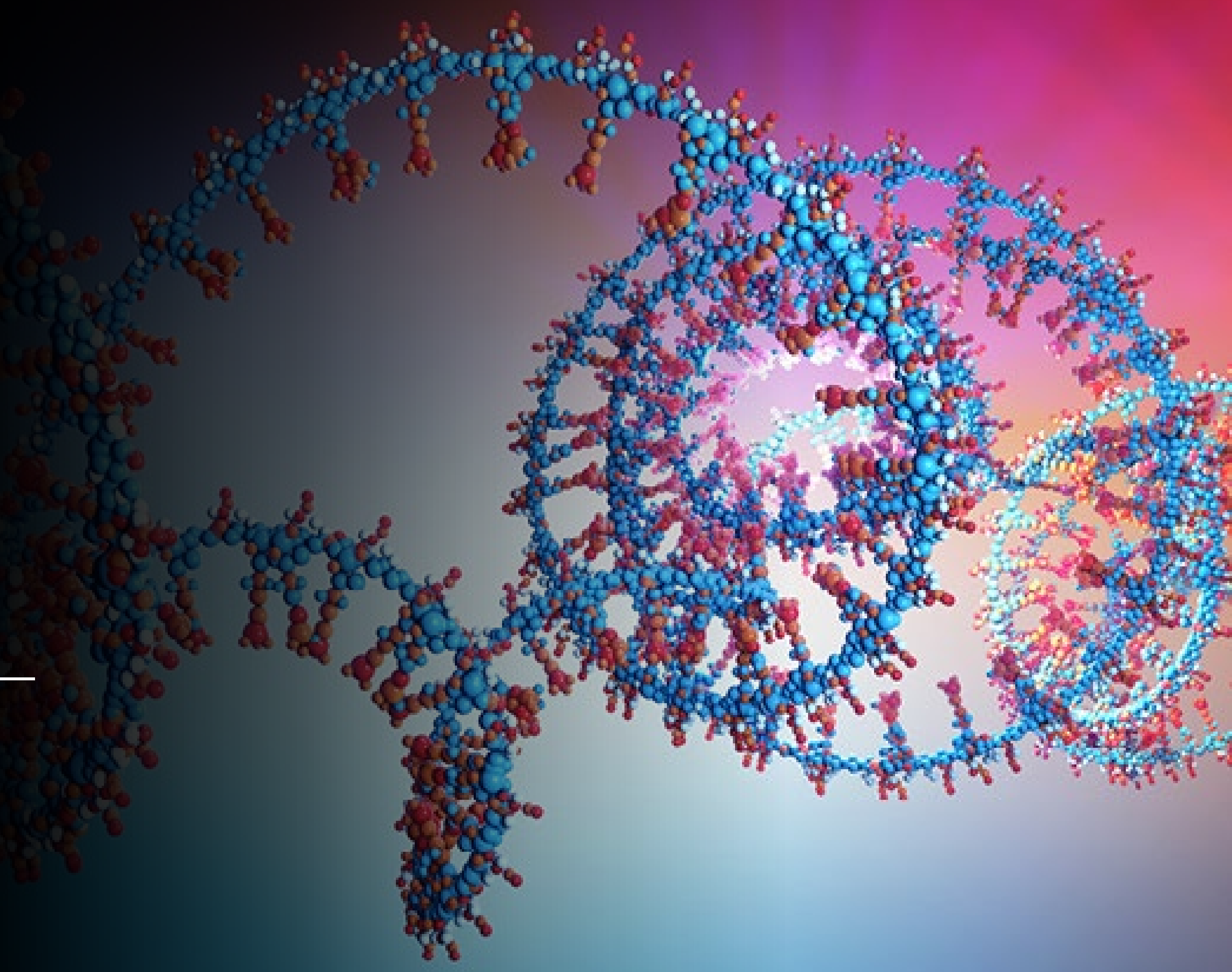
Case 3

- JK, female, 32 years
- HBV-related ALF, intubated, ventilated, on RRT
- Her husband consented to LT
- Bloodless LT (lowest Hgb 5g/dL)
- Died 10 days after LT due to sepsis

