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WHAT THE PAPER SAYS · WHAT IT DOESN'T · WHY IT MATTERS

Wani model ya cire kusan duk hanyoyin tsufa da ke ƙaruwa a hankali. Somatic mutations har yanzu sun kawo ƙarshen gwajin tunani

Model ɗin ba ya cewa mutane za su iya rayuwa zuwa shekaru 194. Yana daskarar da background mortality a matakin shekara 30, yana cire kusan duk sauran progressive aging mechanisms, sannan ya tambayi lokacin da mutation-driven cell loss a modeled tissues huɗu zai haifar da failure. Manyan lambobin conditional outputs ne na model, ba shekarun da ake iya kaiwa a zahiri ko treatment forecasts ba.

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Paper: *Somatic mutations impose an entropic upper bound on human lifespan*, Evgeniy Efimov, Vlad Fedotov, Leonid Malaev, Ekaterina E. Khrameeva & Dmitrii Kriukov, npj Aging (2026), article in press · DOI: 10.1038/s41514-026-00421-6

Samfurin ya cire kusan duk hanyoyin tsufa da ke ƙaruwa da lokaci. Maye gurbi a ƙwayoyin jiki har yanzu ya kawo ƙarshen gwajin tunani

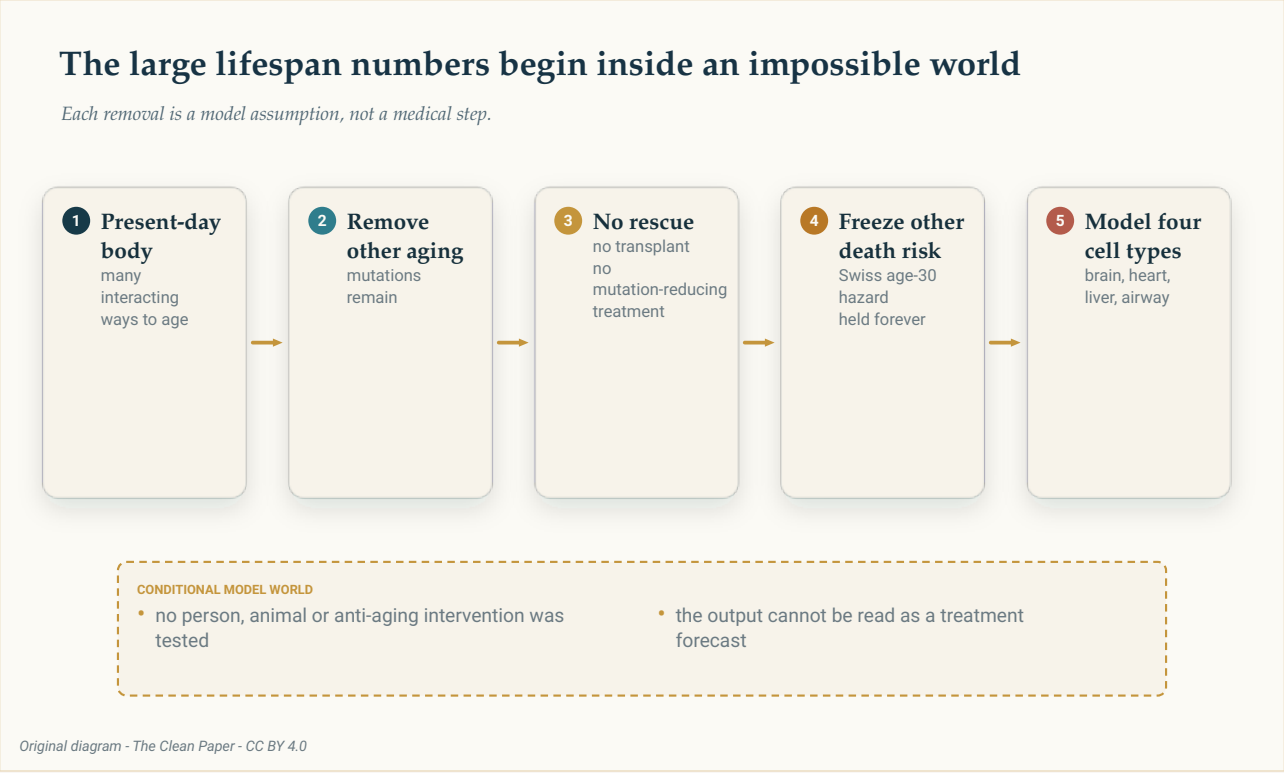
Ka yi tunanin jikin mutum inda kusan duk hanyoyin tsufa da muka saba gani aka kashe. Jijiyoyin jini ba sa lalacewa a hankali. Sunadarai ba sa rasa ingancinsu sannu a hankali. Kumburi, kansa da sauran gazawar da ke ƙaruwa da shekaru ba sa ƙaruwa. Ba a dasa wata gaɓa, kuma babu wani magani da ke rage taruwar canje-canjen DNA a cikin ƙwayoyin halitta.

