FDA Approvals of Aging Therapies Have Started: The Motivation for, Status of, & Path to Eliminating Aging

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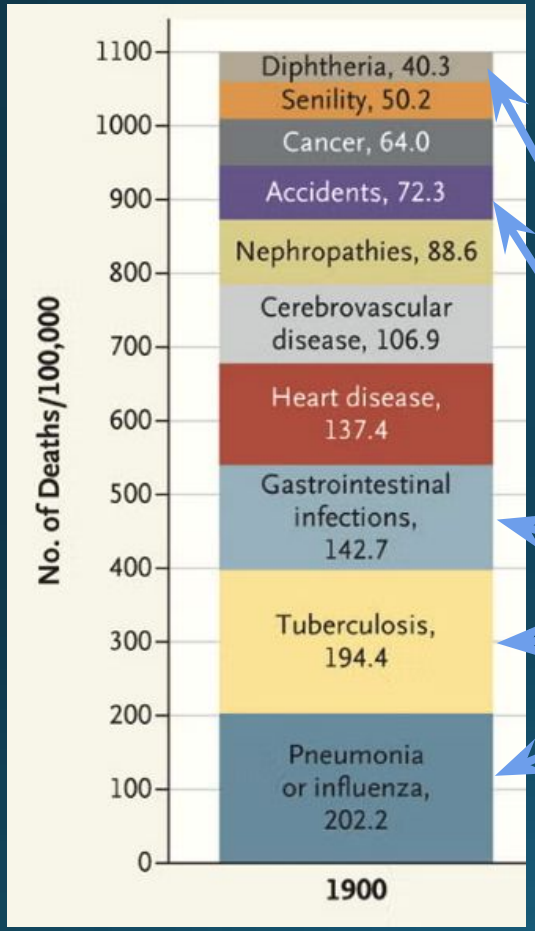
These slides: https://tinyurl.com/AgingPipeline26 or QR:

https://www.linkedin.com/in/karl-r-pfleger/ (Investments disclosed on LinkedIn.)
https://x.com/KarlPfleger

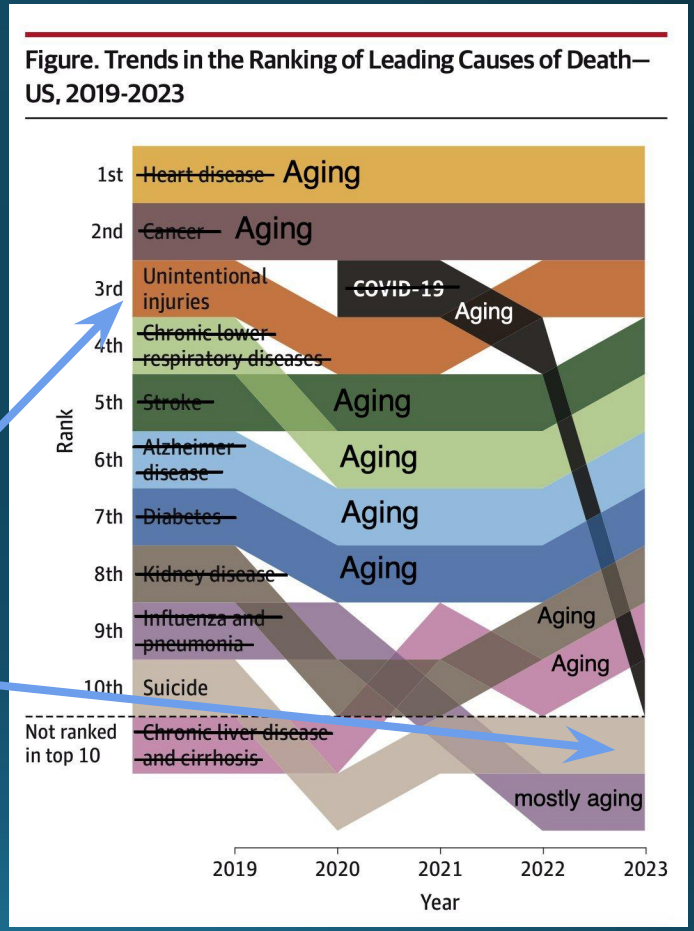
Background: motivation

(9 min)

Top causes of death in 1900 vs. now



not primarily caused by aging (at that time)



1900: half of top 10 not age-related, including the top 3 (all infectious)

now: 9 of top 10 age-related (suicide dropping to #11), with many major infectious diseases largely eliminated

This talk is about doing the same to aging: largely eliminating it.

Simplified capsule history of medicine

antiquity: mystical disease explanations & made up theories (eg “bad humors”)

pre-modern: germ theory, microscopes, chemistry

modern: therapies created by scientific research that discovers how symptoms relate to disease-specific biology/chemistry, for which interventions are developed

With a few exceptions, medicine reactively treats diseases after they start (& even in cases where medicine is preventative (vaccines, statins), most treatments are specific to 1 disease)

Scientific understanding often proceeds backwards along causal chains:

Capsule history of medicine

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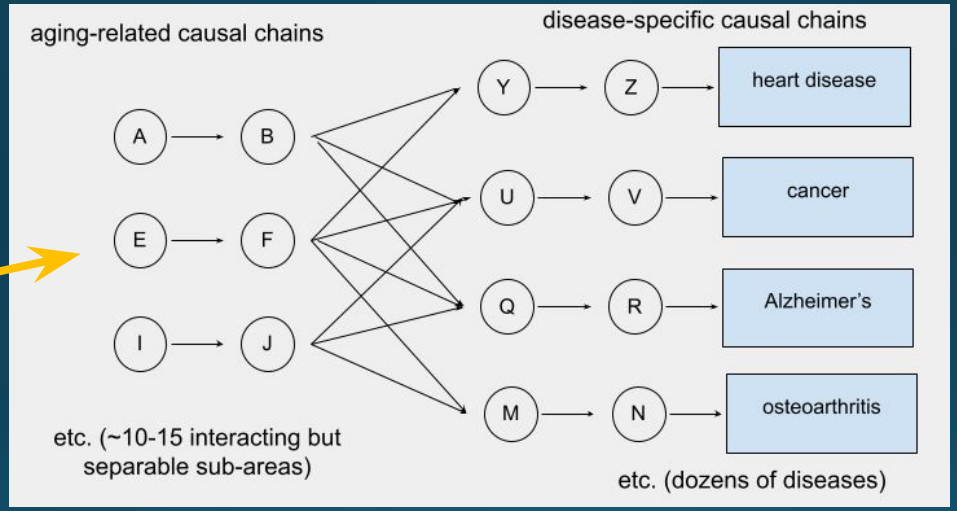
Scientific understanding often proceeds backwards along causal chains:

The geroscience ~~hypothesis~~ paradigm

Backward causal science eventually found shared causes of multiple diseases



interfering with any of these can help mitigate multiple age-related diseases

(too many people in the general population still unaware of this!)

The "Geroscience Hypothesis"

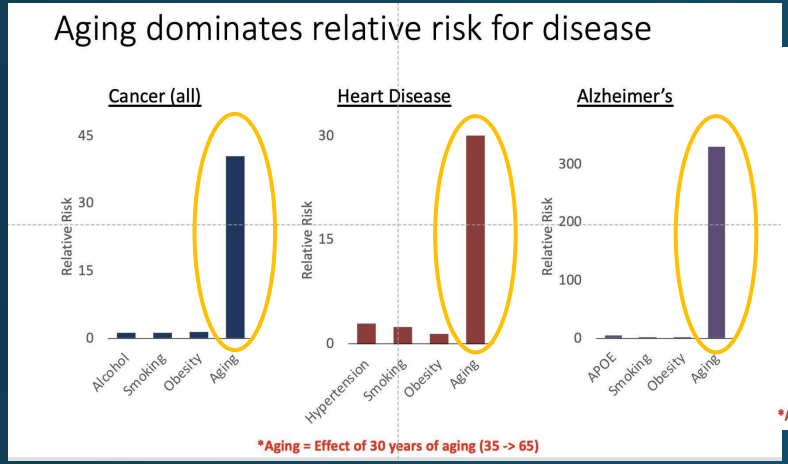
(the north star of the field, *but often forgotten even in the field*)

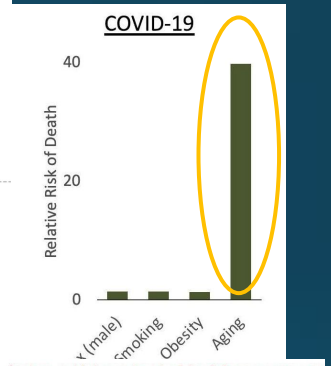
Growing evidence for several decades now,
but only recently (late 2010s) did an aging biotech industry really get going.

Now that it's clear we can interfere with aging itself, it makes clear a:

Huge funding misallocation

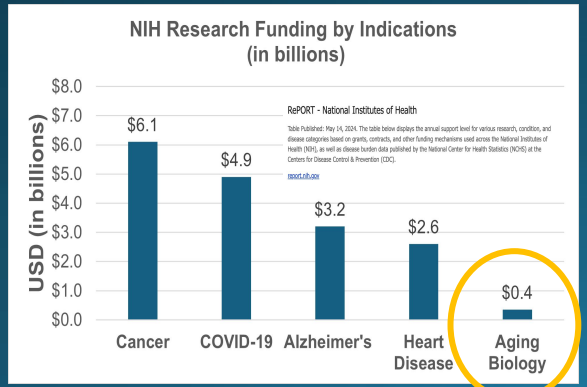
what causes bad diseases & deaths



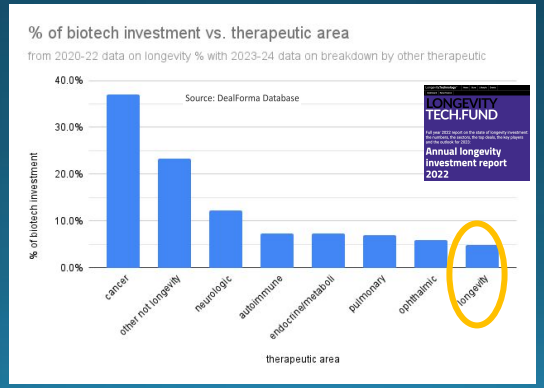


how society allocates R&D $

govt: aging <1% of NIH; cancer gets 10x



venture: aging ~5%, cancer gets ~7.5x



Geroscience motivations

Aging causes 90% of deaths in developed countries,
70%+ globally,
>100,000 deaths/day
(=33 Sept 11 attacks/day, 1-2 Covid pandemics /yr or WW2 every 2-2.5yrs)

Philanthropic:
aging gets small %;
cancer gets 10x+

societal 1yr delay in aging worth $38 trillion (Scott et al, 2021)

Huge funding misallocation

NIH gives only $1/year per American to basic aging research

Aging research gets 80x less per death than cancer research gets

US research funding vs deaths, by cause

NIH research funding of a disease or cause of death in 2024, plotted against annual US deaths from that cause in 2023. Ageing causes over 80% of US deaths, but receives just 0.8% of NIH funding.