The lessons learned

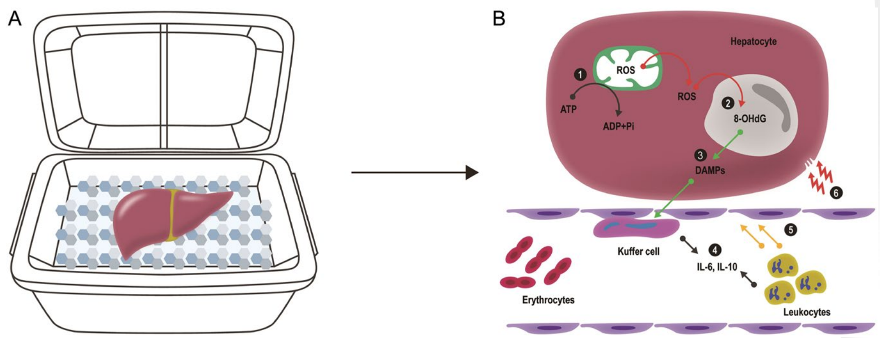
- There is huge variability across JW with regard to consent to blood transfusions
- All dimensions of care should be explored and discussed

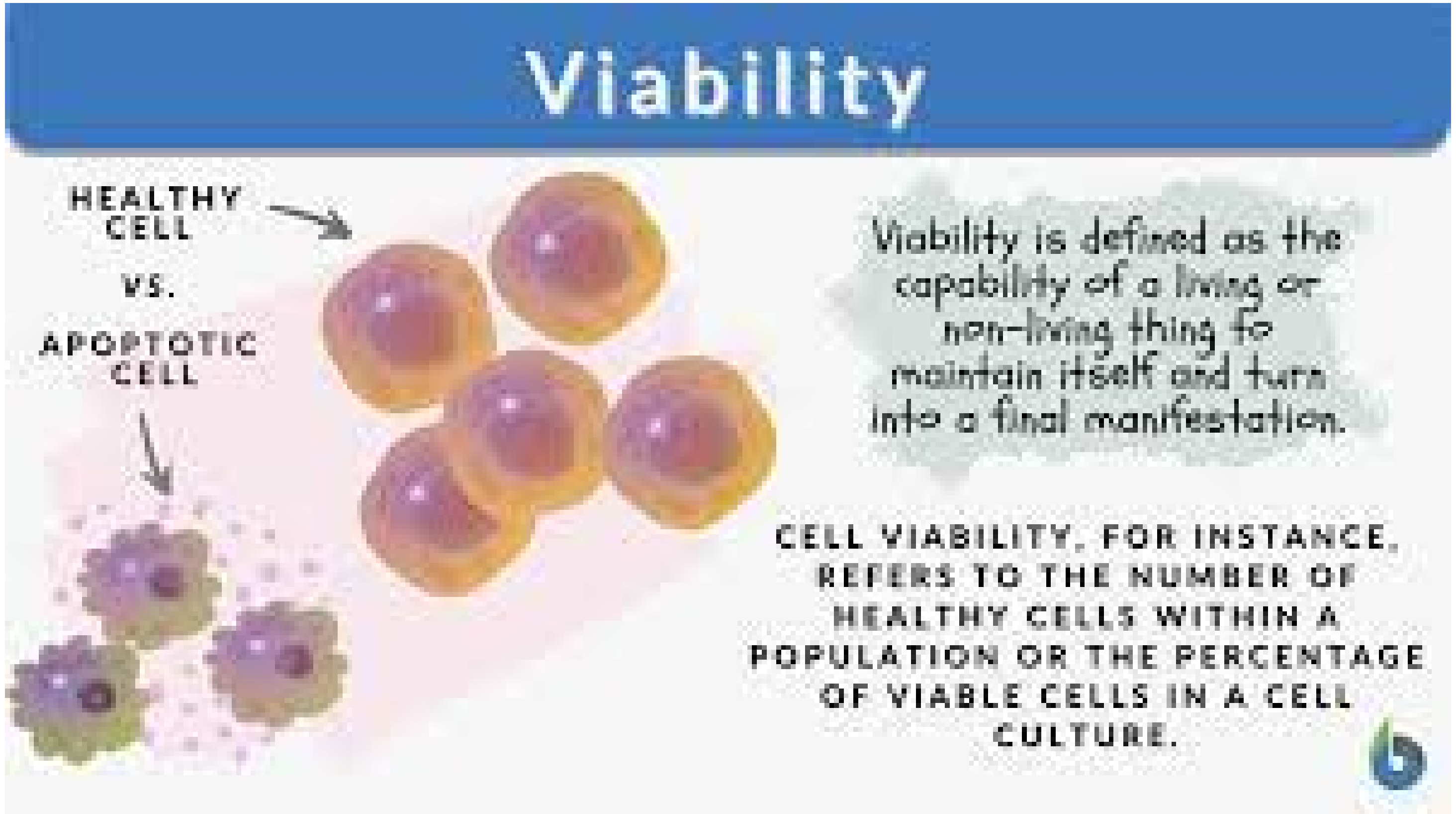
NORMOTHERMIC MACHINE PERFUSION



Paolo De Simone, MD PhD
Hepatobiliary surgery and liver transplantation
University of Pisa Medical School Hospital
Pisa