Me zai fara gaza a gaba?

Wani sabon binciken lissafi ya haɗa curves na rayuwar yawan jama'a da simulations na asarar ƙwayoyin halitta da **somatic mutations** masu cutarwa ke haifarwa a nama huɗu. Ya ba da amsa mai sharadi: asarar ƙwayoyin halitta a hankali bayan irin waɗannan maye gurbi na iya zama ƙuntatawa a ƙarshe, musamman a kwakwalwa da zuciya. **Somatic mutation** canjin DNA ne da wata ƙwayar jiki ta samu a lokacin rayuwa. Ba a gadonsa ta ƙwai ko maniyyi, kuma yawancin irin waɗannan canje-canje ba sa kashe ƙwayar halitta ko haifar da cuta.

Sakamakon da ya fi sauƙin zama kanun labarai shi ne matsakaicin tsawon rayuwa a samfurin tsakanin **shekaru 146 da 194**, gwargwadon yadda aka ɗauki alaƙar gazawar nama huɗun da juna. Amma wannan **ba kiyasin tsawon rayuwar mutane a yau ba ne**. Ba sakamakon da aka hango daga wani magani ba ne. Ba a gwada mutum, dabba ko wata hanyar jinkirta tsufa ba.

Wannan lambar tana cikin wata duniya da aka gina da gangan ta zama ba ta yiwuwa. Fahimtar abin da ke faruwa a wannan duniyar samfurin shi ne ainihin sakamakon.



Samfurin ya cire kusan duk hanyoyin tsufa da ke ƙaruwa da lokaci kafin ya tambayi abin da asarar ƙwayoyin halitta saboda maye gurbi za ta yi. Wannan duniya ce mai sharadin lissafi, ba shirin magani ba.

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Da farko, a gina yawan jama'a da kusan ba sa tsufa

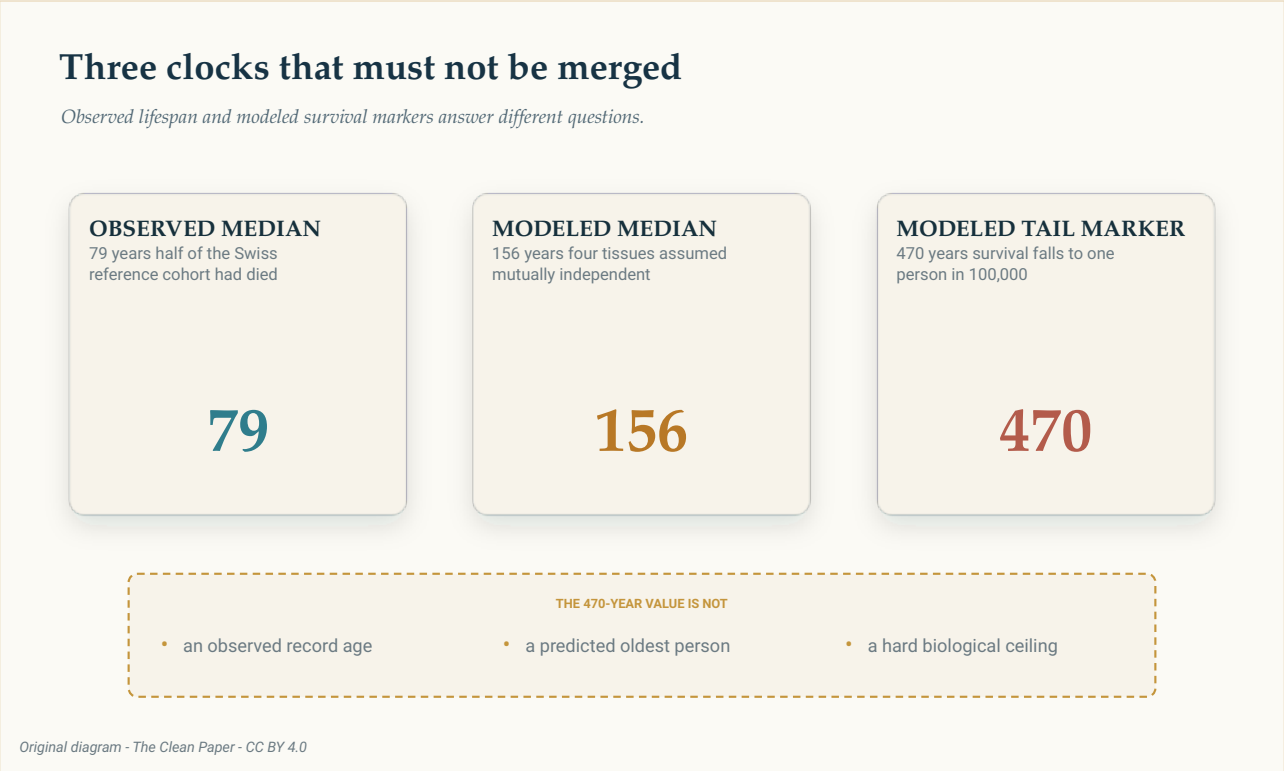
Marubutan sun fara da bayanan mace-mace daga Switzerland. Sun kulle haɗarin mutuwa na shekara-shekara a matakin da aka auna kusa da shekara 30, sannan suka bar wannan ƙaramin haɗari haka har abada. A rayuwa ta gaske, haɗarin mutuwa yana ƙaruwa sosai da shekaru. A wannan matakin farko na samfurin, ba ya ƙaruwa.