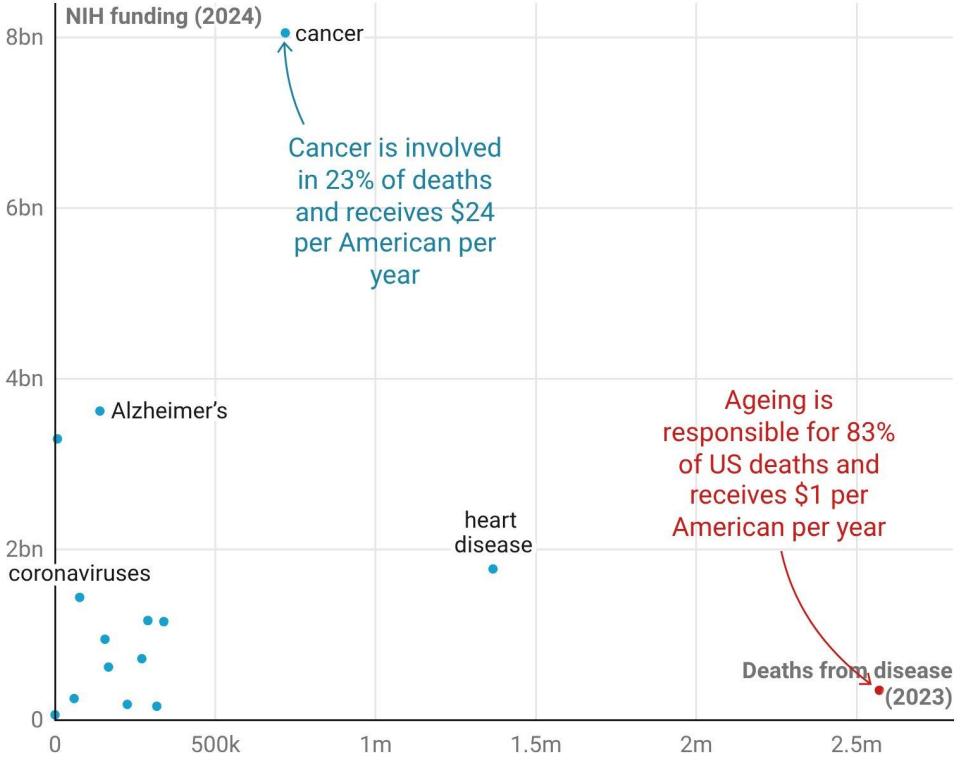


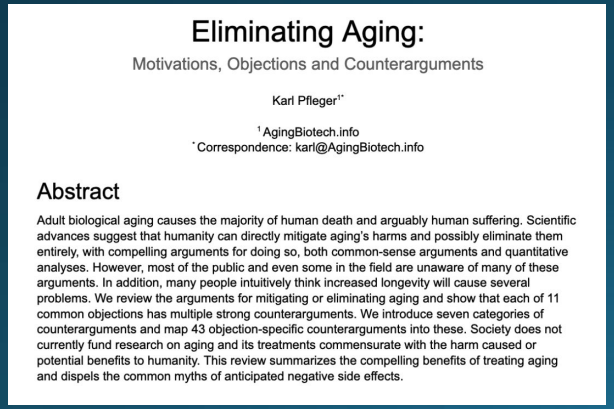
Chart: The Longevity Initiative • Source: RCDC Funding Survey / CDC / analysis by The Longevity Initiative • Created with Datawrapper

Common objections rebutted

Previous slides covered motivations.

There are also objections to the field, but these also have good rebuttals.

New preprint & upcoming book chapter:



Eliminating Aging:

Motivations, Objections and Counterarguments

Karl Pfleger[1*]

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Abstract

Adult biological aging causes the majority of human death and arguably human suffering. Scientific advances suggest that humanity can directly mitigate aging's harms and possibly eliminate them entirely, with compelling arguments for doing so, both common-sense arguments and quantitative analyses. However, most of the public and even some in the field are unaware of many of these arguments. In addition, many people intuitively think increased longevity will cause several problems. We review the arguments for mitigating or eliminating aging and show that each of 11 common objections has multiple strong counterarguments. We introduce seven categories of counterarguments and map 43 objection-specific counterarguments into these. Society does not currently fund research on aging and its treatments commensurate with the harm caused or potential benefits to humanity. This review summarizes the compelling benefits of treating aging and dispels the common myths of anticipated negative side effects.

Most comprehensive/scholarly rebuttals review.

counterargument category → for objection ↓	unlikely	not a problem	ethical perspective	analogy to cancer	net good	reversal test	longevity might help	relationship to other objections
overpopulation	Depends more on fertility rates, which naturally decrease. Underpopulation is now the worry.	We're not close to an upper limit. Adaptation & efficiency gains are possible & likely.	Living people have more right to (continued) life than people who don't exist yet.	If we shouldn't stop trying to cure cancer on population grounds, same applies to aging.	Aging's harms (death, suffering) outweigh harms from overpopulation.	Aging is one of the worst imaginable methods of population control.	Longer lives may improve overall environmental stewardship as people expect to see the results.	Incompatible with only-for-the-rich.
only for the rich	Costs decrease over time, within a generation. Profit margins spread over billions of people.	Even expensive treatments cost less than elder care, so governments will subsidize them.	Morally wrong to withhold things that save lives even if only some people can have them.	Expensive new cancer therapies are cheered as breakthroughs.	Most wealthy would trade wealth for health, showing benefits exceed even high costs.	Imposing aging on the rich if they already had therapies would likely delay wider access.		Incompatible with overpopulation.
long-lived dictators	Globally, the trend is for fewer dictatorships.	Often, dictator death does not end the dictatorship.		Ending cancer R&D to kill dictators isn't advocated.		Condemning billions to death is the worst overthrow plan.		Related to low job turnover.
boredom	Boredom doesn't generally cause death wishes & suicide.	The world becomes less boring over time.	Killing everyone to prevent boredom in some is unacceptable..			Aging is a much worse cure for boredom than other options.	Aging-induced limitations exacerbate boredom.	
slower progress & idea stagnation	Basic desires & universal human drives spur progress not long term future decline & death.	Going slower when one has more time is a luxury, not a problem to be seen as worse.	We don't kill people for producing fewer ideas or not changing their minds.			Aging is a much worse way to spur ideas & faster progress compared to alternatives.	Longer youthful cognition allows wider & deeper knowledge so may create faster progress.	Related to low job turnover (gerontocracy).
longer decrepitude	The current sick care system extends bad health. Treating aging solves this.		We don't kill the decrepit against their will, as demonstrated by current practice.				Treating aging will reduce or eliminate even the current decrepitude.	Related to unsustainable pensions & healthcare costs.
unsustainable pensions / healthcare costs	Same as directly above. Aging & sick-care cause rising healthcare & pension costs.						Eliminating aging will eventually remove the need for pensions & elder care.	Related to longer decrepitude.
unnatural		Unnatural does not imply bad. Many natural things are bad & unnatural good.		Tumors are natural & CAR-T & other cancer treatments are unnatural.				
missing aging's (or death's) good aspects		Experience, wisdom, & the like result from living not aging.	Even if there's a tradeoff, people should have a choice.				Longer longevity should increase wisdom & related good things.	
low job turnover (gerontocracy)	More skilled workers is good for society. New industries will create new jobs.	Wealth, power, & influence will still go to talented & hard working young.				Forced aging & death is a worse policy than forced job turnover.		Related to slower progress & idea stagnation, and to long-lived dictators.
the future will be worse	Objective stats (poverty, health, violence, leisure, GDP/person, …) show the world improving.		Some people's assessment shouldn't condemn others who feel better about the world.			Even a future worse than today would be less bad without aging.		

Table 1: For each of the 11 objections to mitigating aging or increasing longevity, the counterarguments are summarized briefly and categorized into one of seven categories. Each cell in this table corresponds to a specific subsection in the text. Each cell here is necessarily very brief. The corresponding full subsection explains subtleties and in several cases cite references.

Just a few example details:

Overpopulation is unlikely:

70→∞ lifespan change would only raise population by the same amount as a 10% fertility rise.
Fertility naturally declines with economic growth.
#kids/family dropped >50% since 1970s.
Half of humanity now lives in countries with fertility rates <2.

Even expensive therapies won't only be for the rich:

Lifetime 65+ Medicare + support services ~$600-700k in 2055.
Govt saves money by subsidizing therapies where needed.
(Social security roughly doubles the numbers.)

Long-lived dictators don't pass the cancer analogy:

No one advocates ending cancer R&D to kill dictators.

Low job turnover fails the reversal test:

In a world without aging where low job turnover is a problem, creating a pathology that slowly degenerates & tortures everyone for decades before inevitably killing them is a much worse solution than others, e.g.: simple forced job turnover.

[See the chapter coming Sep'26 (or preprint) for references.]

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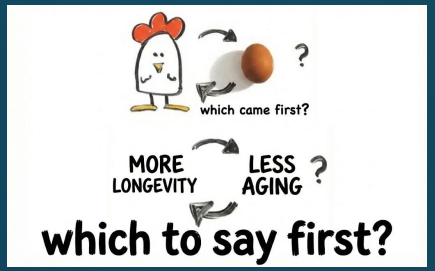
Longevity medicine isn't about getting more of something. It's about treating a pathology.



Aging is the pathology

Longevity is the *side effect* of treatment

scientific field name	path-ology	effect of treating the pathology	NIH institute name	most significant/ cited (conceptual framework) paper	common vernacular	common label is	funding
oncology	**cancer**	overall survival (or progression-free survival)	National **Cancer** Institute	Hallmarks of **Cancer**	**cancer**	the pathology	high
geroscience (or biogerontology)	**aging**	**longevity**	National Institute on **Aging**	Hallmarks of **Aging**	**longevity**	the effect of treating the pathology	low

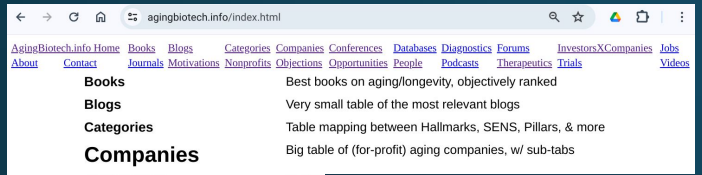
See here for more on this

A focus on mitigating aging pathology avoids hand-wringing about lifespan vs. healthspan.

Field Status,
especially the late clinical stage pipeline

(10 min)