THE NMP CONUNDRUM





Author, Year, Ref	Country	*n*	Viability Parameter	End-Point	Threshold
Ravikumar et al., 2016 [7]	UK	20	Perfusate pH, bile production	30-day graft survival	Stable arterial and portal flow; pH beetwen 7.2 and 7.4 without correction; bile production
Mergental et al., 2016 [32]	UK	6	Perfusate lactate, pH, glucose metabolism, bile production	ITU stay, in-hospital stay	Within 3 h of NMP: Lactate clearance to <2.5 mmol/L or evidence of bile production combined with at least two of the following criteria: 1. Perfusate pH > 7.30 2. Hepatic artery flow >150 mL/min and portal vein flow > 500 mL/min 3. Homogenous perfusion with soft parenchyma consistency
Bral et al., 2017 [9]	Canada	9	Perfusate lactate, pH, transaminases, bilirubin Bile production	Primary: 30-day graft survival Secondary: Patient survival at day 30, peak serum transaminase AST in first 7 days, EAD incidence in first 7 days, liver biochemistry in serum on days 1–7, 10, and 30, major complications defined by Clavien-Dindo score ≥3, patient and graft survival at 6 months, biliary complications at 6 months	pH, Lactate, ALT, AST, bilirubin, perfusion vascular stability, hourly bile production
Watson et al., 2018 [11]	UK	47	Perfusate lactate, pH, transaminases, glucose metabolism Bile production, bile pH, bile glucose	PNF, EAD, biliary complications	1. Peak lactate fall ≥ 4.4 mmol/L/kg/h 2. ALT<6000iU/Lat2h 3. Maximum bile pH > 7.5 4. Bile glucose ≤ 3 mmol/L or 10 mmol less than perfusate glucose 5. Maintain perfusate pH > 7.2 with ≤30 mmol bicarbonate supplementation 6. Falling glucose beyond 2 h OR perfusate glucose < 10 mmol/L with subsequent fall during challenge with 2.5 g glucose
Ghinolfi et al., 2018 [12]	Italy	10	Perfusate lactate	Graft and patient survival at 6 months	1. Lactate downtrend 2.S table flow 3. Acceptable gross appearance with uniform vascularization.

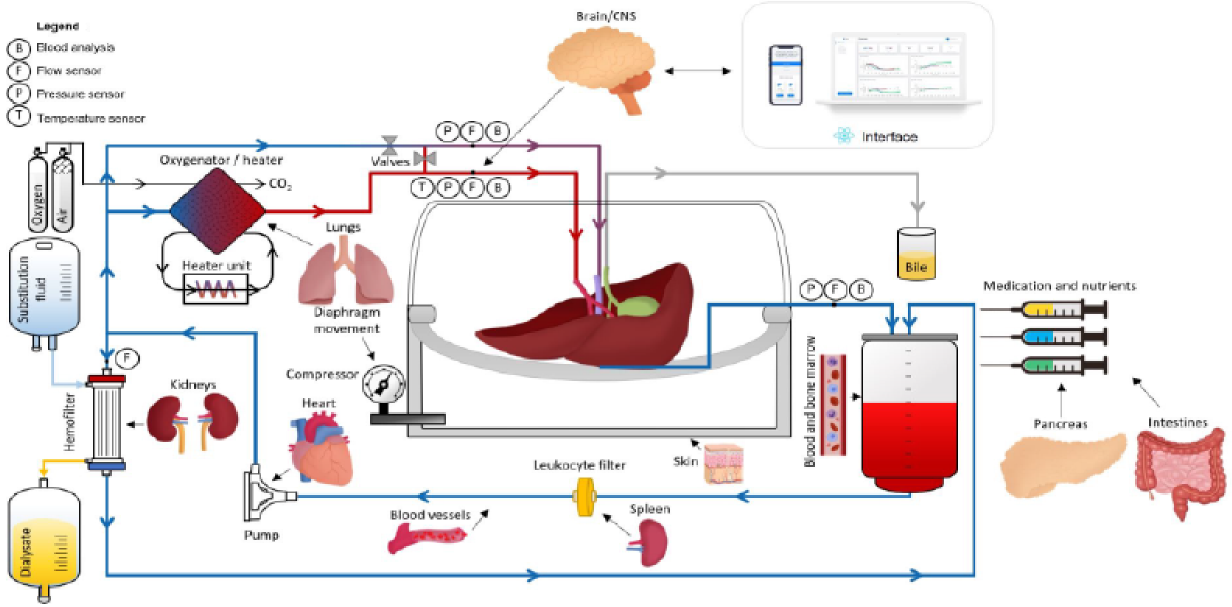
American Journal of Physiology
GASTROINTESTINAL AND LIVER PHYSIOLOGY
Am J Physiol Gastrointest Liver Physiol 322: G183–G200, 2022.
First published November 10, 2021; doi:10.1152/ajpgi.00257.2021

REVIEW

Long-term normothermic machine preservation of human livers: what is needed to succeed?