Ko wannan yawan jama'a da aka saukaka har yanzu suna rasa mutane saboda **mace-macen asali**: duk dalilan mutuwa da ba su cikin tsarin maye gurbi da ake nazari. Amma saboda haɗarin bai taɓa ƙaruwa ba, lissafin yana miƙewa zuwa lokuta masu ban mamaki. Matsakaicin sauran tsawon rayuwa a samfurin ya kai **shekaru 1,759**. Lokacin da mutum ɗaya kawai daga cikin mutane 100,000 na farko ya rage da rai ya zo a **shekaru 29,221**.

Babu ɗayan waɗannan lambobin da yake ikirarin wani abu game da ilimin halittar mutum na gaske. Suna nuna abin da lissafi yake bayarwa idan aka ɗauki ƙaramin haɗarin mutuwa na farkon balaga aka miƙa shi har abada.

Takardar tana amfani da ma'aunan lokaci da yawa waɗanda bai kamata a haɗa su ba:

- **Matsakaicin tsawon rayuwa da aka gani** a yawan mutanen Switzerland da aka yi amfani da su a matsayin ma'auni ya kasance shekaru 79.
- Rikodin tsawon rayuwar mutum da takardar ta yi amfani da shi ya kasance shekaru 122.
- **Matsakaicin rayuwa a samfurin** shi ne lokacin da rabin yawan mutanen da aka kwaikwaya suka mutu.
- Abin da takardar ta kira **matsakaicin iyaka** ba shekarun mutumin da zai fi kowa tsufa ba ne. Shi ne lokacin da rayuwa ta ragu zuwa 0.001%, wato mutum ɗaya daga cikin 100,000 da suka fara.



Tsawon rayuwar da aka gani, matsakaicin rayuwa a samfurin da alamar mutum ɗaya cikin 100,000 suna amsa tambayoyi dabam-dabam. Alamar shekaru 470 ba hasashen rikodin shekaru ba ce kuma ba ƙaƙƙarfan iyakar ilimin halitta ba ce.

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Me ya sa ake kiran mutum ɗaya cikin 100,000 "matsakaicin iyaka"?

Simulation mai curve na rayuwa mai santsi na iya ƙin kaiwa sifili gaba ɗaya. Saboda haka marubutan sun zaɓi ƙaramin kaso sosai na waɗanda suka rage da rai, 0.001%, a matsayin ma'aunin ƙarshen aiki. Wannan yana ba su damar kwatanta gudanarwar samfurin iri-iri da hanya ɗaya. Ba ya nufin akwai bango na ilimin halitta a wannan shekarun, kuma ba ya gano mutum mafi tsufa da zai yiwu.

Ƙwayoyin da ba sa sauƙin maye gurbin kansu sun zama ƙuntatawa da wuri

Mataki na gaba ya ƙara asarar ƙwayoyin halitta saboda maye gurbi. Ana ƙirga maye gurbi a matsayin mai kashe ƙwayar halitta ne kawai idan ya lalata isasshen muhimmin bayanin kwayoyin halitta har ƙwayar ta daina aiki. Ba a san yiwuwar hakan daidai ga kowace ƙwaya ba; samfurin ne ya kiyasta ta maimakon auna ta kai tsaye.