AgingBiotech.info: everything important in the field



focus

academia → biotech → clinic

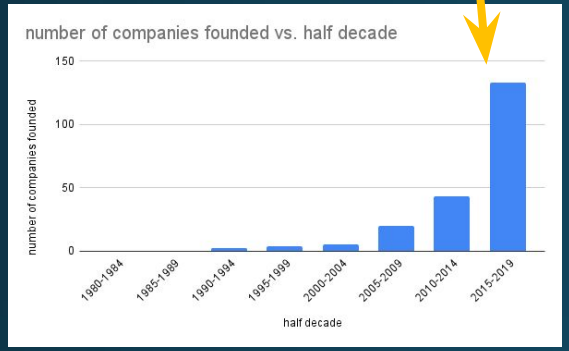
~300 companies + ~200 partial listings

[how to sort/filter] [* = see notes col] [gray = older info]	is it aging?	aging mission?	core aging area?	multiple aging diseases?	core aging cents?	is it rejuvenation?	operating status	short summary (intended to be objective, usually from company website, edited for brevity)	clinical stage (& link to pipeline)	pipeline image [if not clickable, use clin stage link]	Tx or Dx	categories (map to SENS & hallmarks)	diseases/ indications [not comprehensive or canonicalized]	species (beside humans)	clinical trials	targets / pathway / MoAs	modalities	regulatory category	team	geo(s)	public ?
Calico	yes	yes	yes	yes	yes		operating	broad mission to improve health and longevity using technology to advance biological science	ph 2/3 trials (full list of trials)		Tx	big industrial R&D	ALS, cancer, vanishing white matter		10	eIF2B		pharma	Arthur D. Levinson, Cynthia Kenyon	SF	no
BioAge Labs	yes	yes	yes	yes	yes	no	operating	human long-term biobanks + multiomics + AI drug platform for metabolic aging w/ APJ & NLRP3 leads	ph.2 trials		Tx	metabolism, inflammation	obesity, muscle atrophy, neuroinflam		4	APJ, NLRP3	drugs	pharma	Kristen Fortney, Eric Morgen, Paul Rubin	SF	yes
Altos Labs	yes	yes	yes	yes*	yes	yes	operating	cell rejuvenation by partial/epigenetic reprogramming; big & academic-like; aiming to be "Bell Labs" of bio	pre-clinical		Tx, Dx	epigenetic, big industrial R&D				OSKM		pharma	Hal Barron, Rick Klausner, Hans Bishop, Juan Carlos	SF; SD; Cambridge	no
Juvenescence	yes	yes	yes	yes	yes		operating	umbrella company focused on aging w/ both (ketone) supplement & pharma programs (PAI-1, GDF15, CD38, ketones, & plasmalogens, autophagy, liver & limb regen)	commercial, ph.2 trials*		Tx	umbrella company	fibrosis, muscle wasting in cancer, RA, HF, dementia		2	PAI-1, GDF15, CD38,	drugs & others, supplement	pharma, nutraceuticals	Richard Marshall, Greg Bailey, Jim Mellon	London, NYC	no
InSilico Medicine	yes*	yes		yes	yes		operating	AI for drug discovery platform with particular focus on aging diseases	ph.2 trials		Tx	broad platform	IPF, kidneyDs, cancer, Covid		6	TNIK, USP1, QPCTL, PHD, KAT6, 3CLpro	small molecules	pharma	Alex Zhavoronkov, Feng Ren	China, UAE, US, Canada	no
Stealth BioTherapeutics	yes	yes	yes	yes	no	no	operating	mitochondria platform for age & genetic mito diseases; first a peptide to stabilize inner mito membrane	ph.3 trials		Tx	mitochondria	AMD, DMD, ALS, mito-neuroDs		29	cardiolipin	peptides, small molecules	pharma	Reenie McCarthy	Boston	no*
Unity Biotechnology	yes	yes	yes	yes	yes	yes	operating	treat aging, 1st w/ senolytics, esp for eye diseases (knee OA failed); also other programs inc. VEGF & klotho* (partnered)	ph.2 trials		Tx	senescence, klotho	eyeDs, neuroDs		9	Bcl-xL, VEGF, klotho	small molecules, proteins	pharma	Anirvan Ghosh	SF	yes
Alkahest (owned by Grifols)	yes	yes	yes	yes	yes	yes	acquired*, operating independ	leads from blood proteins that go up or down with age, eg young blood fractions	ph.2 trials		Tx	cell communication	AD, PD, wAMD, ESRD MCI		13		drugs, biolog	pharma	Esther Rawner, Tony Wyss-Coray	SF	public owner
Denali Therapeutics	yes*	no*	yes	yes	no		operating	drug discovery for neurodegeneration, optimized for brain delivery, guided by genetics & biomarkers, but also lysosomal storage diseases & systemic inflam.	ph.3 trials		Tx	autophagy, inflammation	PD, FTD, Hunter's, ALS, AD, MS, inflammation		22	iduronate 2-sulfatase, LRRK2,	small molecules, biologics	pharma	Ryan Watts	SF	yes
Life Biosciences	yes	yes	yes	yes	yes	yes	operating	epigenetic reprogramming via OSK and small molecules for chaperone mediated autophagy	pre-clinical		Tx	epigenetic, autophagy	eyeDs, neuroDs			OSK, LAMP2A	gene therapy, small	pharma	David Sinclair, Jerry McLaughlin	Boston	no
Scholar Rock	yes	no	yes	yes	no	no	operating	platform for targeting precursors of growth factors including myostatin & TGFβ	ph.3 trials		Tx	metabolism, inflammation, cancer	muscle atrophy, cardiometabolic, cancer, fibrosis		6	myostatin, TGFβ	monoclonal antibodies	pharma	Jay Backstrom	Boston	yes
Immunis Inc.	yes	yes	yes	yes	yes	yes	operating	stem-cell secretome products for age-driven immune dysfunction, muscle regeneration & metabolism	ph.2a trials		Tx	stem cells	muscle atrophy, wounds, metabDs, neuroDs, immuneDs		1		secretome cocktail	pharma	Hans Keirstead	LA	no
Cambrian Bio	yes	yes	yes	yes	yes		operating	umbrella company focused on aging w/ leads in AMPK, mitochondria, mTOR, & more.	ph.1b trials*		Tx	umbrella company	cardiometabolic, cancer		0*	AMPK, mTOR	drugs	pharma	James Peyer	NYC	no
Juvena Therapeutics	yes	yes	yes	yes	yes	yes	operating	computationally-driven platform based on human stem cell secreted proteins engineered into novel biologics	pre-clinical		Tx	stem cells, cell communication	DM1, obesity, fibrosis, OA				biologics	pharma	Hanadie Yousef, Jeremy O'Connell	z	no
Celularity	yes	yes	yes	yes	no	yes	operating	allogeneic placental-derived cell therapies (MLASCs, CAR-T, NK cells) for aging, degenerative, immune diseases, cancer; also biomaterials	ph.1/2 trials		Tx	stem cells / allogeneic, senescence	cancer, muscleDs, autoimmuneDs		17	MLASCs, CAR-T, NK cells	cell therapy	pharma	Robert Hariri	NYC	yes
Mesoblast	yes	no	yes	yes*	no	yes	operating	allogeneic mesenchymal stem cells for multiple (esp inflammatory) diseases	ph.3 trials*		Tx	stem cells / allogeneic	HF, deg-discD, Covid (& non-agingDs)		42	MSCs	cell therapy	pharma	Silviu Itescu	NYC, Melbourne	yes
Rubedo Life								target pathological cells that drive aging, esp senescent cells, using AI, single cell seq, & precision targeting					AD, psoriosis, IPF, NASH, cancer,				small				

Scope is effectively things that embody the geroscience hypothesis (as primary focus)

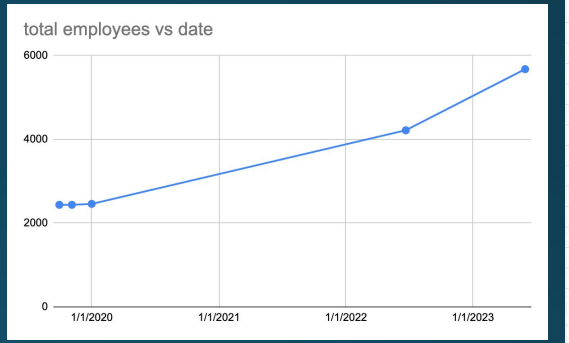
Aging biotech started in earnest late 2010s…

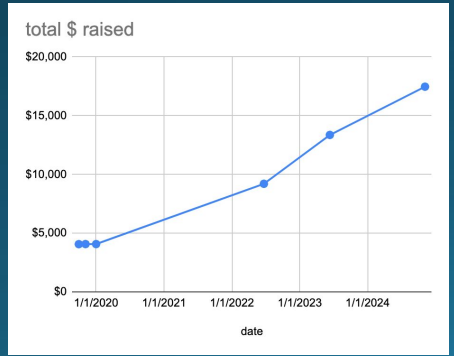
Then steady growth & clinical progress for 5 years, but not yet exponential

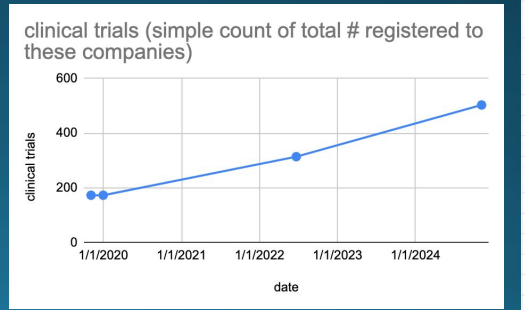


(as of 2024 Nov)

Data from AgingBiotech.info.







	most advanced trial phase		
company	1/1/2020		11/5/2024
Alector	2	↗	3
Alkahest	2		2
Athersys	3		3
BioAge	pre-clinical	↗	2
Biophytis	2	↗	3
Bioquark	1	↘	defunct
Biosplice (was Samumed)	3		3
Calico	pre-clinical	↗	3
Cerevance	1	↗	3
CohBar	1		1
Denali	1	↗	3
Eidos	3		3
GEn1E Lifesciences	pre-clinical	↗	2
Genome Protection	2	↘	defunct
GenSight	3		3
InSilico Medicine	pre-clinical	↗	2
Intervene Immune	pre-clinical	↗	2
Longeveron	2		2
Longevity Biotech	1		1
LyGenesis	pre-clinical	↗	2
Mesoblast	3		3
Minovia	2	↘	1
Navitor	1	↗	2
Pentraxin	2		2
PharmatrophiX	2		2
Proclara	1		1
Proteostasis Tx / Yumanity	2	↘	defunct
resTORbio	3	↘	defunct
Retrotope	3	↘	defunct
Stealth BioTherapeutics	3		3
Vaxxinity (was United Neuro)	2	↗	3
Unity Bio	1	↗	2
regressed or failed		6	
progressed		13	
progressed by 2+ steps		6	
defunct	0		5
pre-clinical	6		0
1	8		4
2	10		11
3	8		12
total	32		32

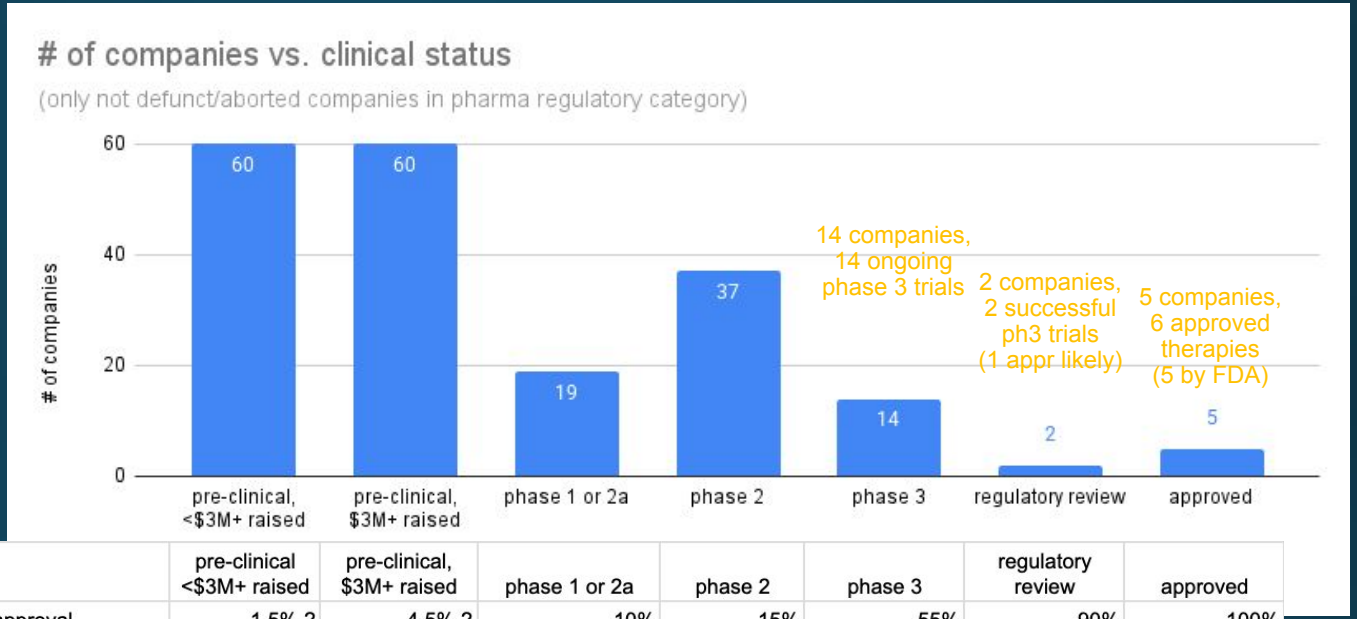
Not shown but happening: conferences increasing, journal impacts increasing, media coverage, etc.

Poll:

How long do you think it until aging is largely eliminated as a cause of death & driver of chronic disease?