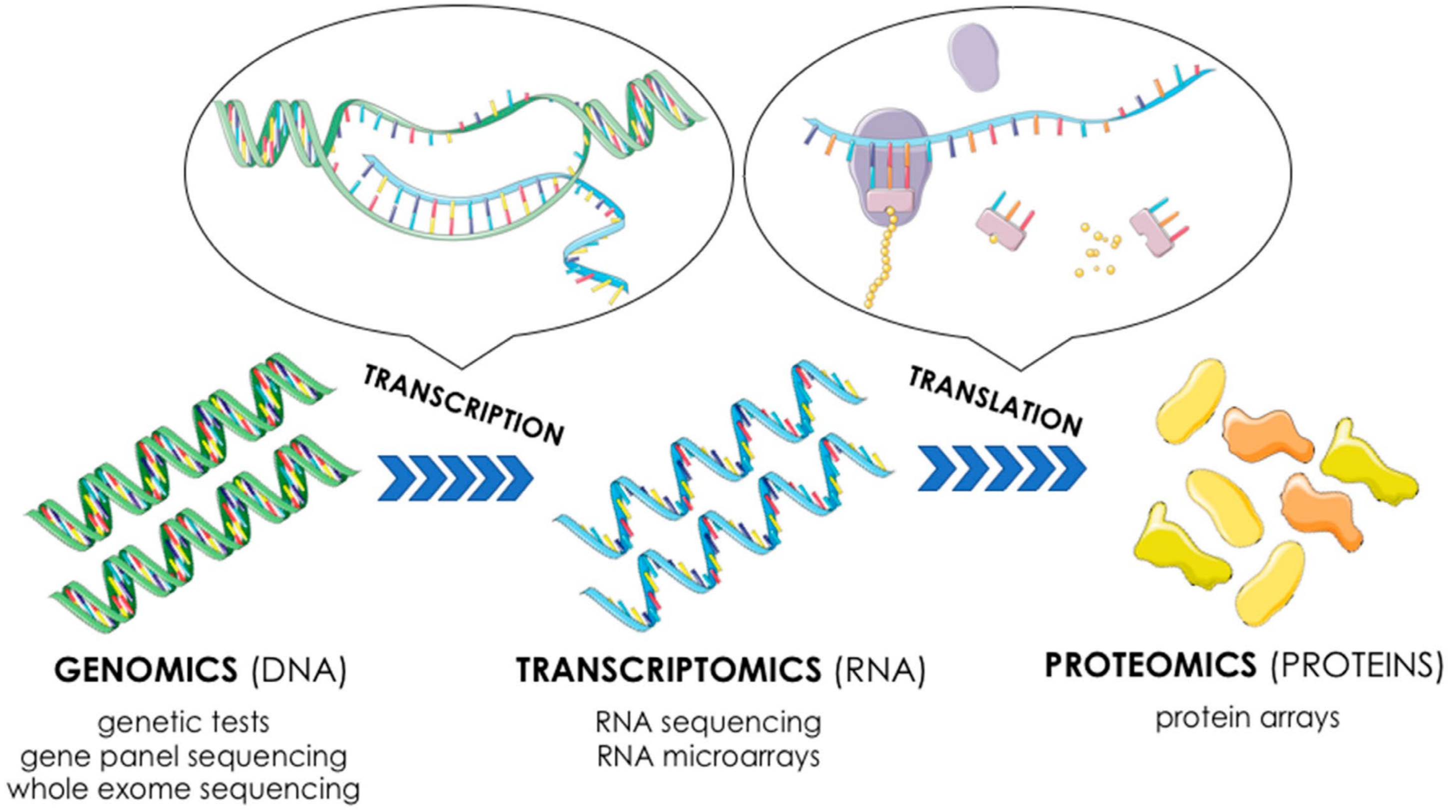
Bianca Lascaris,[1] Adam M. Thorne,[1] Ton Lisman,[2] Maarten W. N. Nijsten,[3] Robert J. Porte,[1] and Vincent E. de Meijer[1]
[1]Section of Hepatopancreatobiliary Surgery & Liver Transplantation, Department of Surgery, University Medical Center Groningen, University of Groningen, Groningen, The Netherlands; [2]Surgical Research Laboratory, Department of Surgery, University Medical Center Groningen, University of Groningen, Groningen, The Netherlands; and [3]Department of Critical Care, University of Groningen, University Medical Center Groningen, Groningen, The Netherlands