Da farko marubutan sun duba rukuni biyu na **post-mitotic cells**: cikakkun ƙwayoyin halitta da ba a saba maye gurbinsu ta rabuwar ƙwaya ba. Misalan su ne cortical neurons da cardiomyocytes, wato ƙwayoyin tsokar da ke sa zuciya ta bugawa.

Da aka ƙara asarar neurons ga kullelen haɗarin mutuwa na asali, matsakaicin rayuwa a samfurin ya kai **shekaru 194**, kuma alamar mutum ɗaya cikin 100,000 ta kai **shekaru 557**. Ga cardiomyocytes, lambobin sun kasance **shekaru 208** da **868**. Idan aka duba gazawar gaɓar kaɗai kafin ƙara mace-macen asali, matsakaicin lokacin gazawar ya kasance kusan shekaru 198 da 212.

Waɗannan sakamakon ba su nuna cewa kwakwalwa ko zuciyar gaske suna da wani agogon kirga baya ba. Suna cewa **a cikin wannan samfurin**, bayan an cire kusan duk sauran matsalolin da ke ƙaruwa da shekaru, asarar ƙwayoyin da ba sa samun sauƙin maye gurbi tana fara zama muhimmi tun kafin ƙaramin haɗarin mutuwa na asali ya mamaye sakamakon.

Ikon maye gurbin ƙwayoyin halitta yana canza lissafin

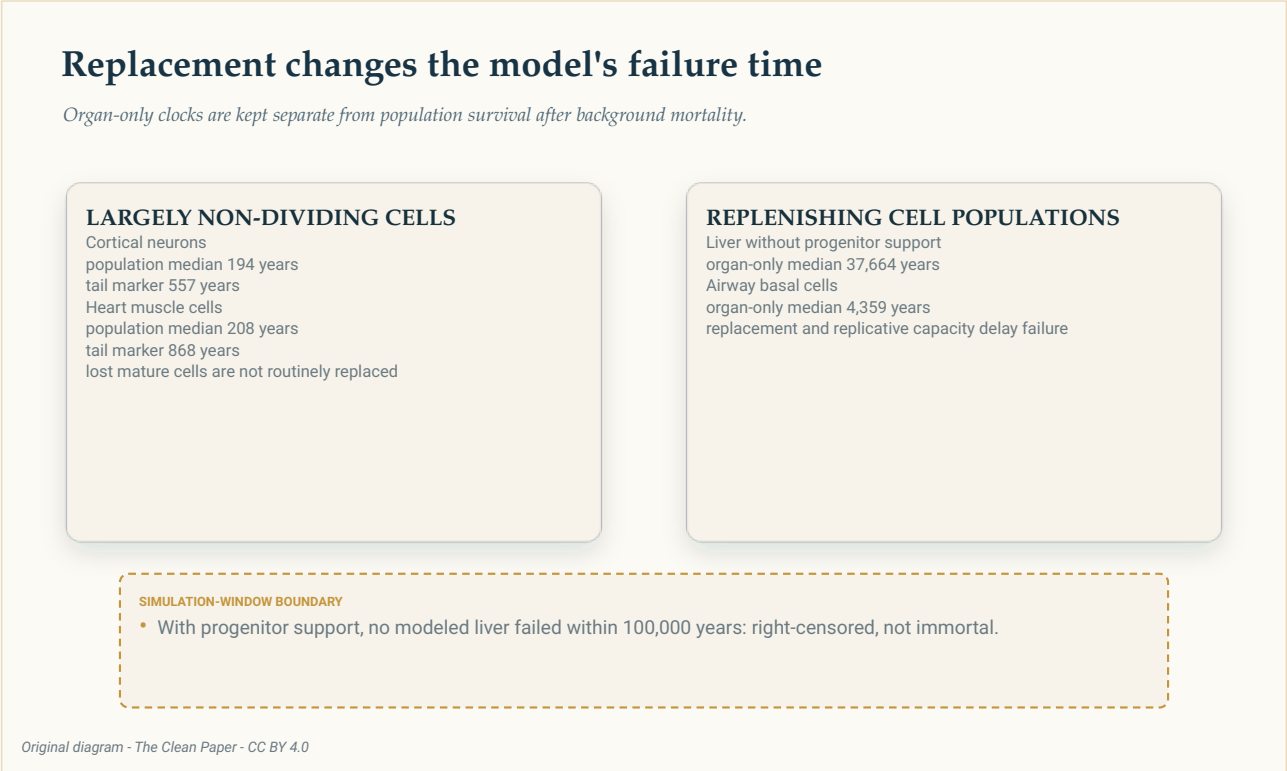
Nama masu rabuwar ƙwaya suna nuna wani hali dabam, domin ana iya cike gurbin ƙwayoyin da suka ɓace.