The next 5-10yrs look exciting

(as of 2025 Nov)



	pre-clinical <$3M+ raised	pre-clinical, $3M+ raised	phase 1 or 2a	phase 2	phase 3	regulatory review	approved
success rate to approval	1.5% ?	4.5% ?	10%	15%	55%	90%	100%
better for non-onco trials			14%				
expected approvals, based on 1 trial per company	1	3	3	6	8	2	6
expected approvals based on counting # individual trials that still have a chance of success					8	2	6
avg time left to approval	8-9yrs	7-8yrs	4.5-5.5yrs	3-4yrs	2-3yrs	<1yr	0

increasing uncertainty

This omits: supplements, diagnostics, veterinary, & trials from companies not aging focused (so underestimates)

[List of approvals & ph3 trials]

Ph.3 trials MoAs generalize

- 3 approved: ATTR treatments (5 if also including from non-aging companies)
- 1 approved (3 inc. Asia) + 4 trials: stem cells (most allogeneic)
- 1 (accelerated) approved + 1 trial: mitochondria MoAs (cardiolipin, ND4)
- 1 met ph3 endpoint (but approval delayed) + 1 trial: anti-myostatin mAb
- 1 met ph3 endpoint (but switching indications): MAS receptor (affects mTOR & AMPK)
- 3 trials: FGF21 mimetic
- 1 trial: NLRP3 (inflammation: IL-1β & IL-18)
- 1 trial: ISR—integrated stress response (proteostasis)
- 1 trial: PGRN—progranulin
- 1 trial: GPR6

These should all be relevant for diverse age-related diseases, embody the geroscience hypothesis.

This is quite different from most of prior biopharma.

Ph3 trials: AgingBiotech.info/trials top row link

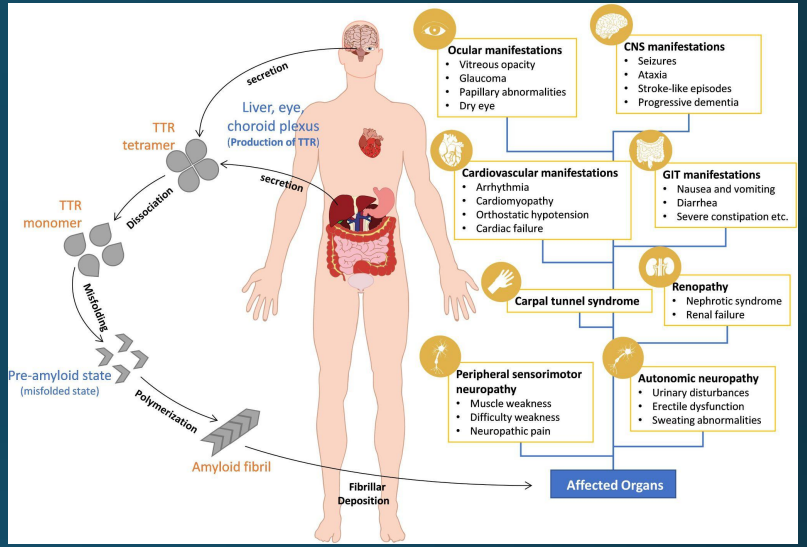
approval status / stage	trials (& link)	# ph3 trials w/ chance of success	company	phase	indication (disease)	indication age related?	target / pathway / MoA [colors in these columns show commononality of target/MoA]	potential for label expansion or off-label prescribing for multiple age-related diseases?	intervention [colors show commonality]	study completion	FDA approval date	ClinicalTrials.gov ID	as of	notes
approved	5 ph3 trials, inc ACT-EARLY		Eidos/BridgeBio	approved	hATTR, ATTR, ATTR-CM	yes, some	ATTR (Transthyretin Amyloidosis), TTR stabilizer	yes, implicated in several areas (also hearing loss)	acoramidis (Attruby)		2024-11-22		2025-02-07	1 of several approved ATTR tx, inc. (not in this table) Pfizer's tafamidis (Vyndaqel or Vyndamax) & Ionis's inotersen (Tegsedi).
approved	3 ph3 trials, inc HELIOS-A, HELIOS-B		Alnylam	approved	hATTR, ATTR, ATTR-CM	yes, some	ATTR (Transthyretin Amyloidosis), RNAi TTR suppressor	yes, implicated in several areas (also hearing loss)	vutrisiran (Amvuttra)		2022--06-13		2025-02-07	1 of several approved ATTR tx, inc. (not in this table) Pfizer's tafamidis (Vyndaqel or Vyndamax) & Ionis's inotersen (Tegsedi).
approved	5 ph3 trials (3 completed), inc APOLLO, HELIOS-A		Alnylam	approved	hATTR, ATTR, ATTR-CM	yes, some	ATTR (Transthyretin Amyloidosis), RNAi TTR suppressor	yes, implicated in several areas (also hearing loss)	patisiran (Onpattro)		2018-08-10		2025-02-07	1 of several approved ATTR tx, inc. (not in this table) Pfizer's tafamidis (Vyndaqel or Vyndamax) & Ionis's inotersen (Tegsedi).
approved	approved 2012 in S. Korea		Medipost	approved	OA (knee)	yes	cord-blood-derived MSCs	yes, for a wide range of age-related diseases	CARTISTEM		Korea 2012 (US & Japan in ph.3)		2025-09-11	
approved	8 ph3 trials (all completed)		Mesoblast (remestemcel)	approved	GVHD	no	allogeneic mesenchymal lineage stem cells	yes, for a wide range of age-related diseases	remestemcel-L (Ryoncil, was called Prochymal)		2024-12-18		2025-02-13	
accelerated approval	4 trials (2 completed)	1	Stealth BioTherapeutics	1 regulatory review, 2 ongoing ph3	Barth Syn, prim mito dis's, dry AMD	no	cardiolipin on inner mitochondria membrane, to stabilize membrane, ↑ATP, ↓ROS	yes, for a wide range of age-related diseases	elamipretide (Forzinity), a peptide also known as SS-31 (used for years by biohackers)				2025-10-01	Sep'25 update: FDA granted accelerated approval for Barth Syndrome. May'25 upadte: FDA rejected approval for Barth after positive phase 3 data & their own advisory committee voted to approve. But Stealth still pursuing Barth accelerated approval & phase 3 trials for the other 2 indications still ongoing. More articles & discussion.
successful phase 3 results	SAPPHIRE	1	Scholar Rock	regulatory review	SMA	no	anti-myostatin monoclonal antibody	yes, should help with broad muscle conditions, age-related atrophy, frailty, sarcopenia*	apitegromab (mAb)	2024-12		NCT05156320	2024-12-05	Trial succeeded, met primary endpoint (news article, academic paper). Approval delayed by unrelated manufacturing issues at Novo Nordisk run plant. *And already in phase 1 by Scholar Rock for obesity.
successful phase 3 results	COVA	1	Biophytis	regulatory review	Covid-19 (soon sarcopenia ph3 to start, see notes*)	yes	activate MAS receptor (component of RAS system, affects mTOR & AMPK) to increase resilience	yes, for a wide range of age-related diseases (& in trials for sarcopenia & obesity)	BIO101 / Ruvembri (a small molecule) (formerly called Sarconeos?)	2022-09		NCT04472728	2024-12-06	Trial succeeded, met primary endpoint (reduced incidence respiratory failure or death) ¡44%, significantly: press release, academic paper, but company doesn't seem to be pursuing approval. Not clear what FDA feedback it got. 2023 press release mentioned planning another ph3 and (*)Oct 2025 news says money raised for ph3 for sarcopenia.
phase 3	3: REVERSE, RESCUE, RESTORE & REFLECT	1	GenSight Biologics	3	LHON	no	mito ND4 gene allotopic expression w/ mitoc targeting of mRNA to mito membrane	yes as part of more allotopic expression of mito genes; unclear for just for ND4	GS010 / Lumevoq (gene therapy)	2018-12 to 2022-07		NCT02652780, NCT02652767, NCT03406104, NCT03293524	2025-02-18	Strange set of trials in which early trials treated 1 eye using other as control but control eye vision improved too, leading to failure relative to "control" despite improvement. 5 year followup data showed sustained vision improvement. Company still seems to be pursuing & considering it to be phase 3 per pipeline.
phase 3	ONYX	1	Scholar Rock	3	SMA	no	anti-myostatin monoclonal antibody	yes, should help with broad muscle conditions, age-related atrophy, frailty, sarcopenia	apitegromab (mAb)	2027-01		NCT05626855	2024-12-05	Follow-up trial to their other SMA trials.
phase 3	SYNCHRONY: 3 NASH/MASH related trials	3	Akero Therapeutics	3	NASH/ MASH	yes	FGF21 mimetic	yes, for a wide range of age-related diseases	Efruxifermin (EFX) (biologic protein)	2026-10 to 2032-11		NCT06161571, NCT06528314, NCT06215716	2024-12-06	
phase 3	INFRONT-3	1	Alector	3	FTD (GRN)	yes	progranulin (PGRN), a key regulator of immune activity	yes, based on progranulin relation to immune function & lysosome function & multiple dementias	AL001 / Latozinemab (mAb)	2027-10		NCT04374136	2024-12-06	See also continuation study NCT06111014.
phase 3	TransportNPC	1	Cyclo Therapeutics	3	Niemann-Pick Disease	no	cyclodextrin for cholesterol transport in place of NPC1	yes, and also in phase 2 for AD by Cyclo (& diff cyclodextrin pursued for CVD by Cyclarity)	Trappsol Cyclo (hydroxypropyl beta cyclodextrin)	2026-06		NCT04860960	2024-12-06	
phase 3	CVN424 for PD trial	1	Cerevance	3	PD	yes	GPR6	yes, GPR6 thought to be a target for several dementias	Solengepras / CVN424	2026-03		NCT06553027	2024-12-06	
phase 3	4 ph3 trials (3 completed, 1 failed)	2	Mesoblast (not remestemcel)	3	HF, cancer, degen. disc disease	yes, some	allogeneic mesenchymal lineage stem cells	yes, for a wide range of age-related diseases	allogeneic mesenchymal lineage stem cells	[various]		NCT02032004, NCT01854567, NCT02412735, NCT06325566	2025-02-08	NCT02032004 failed. NCT01854567 prob failed: its cancer indications not on the pipeline. NCT02412735 ended 2021: had some positive results & in 2023 got RMAT designation, but doesn't seem to be in regulatory review? So call it a ph3 for now.
phase 3	SCUlpTOR trial (Aus/NZ)	1	Cynata Therapeutics	3	OA (knee)	yes	allogeneic MSCs	yes, for a wide range of age-related diseases	allogeneic MSCs			U1111-1234-4897 (ANZCTR)	2025-09-11	Ph3 trial in Australia / New Zealand's Clinical Trials Registry (ANZCTR).
phase 3	Dapansutrile for Acute Gout Flare	1	Olatec	2/3	gout	yes	inhibit NLRP3 to reduce inflammation by reducing cytokines IL-1β and IL-18	yes, with several other clinical trials from Olatec for several age-related diseases	OLT1177 / Dapansutrile (small molecule)	2025-10		NCT05658575	2024-12-06	
phase 3	MASTERS-2	1 but paused	Athersys Inc	3	ischemic stroke	yes	allogeneic Multipotent Adult Progenitor (stem) Cells	yes, for a wide range of age-related diseases	MultiStem (allogeneic MAPCs)	2023-06		NCT03545607	2024-12-06	Planned interim analysis showed study size insufficiently powered to achieved significance, so enrollment paused for further analysis by company. Company pipeline on website says enrollment ongoing.
phase 3	MACoVIA	1 but paused	Athersys Inc	2/3	ARDS (Covid19)	yes	allogeneic Multipotent Adult Progenitor (stem) Cells	yes, for a wide range of age-related diseases	MultiStem (allogeneic MAPCs)	2023-12		NCT04367077	2024-12-06	Paused pending funding per website pipeline.
phase 3	VISTA-1 & VISTA-2	0	Mitotech	3	dry eye syndrome	yes	cardiolipin to inhibit peroxidation in mitochondria	yes, for a wide range of age-related diseases	Visomitin / SkQ1 (small molecule eye drops)	2019-02 & 2020-10		NCT03764735 & NCT04206020	2025-02-16	VISTA-1 succeeded but rather than leading to approval, led to VISTA-2. VISTA-2 met 1 primary endpoint (staining) but seemingly not the 2nd (discomfort). After that 2021 press release talked about a VISTA-3 trial, there doesn't seem to be such a trial & a 2022 press release says Mitotech sold SkQ1 rights for dry eye to Essex Bio, but Mitotech continues to pursue SkQ1 for other indications.
phase 3	NurOwn trial for ALS	0	Brainstorm Cell Therapeutics	3	ALS	yes	autologous bone marrow derived mesenchymal stromal cells (MSC) that secrete more neurotrophic factors	yes, for a wide range of age-related diseases	debamestrocel (NurOwn, MSC-NTF cells)	2020-09		NCT03280056	2025-02-17	Failed, but now planning a phase 3b trial (though not yet on clinicaltrials.gov).
phase 3	hip fracture muscle injury	0	Pluri Inc (prev Pluristem)	3	hip fracture	yes	allogeneic placenta-derived, mesenchymal-like adherent stromal cells	yes, for a wide range of age-related diseases	PLX-PAD (allogeneic mesenchymal-like stromal cells)	2023-09		NCT03451916	2024-12-06	Failed but did demonstrate muscle strength improvements. (See also here.) And product in phase 1 for knee OA, though company no longer has hip fracture as indication in its pipeline.
phase 3	TREASURE	0	Athersys Inc	2/3	ischemic stroke	yes	allogeneic Multipotent Adult Progenitor (stem) Cells	yes, for a wide range of age-related diseases	MultiStem (allogeneic MAPCs)	2023-02		NCT02961504	2024-12-06	Failed.