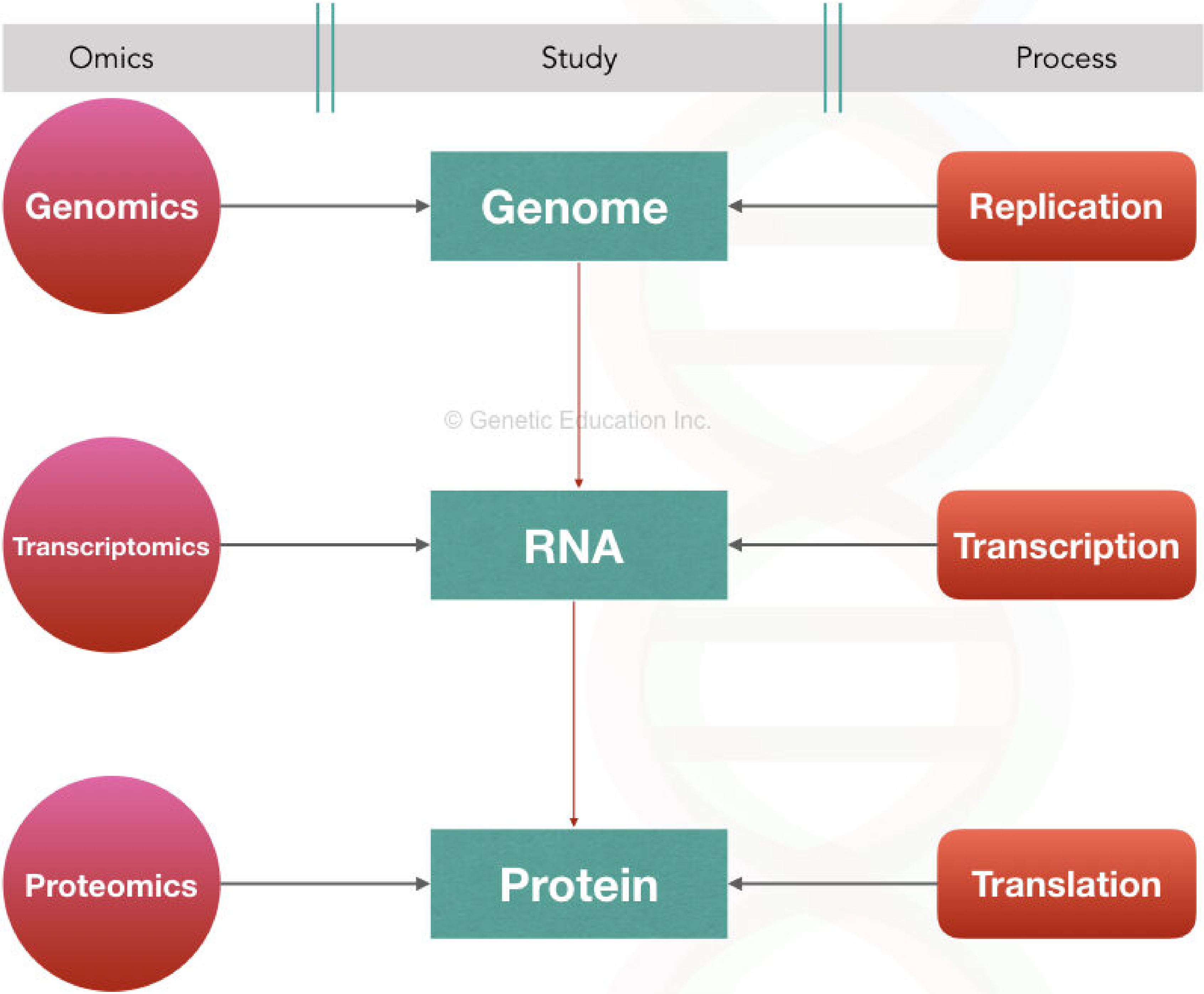
Long-term Normothermic Machine Preservation of human livers: *What Is Needed To Succeed?*



To accomplish long-term (>24 h) normothermic *ex-situ* liver preservation the perfusion machine should mimic the human body by integrating multiple core physiological functions.