Ga ƙwayoyin hanta ba tare da taimakon rukuni na progenitor cells ba, matsakaicin lokacin gazawar gaɓa a samfurin ya kai **shekaru 37,664**. Amma bayan an ƙara kullelen haɗarin mace-macen asali, matsakaicin rayuwar yawan jama'a ya koma **shekaru 1,755**, kusan daidai da samfurin da ba ya tsufa. Gazawar hanta saboda maye gurbi ta zo da latti sosai, don haka mutuwar asali ta rinjaye ta tukuna.

Da samfurin ya ba hanta progenitor cells da za su iya cike gurbin ƙwayoyin da suka ɓace, babu hantar da aka kwaikwaya da ta kai ma'aunin gazawa cikin **shekaru 100,000** na lura. Wannan ba "hanta marar mutuwa" ba ce. Sakamako ne na **right-censoring**: lokacin lura ya ƙare kafin samfurin ya nuna gazawa.

Respiratory basal cells, waɗanda suke taimakawa wajen sabunta rufin hanyoyin numfashi, sun kai matsakaicin lokacin gazawar gaɓa na **shekaru 4,359**, kuma alamar mutum ɗaya cikin 100,000 ta gaɓar kaɗai ta kai **shekaru 7,617**. Bayan ƙara mace-macen asali, matsakaicin rayuwa ya kasance kusan shekaru 1,755, yayin da alamar ƙarshen curve ta kai **shekaru 7,132**.

Waɗannan dubban shekaru ba hasashe ne game da huhun ko hantar mutum na gaske ba. Nama na gaske suna fuskantar kumburi, fibrosis, lalacewar jijiyoyi, kansa, kamuwa da cuta da hulɗa da sauran gaɓoɓi — abubuwan da wannan samfurin da aka rage sosai bai ƙunsa ba.



Kwayoyin da kusan ba sa rabewa da nama masu iya cike gurbin ƙwayoyi suna amsa asarar ƙwayoyin halitta ta hanyoyi dabam. An ware lokutan gazawar gaɓa kaɗai daga rayuwar yawan jama'a bayan an ƙara mace-macen asali.

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Nama huɗu suna ba da shekaru 156 ne kawai idan aka ɗauka gazawarsu ba ta da alaƙa

Sannan marubutan suka haɗa neurons, cardiomyocytes, hepatocytes da respiratory basal cells. An wakilci jiki a matsayin **tsarin amintaccen aiki**: idan wani muhimmin ɓangare ya gaza, jikin da samfurin yake wakilta ya gaza. Kullelen haɗarin mutuwa na shekara 30 ya ci gaba da kasancewa.