ATTR approvals

- At least 5 approvals in recent years

  (inc. by Alnylam & Eidos/BridgeBio)

- ATTR affects many areas with aging
- Thought to kill majority of 110+yo's
- Treatment may extend maximum human lifespan
- Classic misfolded protein pathology, but important outside the brain
- Increasingly thought underdiagnosed; increasing evidence in younger seniors
- More details (X thread)
- Why isn't this discussed more in the field?



Stem cell approvals

- stem cells no longer only a wild west of iffy clinics & medical tourism
- 1st mass-producible, off-the-shelf (allogeneic) HSC tx FDA approved 2023
- 1st mass-producible, off-the-shelf MSC tx FDA approved 2024 (Mesoblast)
- 1st MSC any-country-approval 2012! (Korea: 30k+ treated. Good 5-7yr followup. First disease modifying OA tx! Japan ph3 met all endpoints & approval expected. US ph3 started mid-2026.)
- HSCs + MSCs covers a large fraction of human cells
- Narrow indications but many more in trials
- More details (X thread)
- Why isn't this discussed more in the field?

Minor 2026 update: Japan conditionally approved allogeneic iPSC dopaminergic tx for Parkinson's & cardiomyocyte tx for heart failure. Mostly these are approvals for real world pivotal data trial, but they are based early on safety+efficacy trial data.

4 more successful phase 3 trials

Stealth Bio: cardiolipin mitochondria peptide elamipretide aka SS-31 got accelerated approval for Barth (2025) & in 2 other phase 3s (dAMD, nPMM)

Scholar Rock: anti-myostatin mAb apitegromab ph3 met primary endpoint for SMA (approval delayed: manufacturing issue at Novo run plant); in ph1 for 2nd indication

Biophytis's MAS receptor drug met primary ph3 endpoint for Covid but company pursuing new ph3 for sarcopenia before trying for approval

(as noted) Medipost's Cartistem MSCs for knee OA met all ph3 primary & 2ndary endpoints (in Japan; already approved in Korea & ph3 in US just started)

Aggregate pipeline outlook summary

- 6 approvals so far & expect 10 more within a few years, then steady trickle
- Label expansion possible after approvals (how long is a big question)
- All lower bounds since this is only aging-focused biotechs (others have additional assets, eg GLP-1s, other ATTR drugs)

- Uncertainty 5+yr out (current pre-clinicals, esp. w/ growing # new companies)
- Big extra upside & downside surprise uncertainty:
  - Regulatory/funding changes speed trials/research (A4LI proposals: multi-disease designation & disease-burden-based R&D funding)
  - Staff cuts slow FDA or NIH cuts dry up early research feeding pipeline?

- Clinical implications: Likely will be a long time where quality of off-label prescribing, knowing who needs what MoAs (& how to dose), matters a lot.

Why this is important summary

1. One of the things that will help trigger a public opinion sea change & funding
2. When funding rises, it's expansion of this pipeline that will embody progress
3. If $ don't go 10x, this that will continue to make steady progress anyway (slower than if funding goes 10x, but still better than the sick-care model)

Surprising this isn't discussed more (esp. relative to some stuff that is):

- Different from rapa, metformin, SGLT2, D+Q, supplements in being on-patent so there are financial incentives to run large trials
- Different from GLP-1s in that mostly MoAs likely effective even absent obesity
- Bryan Johnson fully expects to live many more decades but mostly discusses what he uses that's avail now & AI but not what's coming soon in biotech.
- Most Peter Attia clients will live 2+ decades but he discusses mostly available lifestyle, supplements, & drugs & ignores what's coming soon in the pipeline.

Paths to eliminating aging: the different longevity fields

(12 min)

See The 2 Longevity Fields for more details.

THE 2 LONGEVITY FIELDS

or 3

(more distant cousin)

whole-body replacement
(brain transplants)
+ brain rejuvenation or incremental replacement

(dominant subfield)

(pursued but not much recognized)

broadly slowing aging

divide-and-conquer rejuvenation

parts of aging addressed:	most/all	primarily 1 specific sub-pathology	most/all
effect size on affected sub-pathologies:	small (slow small %)	up to a total fix (yrs of reversion, repeatable)	total fix
targets are:	processes	stable structures	stable structures
dosing:	continual	infrequently intermittent	infreq. intermittent

Part vs. whole
&
How much is the goal?

Aging vs. longevity
or
geroscience hypothesis vs. lifespan extension

Many different views of the field. See What counts as a longevity drug.

Some aging therapies may not extend lifespans by themselves.

That doesn't mean they don't embody the geroscience paradigm.

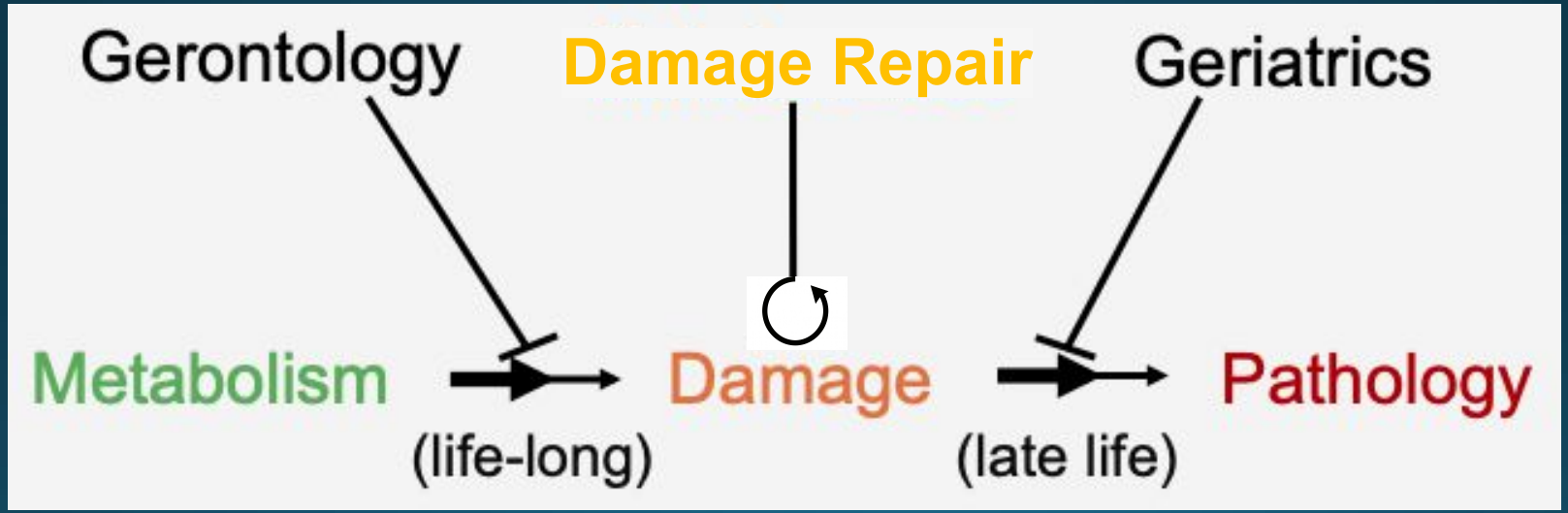
Monotherapy lifespan extension isn't a litmus test for the whole field.

All aging sub-pathologies eventually need therapies. Covering more of them is a type of progress of the field. The field should start measuring progress this way!

Processes vs. stable structures

(broadly slowing aging)

(divide-and-conquer rejuvenation)



(process)

(stable structure)

(Elaboration of a common SENS diagram from Aubrey de Grey.)

Aging can be divided into ~ 7–15 separable sub-pathologies

No universal consensus on the best breakdown (eg, Hallmarks vs. SENS)

But many of them are widely agreed on.

See table or AgingBiotech.info/categories for the best simple mapping I'm aware of.

See de Grey (2023) for the most direct published compare/contrast.

7 SENS damage types (2002 & 2003)	9 Hallmarks of aging (2013) or 14 (2022) or 12 (2023)	7 Pillars of aging (2014)	primarily stable structuress or mostly only processes
cell loss & atrophy	stem cell exhaustion	stem cell regeration	primarily stable structures
cell senescence	cellular senescence		primarily stable structures
nuclear mutations / cancer	genomic instability	macromolecular damage	primarily stable structures
extracellular crosslinks / matrix stiffening	altered mechanical properties (new hallmark)		primarily stable structures
intracellular junk			primarily stable structures
	telomere attrition		primarily stable structures
	epigenetic alterations	epigenetics	primarily stable structures
	microbiome disturbance / disbiosis (new hallmark)		primarily stable structures
extracellular junk	loss of proteostasis	proteostasis	mostly stable structures
mitochondrial mutations	mitochondrial dysfunction		some clear stable structures
	deregulated nutrient sensing	metabolism	primarily processes
	altered intercellular communication		primarily processes
	disabled macroautophagy (new hallmark)		primarily processes
	(chronic) inflammation (new hallmark)	inflammation	primarily processes
	splicing dysregulation (new hallmark)		primarily processes
		stress	primarily processes

How big is the problem of addressing all aspects of aging?

The next few slides give a quick sense by showing the aggregate clinical pipeline (including earlier stages) for just the divide-and-conquer rejuvenation portion of the field.

Majority of the field focuses on processes & slowing aging

Stable structure targets are (inadvertently?) de-emphasized.

ITP Top 10 for lifespan extension: All primarily target process, not stable structure.

Rapamycin: ~26/23% (F/M)
Acarbose: ~22/5% (M/F)
17-α-estradiol: ~19% (M)
16α-hydroxyestriol: ~15% (M)
Canagliflozin: ~14% (M)
Astaxanthin: ~12% (M)
NDGA: ~12% (M)
Halofuginone: ~9% (M)
Mitoglitazone: ~9% (M)
Aspirin & Meclizine *(Tie)*: ~8% (M)

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	disabled macroautophagy (new hallmark)		primarily processes
	(chronic) inflammation (new hallmark)	inflammation	primarily processes
	splicing dysregulation (new hallmark)		primarily processes
		stress	primarily processes

Nir Barzilai & co. top 12 ranking: All but 1 target process.

An Updated Prioritization of Geroscience-Guided FDA-Approved Drugs Repurposed to Target Aging

Michael Leone[1,2], Nir Barzilai [1 2*]

Gerotherapeutic	Hallmarks of aging	Preclinical healthspan	Preclinical lifespan	Human healthspan	Human mortality	Score (out of 12)
SGLT2 inhibitors	2	2	2	3	3	12
Metformin	2	2	1	3	3	11*
Bisphosphonates	2	2	1	3	3	11
GLP1 receptor agonists	2	2	0	3	3	10*
Acarbose	2	2	2	3	0	9*
Rapamycin	2	2	2	3	0	9
Methylene blue	2	2	2	3	0	9
ACE inhibitors/ARBs	2	2	1	3	0	8
Dasatinib + (quercetin)	2	2	1	3	0	8
Aspirin	2	2	2	1	0	7
Beta blockers	1	2	1	0	3	7
N-acetyl cysteine	2	2	1	0	0	5*

Table 1 Ranking of FD
preclinical and clinical
asterisk in the total scor

A-approved drugs as potential gerotherapeutics based on scoring (out of 12) for evidence. Evidence suggesting COVID-19 mortality benefit is delineated by an column.