NMP & TRANSCRIPT OMICS



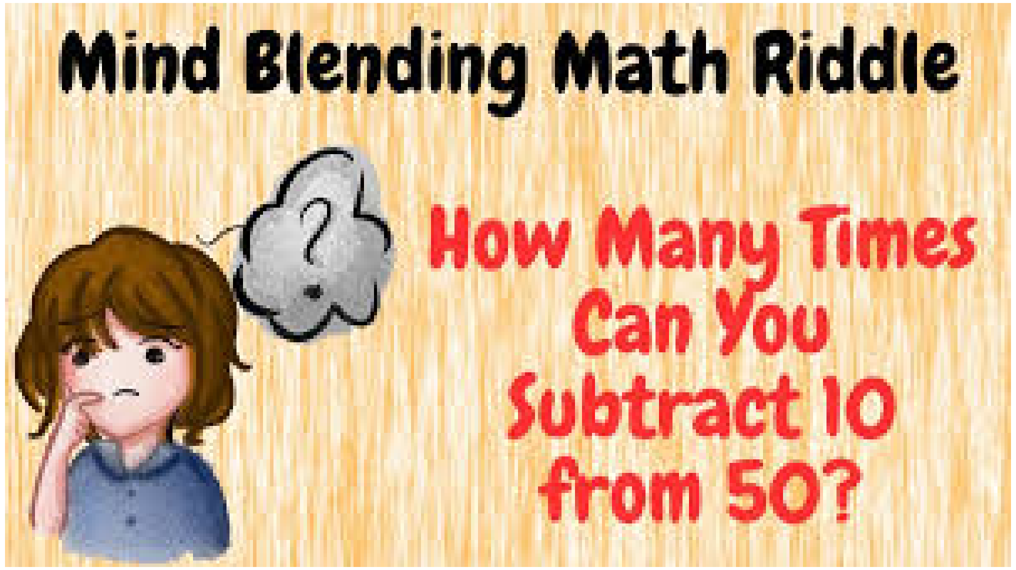

Omics
Study
Process
Genomics
Genome
Replication
© Genetic Education Inc.
Transcriptomics
RNA
Transcription
Proteomics
Protein
Translation

TRANSCRIPTOMICS

- Transcriptomics is the study of the ‘transcriptome,’ a term now widely understood to mean the ***complete set of all the ribonucleic acid*** (RNA) molecules (called transcripts) expressed in some given entity, such as a cell, tissue, or organism
- Transcriptomics encompasses everything relating to RNAs, and this includes their transcription and expression levels, functions, locations, trafficking, and degradation
- It also includes the structures of transcripts and their parent genes with regard to start sites, 5′ and 3′ end sequences, splicing patterns, and posttranscriptional modifications
- Transcriptomics covers all types of transcripts, including messenger RNAs (mRNAs), microRNAs (miRNAs), and different types of long noncoding RNAs (lncRNAs).

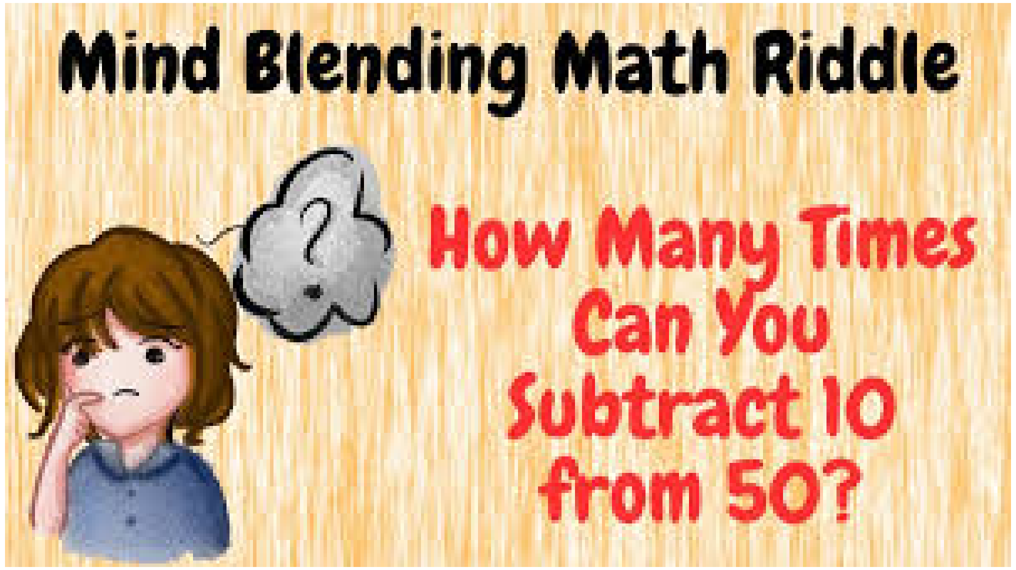
TRANSCRIPTOMICS CAN HELP SOLVE THE RIDDLE