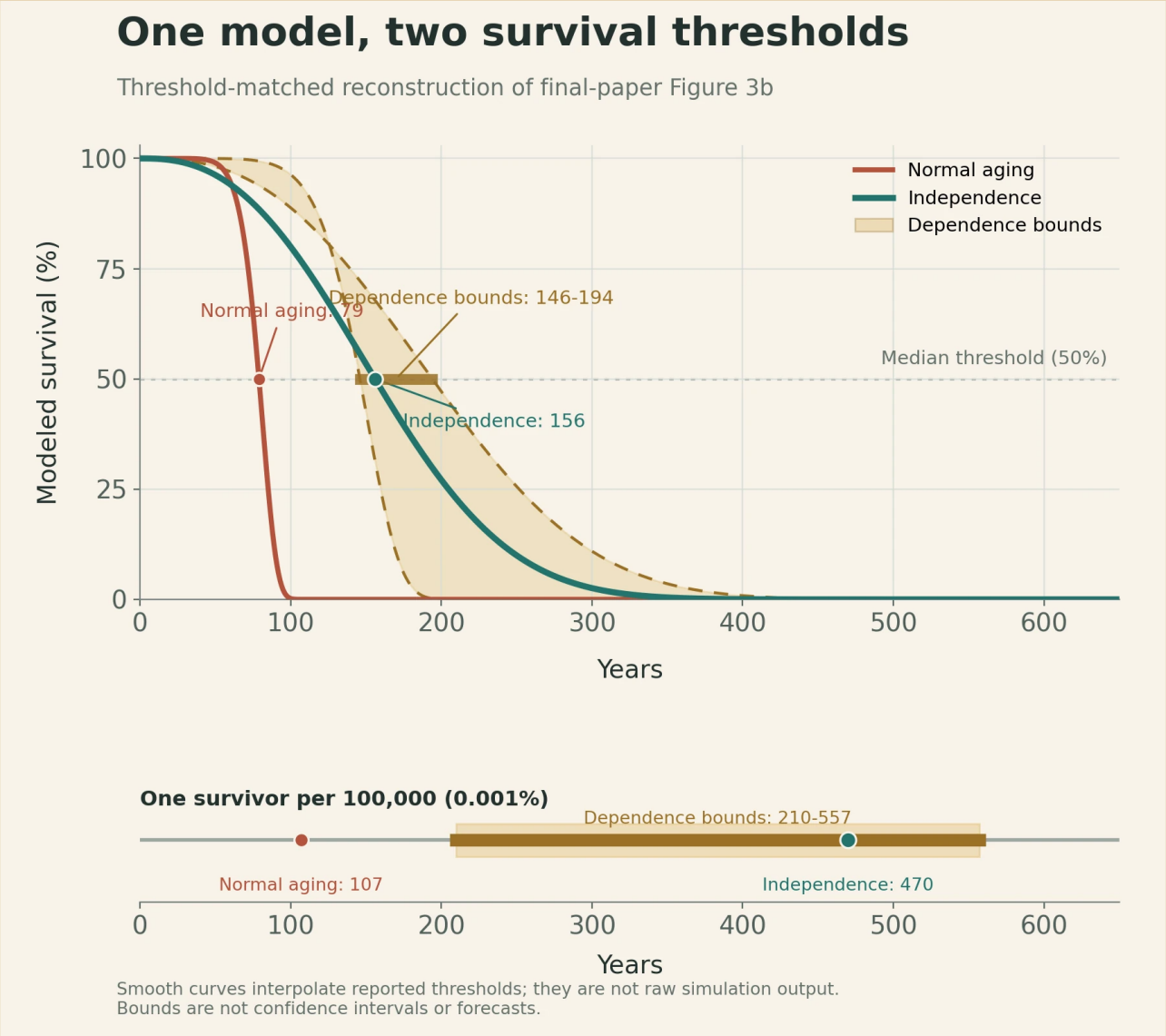
Don haɗa samfuran nama huɗun, marubutan sun ɗauki jikin a matsayin series system: samfurin ya ci gaba da rayuwa ne kawai muddin kowane muhimmin nama yana aiki. A ƙarƙashin zato na **rashin alaƙar gazawa da juna**, sanin lokacin da nama ɗaya ya gaza ba zai canza yiwuwar gazawar wani ba; saboda haka ana iya ninka yiwuwar rayuwar nama huɗun. Da wannan zato, matsakaicin tsawon rayuwa a samfurin ya kasance **shekaru 156**. Alamar mutum ɗaya cikin 100,000 ta kai **shekaru 470**.

Wannan zato yana saukaƙa lissafi, amma gaɓoɓin jiki ba injuna masu zaman kansu ba ne. Suna raba jini, kumburi, hormones, jijiyoyi da matsin da ke shafar dukan jiki. Gazawar ɗaya na iya canza yanayin wani.

Don nuna yadda rashin sanin wannan alaƙa zai iya motsa amsar, marubutan sun ƙididdige **Fréchet bounds**: iyakokin lissafi mafi faɗi ga haɗaɗɗen curve na rayuwa idan an san curve na kowane ɓangare amma ba a san yadda gazawarsu ke da alaƙa ba. Matsakaicin rayuwa ya faɗa cikin **shekaru 146 zuwa 194**. Alamar mutum ɗaya

cikin 100,000 ta kasance **shekaru 210 zuwa 557**.

Waɗannan ranges **ba confidence intervals na wani hasashe ba ne**. Kimar sama tana daidai da yanayin da lokutan gazawar suka yi daidai sosai. Idan abubuwa sun fi biyu, ƙananan Fréchet bound ma ba lallai ya dace da wani tsarin haɗin gazawa da zai iya faruwa a zahiri ba. Iyakokin suna nuna yadda amsar za ta iya motsawa idan samfurin ya san halin kowane ɓangare amma bai san yadda gazawarsu ke tafiya tare ba.



Curve mai launin teal yana nuna sakamakon nama huɗu idan aka ɗauka gazawarsu ba ta da alaƙa. Envelope mai launin amber yana haɗa sake gina iyakokin alaƙa bisa ma'aunan da aka bayar, yayin da curve mai rust ke nuna ma'aunin tsufa na takardar. Tun da ba a wallafa bayanan curve na ƙarshe ba, layukan masu santsi suna haɗa wuraren da aka ruwaito na 50% da 0.001%; ba sake gudanar da simulation ba ne. Iyakokin lissafi ne, ba confidence intervals ko hasashe ba.