Stable structural aging subpathology subcategories & why important (related diseases)

structural subpathology category label [not exhaustive]	subcategories [not exhaustive]	diseases caused/execerbated [not exhaustive]
(long-lived) senescent cells	senescent: fibroblasts, endothelial cells, glial cells, preadipocytes, immune cells	IPF, OA, cancer, CKD, CVD, T2D, AD, PD
non-senescent stable pathological cells	exhausted/anergic T-cells, CHIP, persistent myofibroblasts, hypertrophic/inflamed adipocytes	immunosenescence, CVD, fibrotic diseases, T2D
extracellular matrix remodeling & stiffening	AGEs & collagen closslinking, elastin fragmentation, vascular calcification, lens crystalin crosslinking	diabetic retinopathy, hypertension, CVD, aneurysms, CKD, skin aging, presbyopia
protein misfolding & aggregates	ATTR, α-synuclein, tau, Aβ	HF, neuropathy; dementias: PD, AD, Lewy body dementia
intracellular toxic molecules	lipofuscin, 7-ketocholesterol, unesterified free cholesterol	atherosclerosis, AMD, AD, PD
cell loss / tissue atrophy & stem cell degradation	neural stem cell depletion, muscle satellite cell degradation, thymus involution, cartilage loss, bone degradation, beta-cell loss	T2D, sarcopenia, cognitive decline, immunosenescence, OA, osteroporosis
mitochondria DNA mutations	4977-bp mtDNA deletion, mitochondria clonal expansion	sarcopenia, PD, presbycusis, HF
nuclear DNA changes	cancer mutations, non-malignant clonal expansion (inc. CHIP), telomere shortening	cancer, athersclerosis, all senescent cell diseases (IPF, CKD, OA, ...)
nuclear DNA epigenetic changes	stable, age-related methylation pattern changes, heterochromatin decondensation & retrotransposons	OA, T2D, AD, diabetic retinopathy
non-DNA mitochondria structural issues	cardiolipin peroxidation & cristae collapse, stably altered ER-Mitochondria Tethering (MAMs)?	sarcopenia, HF, AD

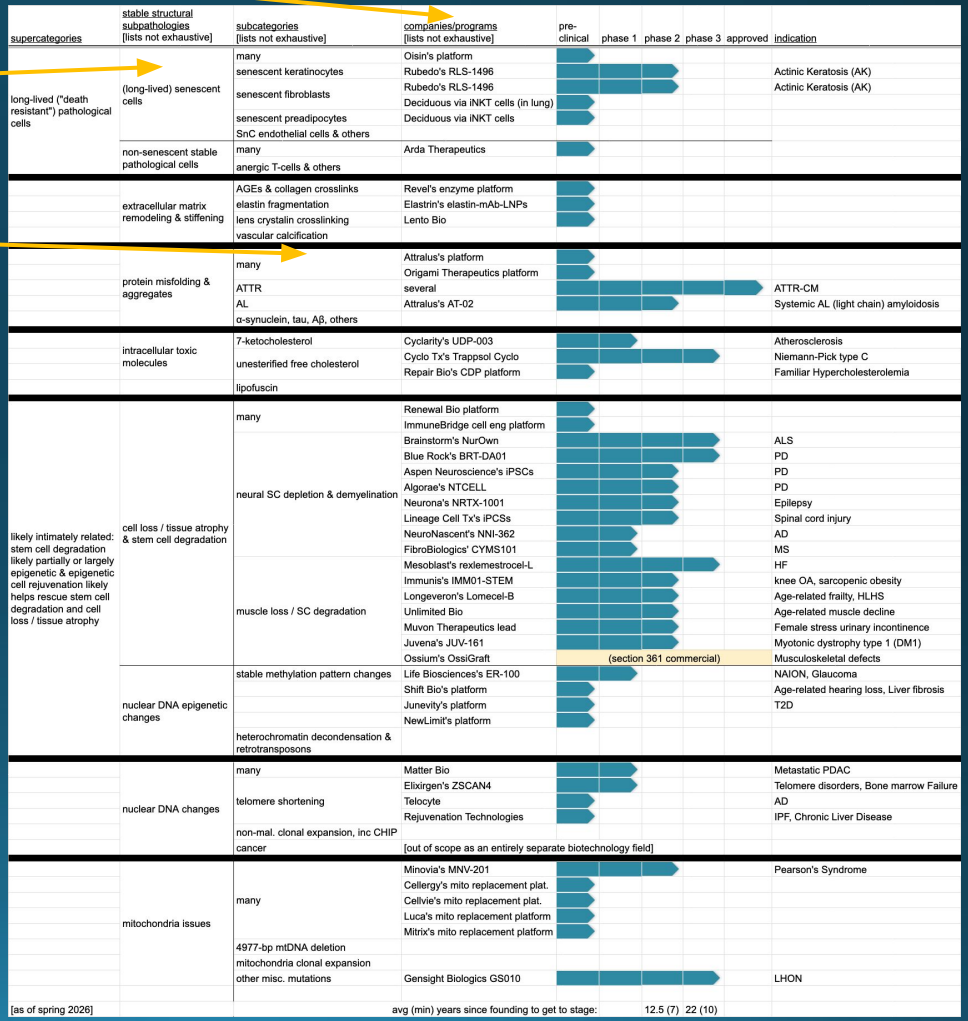
Aggregate pipeline

company/program

phase: pre 1 2 3 approved

aging subpathology

subpathology subcategory



supercategories	stable structural subpathologies [lists not exhaustive]	subcategories [lists not exhaustive]	companies/programs [lists not exhaustive]	pre-clinical	phase 1	phase 2	phase 3	approved	indication
long-lived ("death resistant") pathological cells	(long-lived) senescent cells	many	Oisin's platform						
		senescent keratinocytes	Rubedo's RLS-1496						Actinic Keratosis (AK)
		senescent fibroblasts	Rubedo's RLS-1496						Actinic Keratosis (AK)
			Deciduous via iNKT cells (in lung)						
		senescent preadipocytes	Deciduous via iNKT cells						
		SnC endothelial cells & others							
	non-senescent stable pathological cells	many	Arda Therapeutics						
		anergic T-cells & others							
	extracellular matrix remodeling & stiffening	AGEs & collagen crosslinks	Revel's enzyme platform						
		elastin fragmentation	Elastrin's elastin-mAb-LNPs						
		lens crystalin crosslinking	Lento Bio						
		vascular calcification							
	protein misfolding & aggregates	many	Attralus's platform						
			Origami Therapeutics platform						
		ATTR	several						ATTR-CM
		AL	Attralus's AT-02						Systemic AL (light chain) amyloidosis
		α-synuclein, tau, Aβ, others							
	intracellular toxic molecules	7-ketocholesterol	Cyclarity's UDP-003						Atherosclerosis
		unesterified free cholesterol	Cyclo Tx's Trappsol Cyclo						Niemann-Pick type C
			Repair Bio's CDP platform						Familiar Hypercholesterolemia
		lipofuscin							
likely intimately related: stem cell degradation likely partially or largely epigenetic & epigenetic cell rejuvenation likely helps rescue stem cell degradation and cell loss / tissue atrophy	cell loss / tissue atrophy & stem cell degradation	many	Renewal Bio platform						
			ImmuneBridge cell eng platform						
		neural SC depletion & demyelination	Brainstorm's NurOwn						ALS
			Blue Rock's BRT-DA01						PD
			Aspen Neuroscience's iPSCs						PD
			Algorae's NTCELL						PD
			Neurona's NRTX-1001						Epilepsy
			Lineage Cell Tx's iPCSs						Spinal cord injury
		muscle loss / SC degradation	NeuroNascent's NNI-362						AD
			FibroBiologics' CYMS101						MS
			Mesoblast's rexlemestrocel-L						HF
			Immunis's IMM01-STEM						knee OA, sarcopenic obesity
			Longeveron's Lomecel-B						Age-related frailty, HLHS
			Unlimited Bio						Age-related muscle decline
			Muvon Therapeutics lead						Female stress urinary incontinence
			Juvena's JUV-161						Myotonic dystrophy type 1 (DM1)
			Ossium's OssiGraft	(section 361 commercial)					Musculoskeletal defects
	nuclear DNA epigenetic changes	stable methylation pattern changes	Life Biosciences's ER-100						NAION, Glaucoma
			Shift Bio's platform						Age-related hearing loss, Liver fibrosis
			Junevity's platform						T2D
			NewLimit's platform						
		heterochromatin decondensation & retrotransposons							
	nuclear DNA changes	many	Matter Bio						Metastatic PDAC
		telomere shortening	Elixirgen's ZSCAN4						Telomere disorders, Bone marrow Failure
			Telocyte						AD
			Rejuvenation Technologies						IPF, Chronic Liver Disease
		non-mal. clonal expansion, inc CHIP							
		cancer	[out of scope as an entirely separate biotechnology field]						
	mitochondria issues	many	Minovia's MNV-201						Pearson's Syndrome
			Cellergy's mito replacement plat.						
			Cellvie's mito replacement plat.						
			Luca's mito replacement platform						
			Mitrix's mito replacement platform						
		4977-bp mtDNA deletion							
		mitochondria clonal expansion							
		other misc. mutations	Gensight Biologics GS010						LHON
[as of spring 2026]			avg (min) years since founding to get to stage:		12.5 (7)	22 (10)			

Much progress, but many holes (subproblems unaddressed yet) & many of these programs will fail.

[programs of aging focused biotechs only; not exhaustive]

We don't yet know how beneficial combinations of many of these will be.

Aggregate pipeline:

my portfolio

phase: pre 1 2 3 approved

supercategories	stable structural subpathologies [lists not exhaustive]	subcategories [lists not exhaustive]	companies/programs [lists not exhaustive]	pre-clinical	phase 1	phase 2	phase 3	approved	indication
long-lived ("death resistant") pathological cells	(long-lived) senescent cells	many	Oisin's platform						
		senescent keratinocytes	Rubedo's RLS-1496						Actinic Keratosis (AK)
		senescent fibroblasts	Rubedo's RLS-1496						Actinic Keratosis (AK)
			Deciduous via iNKT cells (in lung)						
		senescent preadipocytes	Deciduous via iNKT cells						
		SnC endothelial cells & others							
	non-senescent stable pathological cells	many	Arda Therapeutics						
		anergic T-cells & others							
	extracellular matrix remodeling & stiffening	AGEs & collagen crosslinks	Revel's enzyme platform						
		elastin fragmentation	Elastrin's elastin-mAb-LNPs						
		lens crystalin crosslinking	Lento Bio						
		vascular calcification							
	protein misfolding & aggregates	many	Attralus's platform						
			Origami Therapeutics platform						
		ATTR	several						ATTR-CM
		AL	Attralus's AT-02						Systemic AL (light chain) amyloidosis
		α-synuclein, tau, Aβ, others							
	intracellular toxic molecules	7-ketocholesterol	Cyclarity's UDP-003						Atherosclerosis
		unesterified free cholesterol	Cyclo Tx's Trappsol Cyclo						Niemann-Pick type C
			Repair Bio's CDP platform						Familiar Hypercholesterolemia
		lipofuscin							
likely intimately related: stem cell degradation likely partially or largely epigenetic & epigenetic cell rejuvenation likely helps rescue stem cell degradation and cell loss / tissue atrophy	cell loss / tissue atrophy & stem cell degradation	many	Renewal Bio platform						
			ImmuneBridge cell eng platform						
		neural SC depletion & demyelination	Brainstorm's NurOwn						ALS
			Blue Rock's BRT-DA01						PD
			Aspen Neuroscience's iPSCs						PD
			Algorae's NTCELL						PD
			Neurona's NRTX-1001						Epilepsy
			Lineage Cell Tx's iPCSs						Spinal cord injury
			NeuroNascent's NNI-362						AD
			FibroBiologics' CYMS101						MS
		muscle loss / SC degradation	Mesoblast's rexlemestrocel-L						HF
			Immunis's IMM01-STEM						knee OA, sarcopenic obesity
			Longeveron's Lomecel-B						Age-related frailty, HLHS
			Unlimited Bio						Age-related muscle decline
			Muvon Therapeutics lead						Female stress urinary incontinence
			Juvena's JUV-161						Myotonic dystrophy type 1 (DM1)
			Ossium's OssiGraft		(section 361 commercial)				Musculoskeletal defects
	nuclear DNA epigenetic changes	stable methylation pattern changes	Life Biosciences's ER-100						NAION, Glaucoma
			Shift Bio's platform						Age-related hearing loss, Liver fibrosis
			Junevity's platform						T2D
			NewLimit's platform						
		heterochromatin decondensation & retrotransposons							
	nuclear DNA changes	many	Matter Bio						Metastatic PDAC
		telomere shortening	Elixirgen's ZSCAN4						Telomere disorders, Bone marrow Failure
			Telocyte						AD
			Rejuvenation Technologies						IPF, Chronic Liver Disease
		non-mal. clonal expansion, inc CHIP							
		cancer	[out of scope as an entirely separate biotechnology field]						
	mitochondria issues	many	Minovia's MNV-201						Pearson's Syndrome
			Cellergy's mito replacement plat.						
			Cellvie's mito replacement plat.						
			Luca's mito replacement platform						
			Mitrix's mito replacement platform						
		4977-bp mtDNA deletion							
		mitochondria clonal expansion							
		other misc. mutations	Gensight Biologics GS010						LHON
[as of spring 2026]			avg (min) years since founding to get to stage:			12.5 (7)	22 (10)		

Anything is on the path if it helps trigger a sea change of public awareness, support, & funding, but which will help?

- Pet life extension? (most of society owns or know those who do)
- GLP-1 drugs? (high use + financial & celebrity press)
- Presbyopia tx? (no more reading glasses, nearly everyone ~45+)
- Skin rejuvenation? (visible; senolytic & reprogramming biotechs pursuing)
- Robust mouse results (eg RMR by LEVF)?
- Big healthspan trials (eg TAME)?
- Whole body / brain transplants?
- Prizes (eg X-Prize)?
- Aging biomarkers (eg age clocks as common as step counts)?
- Social movements (eg Vitalism)?
- Petitions/declarations (eg Dublin Longevity Declaration)?
- Consistent public education (eg Lifespan.io/LRI)?
- Biohackers, podcasters, & social media influencers (eg Bryan Johnson)?
- Entertainer & celebrity engagement & education (eg ALSAE)?
- Multiple new on-patent treatments for core aging pathologies label expanding or being prescribed off-label for diverse aging diseases?

(includes slow aging approaches)

As a table with more details, see: AgingBiotech.info/convincers

Broadly slowing aging vs. divide-and-conquer rejuvenation: tradeoffs

- Industrialized societies suffer high prevalence of lifestyle-mediated age acceleration (from poor diet, inactivity, sleep deprivation…; & resulting obesity)
- Lifestyle makes a 10-20 year difference in human lifespan (sources & analysis)
- Broadly slowing aging has breadth so yields immediate effects on healthspan, especially by mitigating the lifestyle-based age acceleration (most pharma $ drawn to this!)
- But existing data suggest that the tradeoff for slow aging approaches having benefits against most aging subpathologiest is not coming close to totally eliminating any & having limited additive effects, so limited long-term total effect sizes (eg, <50% healthspan/lifespan extension in mice, small % in humans)

- Divide-and-conquer rejuvenation is the default path to fully eliminating aging pathology in the long run, and it can deliver full elimination of some subpathologies in the short-term, with beneficial effects vs. multiple diseases
- With subpathology-specific biomarkers, trials need lower n to show efficacy
- Individual therapies don't broadly rescue common lifestyle age acceleration (but a program of many will, & go further esp. as it approaches comprehensiveness)

Incentives lacking for combination work

To my knowledge this is the first ever broad assessment of the clinical translational status of the divide-and-conquer approach to rejuvenation or fully eliminating aging (such assessment has only become possible in the past ~5yrs).

Prior SENS Research Foundation status summaries from many years ago were from a time before many companies had even spun out to directly address stable structural aging subpathologies & from when all were still far from starting clinical trials.

A lot of this you won't hear in most discussion of the aging/longevity field because there's no little incentive in academia or biotech to combine the work of others. So right now, combining therapies is left to only the very last step: clinical medical practice, with no systematic study of how total effectiveness scales with # of therapies or category.

Poll:
What would you like to hear more about in Q&A?

These slides: https://tinyurl.com/AgingPipeline26 or QR:

Take-homes to remember

- Before the mid-1800s, eliminating top killer infectious diseases seemed fanciful
- Therapies targeting core aging areas are making it to phase 3 and to approvals
- Aging research receives 80x less US government funding per death than cancer
- Broadly slowing aging & divide-&-conquer rejuvenation are different subfields
- Divide-&-conquer progress is happening but must be judged by effective coverage (not 1-intervention lifespan)
- We don't yet know how good aging therapies will be in combination

Questions?

These slides: https://tinyurl.com/AgingPipeline26 or QR:

"I also treat my body like a temple: an ancient structure in desperate need of repair, long ignored and of rapidly decreasing significance to a largely indifferent society,"

Aggregate pipeline:

(squished from a traditional bar chart into a table)

template, i.e. scope of the problem

(at least, not exhaustive)

stable structural aging subpathologies ↓							
supercategories	main categories	specific subcategories & company programs addressing this area therapeutically					
long-lived ("death resistant") pathological cells	(long-lived) senescent cells	senescent fibroblasts	senescent keratinocytes	senescent endothelial cells	senescent preadipocytes	senescent immune cells	
	non-senescent stable pathological cells	exhausted/anergic T-cells	persistent myofibroblasts	hypertrophic/inflamed adipocytes	macrophage foam cells (see intracell toxins / cholesterols)	CHIP (see DNA / clonal expansion)	
	extracellular matrix remodeling & stiffening	AGEs & collagen closslinking	elastin fragmentation	vascular calcification	lens crystalin crosslinking		
	protein misfolding & aggregates	ATTR	α-synuclein	tau	Aβ	TDP-43	AL
	intracellular toxic molecules	lipofuscin	7-ketocholesterol	unesterified free cholesterol			
likely intimately related: stem cell degradation likely partially or largely epigenetic & epigenetic cell rejuvenation likely helps rescue stem cell degradation and cell loss / tissue atrophy	cell loss / tissue atrophy & stem cell degradation	neural stem cell depletion & neuron demyelination	muscle satellite cell degradation / muscle loss	thymus involution	cartilage loss	vascular network degradation	misc. other cell loss/degradation
	nuclear DNA epigenetic changes	stable methylation pattern changes	heterochromatin decondensation & retrotransposons				
	nuclear DNA changes	telomere shortening	non-malignant clonal expansion (inc. CHIP)	cancer mutations			
				[out of scope as entirely separate field]			
structural mitochondrial aging	mitochondria DNA mutations	4977-bp mtDNA deletion	mitochondria clonal expansion	other mutations			
	non-DNA mitochondria structural issues	cardiolipin peroxidation & cristae collapse	stably altered ER-Mitochondria Tethering?				
	barrier integrity degradation	BBB	gut	skin?			
color key →	not yet but maybe in the works (spinning out from academia)	company failed financially or pivoted away but approach still scientifically valid	pre-clinical	ph.1	ph.2	ph.3	approved

Aggregate pipeline:

my investment portfolio

We need more investors focused on this, especially attacking it comprehensively.

supercategories	main categories	specific subcategories & company programs addressing this area therapeutically					
long-lived ("death resistant") pathological cells	(long-lived) senescent cells	Oisin's platform for all SnCs based on overexpression of p16 (or p21 or p53)					
		senescent fibroblasts	senescent keratinocytes	senescent endothelial cells	senescent preadipocytes	senescent immune cells	
		Rubedo's RLS-1496	Rubedo's RLS-1496				
		Deciduous via iNKT cells (in lung)			Deciduous via iNKT cells		
	non-senescent stable pathological cells	exhausted/anergic T-cells	persistent myofibroblasts	hypertrophic/inflamed adipocytes	macrophage foam cells	CHIP	
					[see intracell toxins / cholesterols]	[see DNA / clonal expansion]	
	extracellular matrix remodeling & stiffening	AGEs & collagen closslinking	elastin fragmentation	vascular calcification	lens crystalin crosslinking		
		Revel Pharma's enzyme engineering platform	Elastrin's elastin-mAb-LNPs				
	protein misfolding & aggregates	Origami Tx's protein degraders platform					
		Enclear Therapies' platform					
		Covalent Bio's catalytic antibodies					
		ATTR	α-synuclein	tau	Aβ	TDP-43	AL
	intracellular toxic molecules	lipofuscin	7-ketocholesterol	unesterified free cholesterol			
			Cyclarity's UDP-003	Repair Bio's cholesterol degrading platform			
	stealth reprogramming company						
	ImmuneBridge cell engineering platform						
	stealth EV company						
	cell loss / tissue atrophy & stem cell degradation	neural stem cell depletion & neuron demyelination	muscle satellite cell degradation / muscle loss	thymus involution	cartilage loss	vascular network degradation	misc. other cell loss/degradation
		Reneu Bio's lead program	Immunis's IMM01-STEM	Lygenesis thymus program (indirect portco)	not a done deal but newco about to spin out		
		stealth glial replacement company	Juvena's JUV-161	not a done deal but newco about to spin out			
	nuclear DNA epigenetic changes	stable methylation pattern changes [below here better at the supercategory level?]	heterochromatin decondensation & retrotransposons				
		Shift Bio's platform					
		Junevity's platform					
		Turn Bios' OSKMLN platform					
	nuclear DNA changes	telomere shortening	non-malignant clonal expansion (inc. CHIP)	cancer mutations			
		Rejuvenation Technologies		[out of scope as entirely separate field]			
structural mitochondrial aging	Cellergy's mitochondria replacement platform						
	mitochondria DNA mutations	4977-bp mtDNA deletion	mitochondria clonal expansion	other mutations			
	non-DNA mitochondria structural issues	cardiolipin peroxidation & cristae collapse	stably altered ER-Mitochondria Tethering?				
		Retrotope D-PUFAs					
	barrier integrity degradation	BBB	gut	skin?			
		Reservoir Neuro's platform					
color key →	not yet but maybe in the works (spinning out from academia)	company failed financially or pivoted away but approach still scientifically valid	pre-clinical	ph.1	ph.2	ph.3	approved