- Characterize different states of cells (i.e. development stages), tissues or [cell cycle phases]() by expression patterns
- Explore the molecular mechanisms underlying a phenotype
- Identify biomarkers differently expressed between the diseased state and healthy state
- Distinguish disease stages or subtypes (e.g. cancer stages)
- Establish the causative relationship between genetic variants and gene expression patterns to illuminate the etiology of diseases



TRANSCRIPTOMICS CAN HELP SOLVE THE RIDDLE

- Which molecule(s) is (are) a hallmark of liver graft repair/regenerative capacity?
- Which set of molecules indicate a poor prognosis (graft failure) or a good therapeutic response (graft function)?
- Which genes and pathways respond to gene perturbations and treatments?



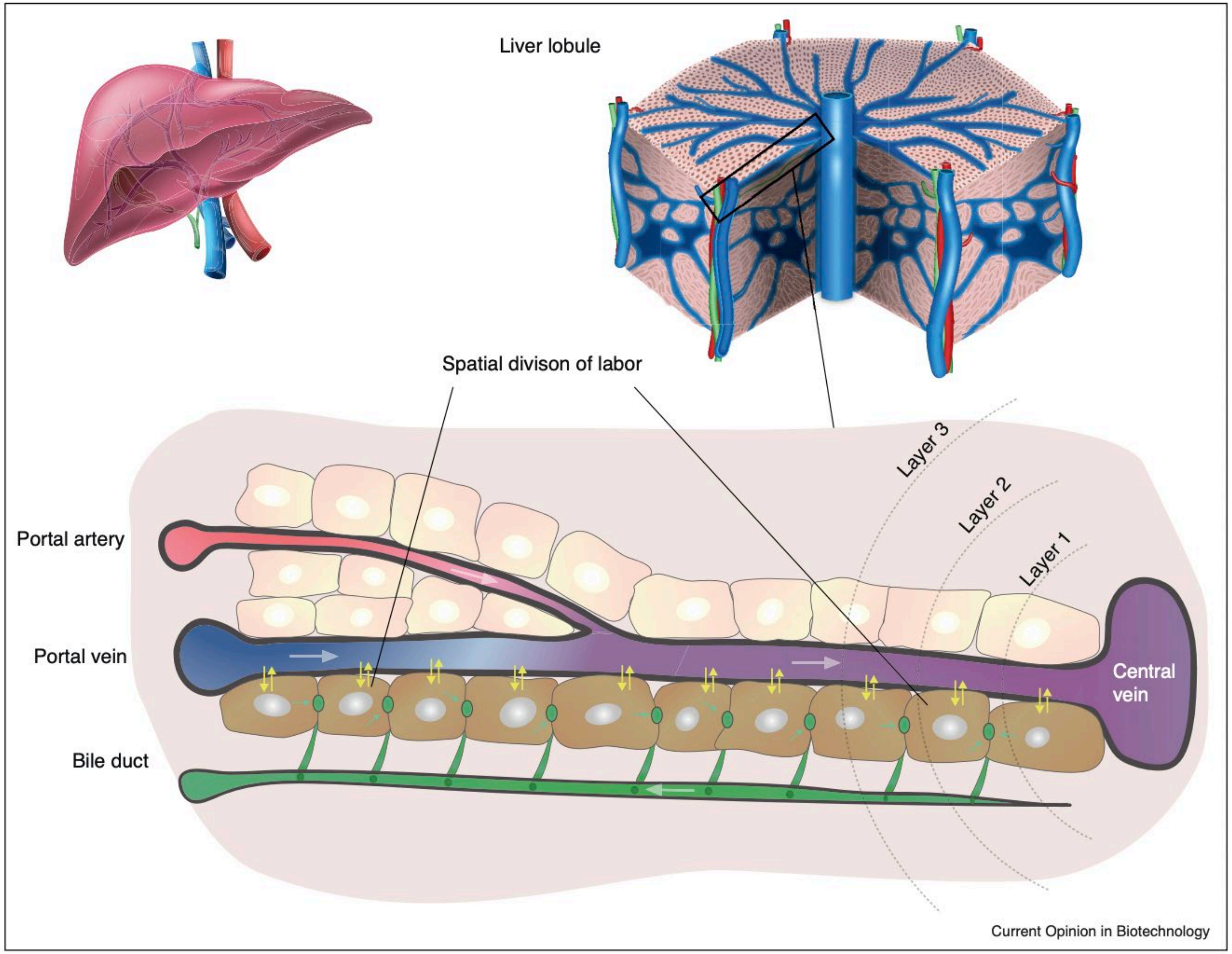
Spatial Transcriptomics

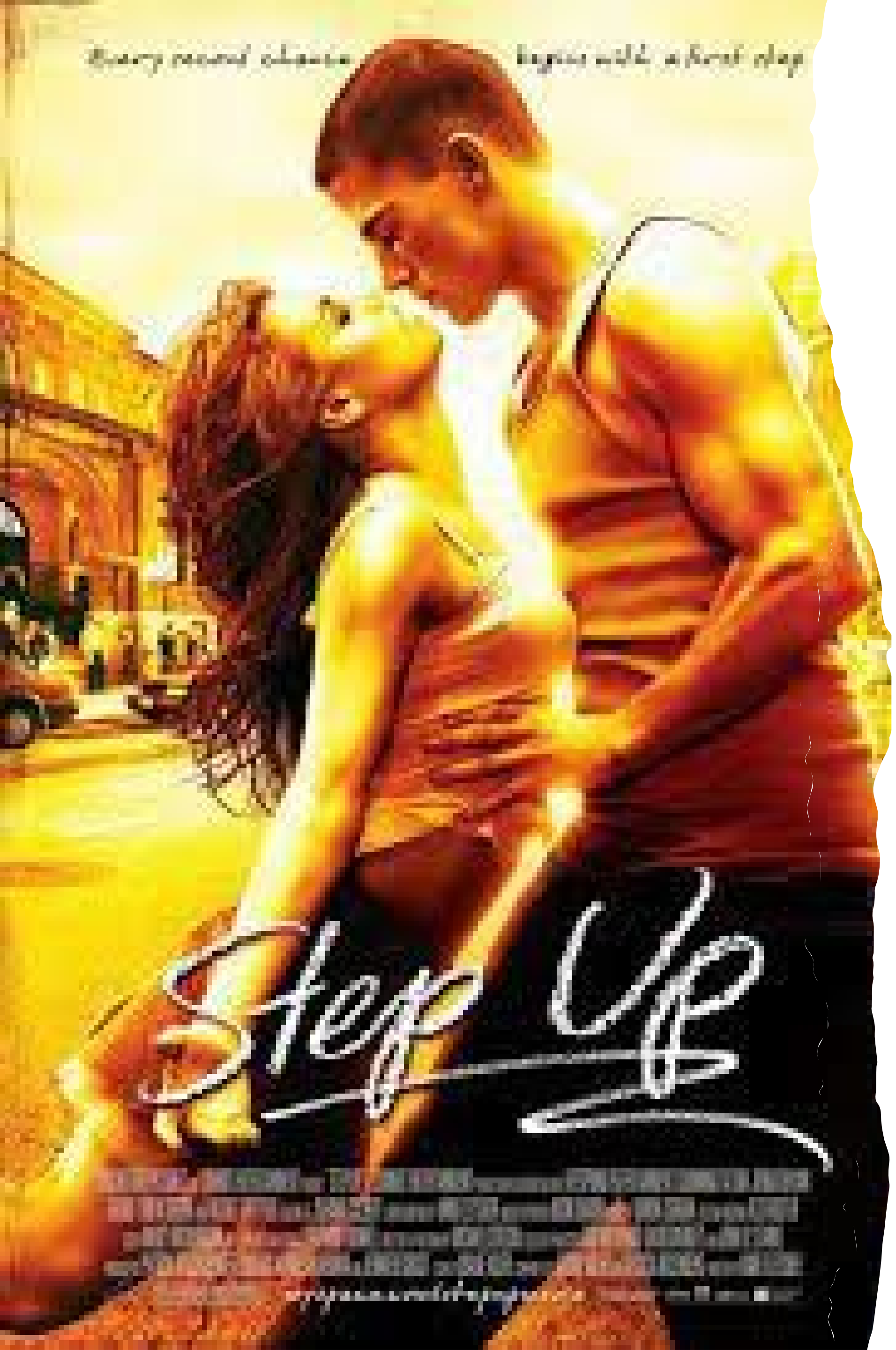
- Transcript analysis can be spatially resolved (located)
- Provides information on sites of phenotype activation
- Can help locate repair/regenerative process

Available online at www.sciencedirect.com
ScienceDirect
Current Opinion in Biotechnology

Spatial transcriptomics: paving the way for tissue-level systems biology

Andreas E Moor and Shalev Itzkovitz





INITIATIVES

Step up our action together