Original chart - The Clean Paper; thresholds from Efimov et al., npj Aging (2026), Figure 3b CC BY 4.0

Sakamakon rashin alaƙar gazawa da juna yana ɗaya daga cikin yanayin kwatantawa. Iyakokin alaƙa iyakokin lissafi ne, sannan parameter sets 300 suna nuna ƙarin rashin tabbas game da yadda ake ɗaukar yiwuwar maye gurbi ya kashe ƙwayar halitta.

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Mene ne dependence bound?

Ka ɗauka muna sanin yiwuwar kowane ɓangare huɗu ya ci gaba da aiki a wani lokaci, amma ba mu san ko suna yawan gazawa tare ba. Fréchet bounds suna ba da mafi faɗin range da lissafi ya yarda da shi ga sakamakon haɗin, ba tare da zaɓar wani takamaiman tsarin alaƙa ba. Shinge ne ga bayanin da ya ɓace, ba error bars daga maimaita lura da mutane ba.

Yiwuwar maye gurbi ya kashe ƙwayar halitta babbar tushen rashin tabbas ce

Wata shigarwar samfurin tana da wahalar sanin ƙimarta: yiwuwar sabon maye gurbi ya zama mai kashe ƙwayar halitta.

Ƙarin bayanan binciken sun sake gudanar da nazarin da **parameter sets 300**. Ga single-letter mutations da ƙananan insertions ko deletions, ƙananan iyakar yiwuwar cewa maye gurbi guda ya kashe ƙwayar halitta ta kasance **1.94 × 10^-7**. Manyan iyakokin da suka bambanta da nau'in ƙwaya sun kasance **2.25 × 10^-4** ga neurons, **1.08 × 10^-4** ga cardiomyocytes, **1.02 × 10^-4** ga hepatocytes, **1.60 × 10^-4** ga liver progenitor cells da **1.77 × 10^-4** ga airway basal cells. An zaɓi ƙimomin dabam-dabam a logarithmic scale, don haka za su iya bambanta da umarnin girma,

ba da ƙananan kaso kaɗai ba.

Canza waɗannan shigarwar marasa tabbas ya motsa shekarun gazawar wasu nama da kusan sau 10 zuwa 100. Duk da haka, a duk parameter sets da aka gwada, babban jerin ya tsaya iri ɗaya: nama masu ƙwayoyin da ba sa rabewa sun fara zama masu iyaka saboda maye gurbi tun kafin nama masu iya cike gurbin ƙwayoyi. Wannan daidaiton yana goyon bayan **kwatancin nau'ikan nama**, amma ba ya gaya mana wace takamaiman lambar tsawon rayuwa ce daidai.

Sensitivity analysis tana amsa tambayar "shin babban sakamakon yana tsayawa idan shigarwar da ba mu tabbatar da ita ba ta canza?" Ba ta gano wace ƙimar shigarwa ce ta gaske ba.

Samfurin ya cire abubuwan ilimin halitta da a rayuwa ta gaske za su zo da wuri

Yanayin samfurin ya haɗa rukunan ƙwayoyin halitta huɗu kawai. Yana ɗaukar maye gurbi masu kashe ƙwaya a matsayin abubuwan da suke faruwa ga kowane cell daban, kuma yana wakiltar gazawar gaɓa da wasu thresholds na yawan ƙwayoyin da aka zaɓa. Bai haɗa **sublethal dysfunction** ba, inda ƙwaya ta tsira amma ba ta aiki yadda ya kamata. Bai haɗa faɗaɗar damaged clones da za su rinjayi ƙwayoyi masu lafiya ba. Ya saukaƙa hulɗar gaɓoɓi da juna.

Haka kuma an ware kansa. Samfurin yana ɗauka cewa immune surveillance tana kawar da malignant transformations, don haka haɗarin kansa ba ya ƙaruwa da shekaru. An cire ƙaruwa a kumburi da matsalolin endocrine, jijiyoyin jini da tsarin jijiya.

Akwai matsala mafi zurfi ta counterfactual. An kiyasta yawan maye gurbi daga nama na gaske a jikin mutane da suke tsufa a zahiri. Amma samfurin sai ya ɗauki waɗannan rates ya saka su cikin jiki inda oxidative stress da sauran hanyoyin tsufa da ke ƙaruwa da lokaci suka ɓace. Babu wata yawan jama'a ta gaske da za a iya gwada wannan haɗin zato a cikinta kai tsaye.

Kara wasu hanyoyin gazawa da aka cire zai iya sa duk wata iyakar sama ta zo **da wuri**, ba ya sa shekaru masu yawa da aka ruwaito su zama mafi saukin kaiwa.