Aggregate pipeline:

aging focused biotechs, phase 1 on

(no veterinary or supplements, misses programs in companies not aging focused, but some of these will fail)

supercategories	main categories	specific subcategories & company programs addressing this area therapeutically					
long-lived ("death resistant") pathological cells	(long-lived) senescent cells	senescent fibroblasts	senescent keratinocytes	senescent endothelial cells	senescent preadipocytes	senescent immune cells	
		Rubedo's RLS-1496	Rubedo's RLS-1496				
	non-senescent stable pathological cells	exhausted/anergic T-cells	persistent myofibroblasts	hypertrophic/inflamed adipocytes	macrophage foam cells	CHIP	
					[see intracell toxins / cholesterols]	[see DNA / clonal expansion]	
	extracellular matrix remodeling & stiffening	AGEs & collagen closslinking	elastin fragmentation	vascular calcification	lens crystalin crosslinking		
	protein misfolding & aggregates	ATTR	α-synuclein	tau	Aβ	TDP-43	AL
		[many approvals slow progression without being rejuvenative, but maybe slow by a lot]					Attralus's AT-02
	intracellular toxic molecules	lipofuscin	7-ketocholesterol	unesterified free cholesterol			
			Cyclarity's UDP-003	Cyclo Therapeutics's Trappsol Cyclo			
likely intimately related: stem cell degradation likely partially or largely epigenetic & epigenetic cell rejuvenation likely helps rescue stem cell degradation and cell loss / tissue atrophy	cell loss / tissue atrophy & stem cell degradation	neural stem cell depletion & neuron demyelination	muscle satellite cell degradation / muscle loss	thymus involution	cartilage loss	vascular network degradation	misc. other cell loss/degradation
		Brainstorm's NurOwn	Mesoblast's rexlemestrocel-L	Intervene Immune's TRIIM	Medipost Cartistem (Korea; ph3:Japan✓, US)	Athersys's MultiStem	Endogena's EA-2353 (eye)
		Blue Rock's BRT-DA01	Immunis's IMM01-STEM		Mesoblast's rexlemestrocel-L	Mesoblast's rexlemestrocel-L	Lineage Cell's iPCSs (eye)
		Aspen Neuroscience's iPSCs	Longeveron's Lomecel-B		Cynata' CYP-004	Hemostemix's ACP-01	
		Algorae's NTCELL	Muvon Therapeutics lead		Pluri's PLX-PAD		
		Neurona's NRTX-1001	Juvena's JUV-161				
		Lineage Cel Tx's iPCSs	Ossium's Ossigraft (section 361 commercial)				
		NeuroNascent's NNI-362					
		FibroBiologics' CYMS101					
	nuclear DNA epigenetic changes	stable methylation pattern changes	heterochromatin decondensation & retrotransposons				
		Life Biosciences's ER-100					
	nuclear DNA changes	telomere shortening	non-malignant clonal expansion (inc. CHIP)	cancer mutations			
		Elixirgen's ZSCAN4		[out of scope as entirely separate field]			
structural mitochondrial aging	Minovia's MNV-201						
	mitochondria DNA mutations	4977-bp mtDNA deletion	mitochondria clonal expansion	other mutations			
				Gensight Biologics GS010			
	non-DNA mitochondria structural issues	cardiolipin peroxidation & cristae collapse	stably altered ER-Mitochondria Tethering?				
	barrier integrity degradation	BBB	gut	skin?			
color key →	not yet but maybe in the works (spinning out from academia)	company failed financially or pivoted away but approach still scientifically valid	pre-clinical	ph.1	ph.2 (years since founding: min 7, median 12.5)	ph.3 (yrs f/ founding: min 10, med 22)	approved

Aggregate pipeline:

aging focused biotechs, inc. preclin

Not exhaustive, problems or therapies.

We have no idea how beneficial combinations of many of these will be.

supercategories	main categories	specific subcategories & company programs addressing this area therapeutically					
long-lived ("death resistant") pathological cells	(long-lived) senescent cells	Oisin's platform for all SnCs based on overexpression of p16 (or p21 or p53)					
		senescent fibroblasts	senescent keratinocytes	senescent endothelial cells	senescent preadipocytes	senescent immune cells	
		Rubedo's RLS-1496	Rubedo's RLS-1496		Deciduous via iNKT cells		
		Deciduous via iNKT cells (in lung)					
	non-senescent stable pathological cells	Arda Therapeutics					
		exhausted/anergic T-cells	persistent myofibroblasts	hypertrophic/inflamed adipocytes	macrophage foam cells	CHIP	
					[see intracell toxins / cholesterols]	[see DNA / clonal expansion]	
	extracellular matrix remodeling & stiffening						
		AGEs & collagen closslinking	elastin fragmentation	vascular calcification	lens crystalin crosslinking		
		Revel Pharma's enzyme engineering platform	Elastrin's elastin-mAb-LNPs		Lento Bio		
	protein misfolding & aggregates	Attralus's platform					
		Origami Therapeutics platform					
		ATTR	α-synuclein	tau	Aβ	TDP-43	AL
		[many approvals slow progression without being rejuvenative, but maybe slow by a lot]					Attralus's AT-02
	intracellular toxic molecules						
		lipofuscin	7-ketocholesterol	unesterified free cholesterol			
			Cyclarity's UDP-003	Cyclo Therapeutics's Trappsol Cyclo			
				Repair Bio's cholesterol degrading			
likely intimately related: stem cell degradation likely partially or largely epigenetic & epigenetic cell rejuvenation likely helps rescue stem cell degradation and cell loss / tissue atrophy		Renewal Bio platform					
		ImmuneBridge cell engineering platform					
	cell loss / tissue atrophy & stem cell degradation	neural stem cell depletion & neuron demyelination	muscle satellite cell degradation / muscle loss	thymus involution	cartilage loss	vascular network degradation	misc. other cell loss/degradation
		Brainstorm's NurOwn	Mesoblast's rexlemestrocel-L	Intervene Immune's TRIIM	Medipost Cartistem (Korea; ph3 Japan✅, US)	Athersys's MultiStem	Endogena's EA-2353 (eye)
		Blue Rock's BRT-DA01	Immunis's IMM01-STEM	Thymmune Therapeutics	Mesoblast's rexlemestrocel-L	Mesoblast's rexlemestrocel-L	Lineage Cell's iPCSs (eye)
		Aspen Neuroscience's iPSCs	Longeveron's Lomecel-B	Tolerance Bio	Cynata' CYP-004	Hemostemix's ACP-01	
		Algorae's NTCELL	Unlimited Bio	TECregen	Pluri's PLX-PAD	Unlimited Bio	
		Neurona's NRTX-1001	Muvon Therapeutics lead				
		Lineage Cel Tx's iPCSs	Juvena's JUV-161				
		NeuroNascent's NNI-362	Ossium's Ossigraft (section 361 commercial)				
		FibroBiologics' CYMS101					
	nuclear DNA epigenetic changes	stable methylation pattern changes [below here better at the supercategory level?]	heterochromatin decondensation & retrotransposons				
		Life Biosciences's ER-100					
		Shift Bio's platform					
		Junevity's platform					
		NewLimit's platform					
	nuclear DNA changes	Matter Bio					
		telomere shortening	non-malignant clonal expansion (inc. CHIP)	cancer mutations			
		Elixirgen's ZSCAN4		[out of scope as entirely separate field]			
		Telocyte					
		Rejuvenation Technologies					
structural mitochondrial aging		Minovia's MNV-201					
		Cellergy's mitochondria replacement platform					
		Cellvie's mitochondria replacement platform					
		Luca's mitochondria replacement platform					
		Mitrix's mitochondria replacement platform					
	mitochondria DNA mutations	4977-bp mtDNA deletion	mitochondria clonal expansion	other mutations			
				Gensight Biologics GS010			
	non-DNA mitochondria structural issues	cardiolipin peroxidation & cristae collapse	stably altered ER-Mitochondria Tethering?				
	barrier integrity degradation	BBB	gut	skin?			

Aggregate pipeline:

diagnostics

(poor coverage)

stable structural aging subpathologies ↓							
supercategories	main categories	specific subcategories & clinical diagnostics					
long-lived ("death resistant") pathological cells	(long-lived) senescent cells	senescent fibroblasts	senescent keratinocytes	senescent endothelial cells	senescent preadipocytes	senescent immune cells	
	non-senescent stable pathological cells	exhausted/anergic T-cells	persistent myofibroblasts	hypertrophic/inflamed adipocytes	macrophage foam cells (see intracell toxins / cholesterols)	CHIP (see DNA / clonal expansion)	
	extracellular matrix remodeling & stiffening	AGEs & collagen closslinking	elastin fragmentation	vascular calcification	lens crystalin crosslinking		
				CCTA			
	protein misfolding & aggregates	Amprion platform					
		ATTR	α-synuclein	tau	Aβ	TDP-43	AL
		scan (non-clinical)	Amprion	some scans & related blood tests, but clinical use uneven			
	intracellular toxic molecules	lipofuscin	7-ketocholesterol	unesterified free cholesterol			
likely intimately related: stem cell degradation likely partially or largely epigenetic & epigenetic cell rejuvenation likely helps rescue stem cell degradation and cell loss / tissue atrophy	cell loss / tissue atrophy & stem cell degradation	neural stem cell depletion & neuron demyelination	muscle satellite cell degradation / muscle loss	thymus involution	cartilage loss	vascular network degradation	misc. other cell loss/degradation
			DEXA indirectly, functional tests	scans (non-clinical?)	MRI (only individually, joint by joint)		DEXA (bone)
	nuclear DNA epigenetic changes	stable methylation pattern changes	heterochromatin decondensation & retrotransposons				
	nuclear DNA changes	telomere shortening	non-malignant clonal expansion (inc. CHIP)	cancer mutations			
		mostly only for blood & not critically short only		[out of scope as entirely separate field]			
structural mitochondrial aging	mitochondria DNA mutations	4977-bp mtDNA deletion	mitochondria clonal expansion	other mutations			
	non-DNA mitochondria structural issues	cardiolipin peroxidation & cristae collapse	stably altered ER-Mitochondria Tethering?				
	barrier integrity degradation	BBB	gut	skin?			
color key →	not yet but maybe in the works (spinning out from academia)	company failed financially or pivoted away but approach still scientifically valid	pre-commercial	commercial			

Additional dimensions for the ‘divide’ of divide-and-conqeuer…

The whole body: compartment/organ & tissue-type/cell-type

macro compartment	organ	epithelial / endothelial cells	epithelial / hepatocytes	epithelial / enterocytes	epithelial / enterocytes	epithelial / pneumocytes	epithelial / Kupffer cells	connective / fibroblasts	connective / osteoblasts	connective / adipocytes	connective / chondrocytes	connective / osteoclasts	connective / erythrocytes (RBCs)	connective / T-cells	connective / macrophages	connective / multipotent stem cells	muscle / cardiomyocytes	muscle / smooth muscle	muscle / skeletal muscle	nervous / neurons	nervous / astrocytes	nervous / oligodendrocytes	nervous / microglia
CNS	spinal cord																						
CNS	cerebral cortex																						
CNS	hippocampus																						
CNS	cerebellum																						
CNS	basal ganglia & striatum																						
CNS	retina & optic nerve																						
CNS	olfactory epithelium																						
CNS	hypothalamus & thalamus																						
CNS	brainstem																						
periphery	heart																						
periphery	lungs																						
periphery	liver																						
periphery	kidneys																						
periphery	pancreas																						
periphery	stomach																						
periphery	intestines & appendix																						
periphery	gallbladder																						
periphery	bladder																						
periphery	thyroid & parathyroid																						
periphery	adrenal glands																						
periphery	spleen																						
periphery	thymus																						
periphery	lymph nodes																						
periphery	prostate																						
periphery	ovaries or testes																						
periphery	uterus																						
periphery	skeletal muscle																						
periphery	bones																						
periphery	cartilage & joints																						
periphery	adipose tissue																						
periphery	skin																						
periphery	bone marrow																						
periphery	vasculature & blood																						
periphery	peripheral nervous system																						
microbiome	gut																						
microbiome	oral																						
microbiome	skin surface																						
microbiome	sinus & respiratory tract																						
microbiome	vaginal																						

Species: humans, mice, dogs

mice:

- LEVF trying combos
- no one is capturing biotech preclinical therapy data nor are the research-grade treatments companies create on the way to IND broadly usable by others

dogs:

- now a handful of companies not just 1
- but most using broad slow-aging approaches
- not enough stable structural rejuvenation therapies yet for dogs for meaningful aggregate pipeline

Ironically, things with small effect size (obesity, metabolism) attract huge $$$ distorting company incentives & programs

Example companies (just in my portfolio) where focus/programs altered by the huge gravitational pull of money in obesity & metabolism:

- Immunis
- Juvena
- Oisin
- Junevity
- Gordian

- (also Bioage—not in my portfolio but almost was & its founding was the inspiration for my own investing start)

Many more examples outside my portfolio.

Not so much a criticism of these companies—great if they can capture some of this money for the overall field, but still a lament of the phenomenon's consequence of drawing resources away from the other main subfield.