To mene ne amfanin manyan lambobin?

Idan aka karanta takardar gaba-gaba, tana kama da tafiya daga shekaru 1,759 zuwa 156. Idan aka duba manufarta ta baya, abin da take son nuna wa ya fi bayyana.

Matsakaicin shekaru 1,759 an gina shi da gangan ya zama abin da ba zai faru a zahiri ba. Yana kafa duniya inda shekaru ba sa ƙara yawancin haɗarin mutuwa. Sannan asarar ƙwayoyin halitta saboda maye gurbi a kwakwalwa da zuciyar da aka kwaikwaya tana jawo wannan duniya zuwa wani range da har yanzu ya fi duk tsawon rayuwar mutum da aka gani, amma ya yi ƙasa sosai da wannan matakin farko na wucin gadi.

Wannan bambancin yana goyon bayan ra'ayi mai kunkuntar ma'ana: **taruwar somatic mutations na iya ci gaba**

da zama wani muhimmin ƙuntatawa ko da an cire hanyoyin tsufa da yawa. Bai tabbatar cewa maye gurbi shi ne dalilin tsufa guda ɗaya ba. Bai ce kawar da maye gurbi zai kai mutum ga waɗannan shekarun ba. Binciken bai kwaikwayi wani magani ba, kuma bai yi nazarin illoli da ciniki-cinikar da canza yawan maye gurbi zai kawo ba.

Darajar gwajin tunani ba alkawarin rayuwa mai tsawo ƙwarai ba ce. Hanya ce ta tambayar: **waɗanne gazawa ne za su rage idan an cire waɗanda suka fi bayyana?**

Takaitaccen bayani

Wannan binciken ya yi amfani da samfurin demography da amintaccen aikin nama don tambayar yadda asarar ƙwayoyin halitta saboda maye gurbi za ta iya iyakance tsawon rayuwa a wata duniya ta counterfactual inda kusan duk sauran hanyoyin tsufa da ke ƙaruwa da lokaci aka cire. An kulle mace-macen asali har abada a matakin mutanen Switzerland masu kusan shekara 30. Rukunan ƙwayoyin halitta huɗu kawai aka haɗa, kuma ba a ba da izinin dasa gaɓa ko wani magani da ke rage maye gurbi ba. Idan aka ɗauka gazawar nama huɗun ba ta da alaƙa da juna, samfurin ya ba da matsakaicin rayuwa na **shekaru 156** da alamar mutum ɗaya cikin 100,000 na **shekaru 470**. Idan aka yarda da duk alaƙar gazawa da lissafi zai iya ba da izini, iyakokin waje sun faɗaɗa zuwa **shekaru 146–194** da **210–557**. Neurons da ƙwayoyin tsokar zuciya sun zama ƙuntatawa da wuri fiye da hanta da airway cells masu iya cike gurbin ƙwayoyi. Waɗannan sakamakon simulation ne masu sharadi — ba iyakar rayuwar mutum da aka gani ba, ba hasashen magani ba, kuma ba hujjar cewa mutane za su iya kai waɗannan shekarun ba.

Bincike ba tare da ƙarin gishiri ba

Abin da takardar ta nuna: A samfurin da aka cire masa kusan duk sauran hanyoyin tsufa, asarar ƙwayoyin halitta saboda maye gurbi a ƙwayoyin da kusan ba sa rabewa tana zama muhimmin ƙuntatawa tun kafin ƙaramin haɗarin mace-macen asali da aka kulle ya mamaye. Ainihin lambobin suna dogara da samfurin gaɓa, zato game da alaƙar gazawa da parameters na yiwuwar maye gurbi ya kashe ƙwaya.

Abin da yake da amfani amma yana da sharadi: Matsakaicin haɗin nama huɗu ya kasance shekaru 156 idan aka ɗauka gazawarsu ba ta da alaƙa. Da curves iri ɗaya amma ba a san alaƙar gazawa ba, iyakokin lissafi sun ba da shekaru 146–194. Alamar mutum ɗaya cikin 100,000 ta kasance shekaru 470 a ƙarƙashin rashin alaƙa, da 210–557 a iyakokin.

Abin da bai nuna ba: Cewa mutane za su iya rayuwa shekaru 194 ko 557; cewa waɗannan shekaru ƙaƙƙarfan iyakar ilimin halitta ne; cewa somatic mutations su kaɗai ne dalilin tsufa; cewa wani magani zai iya cire sauran hanyoyin tsufa; ko cewa rage maye gurbi zai samar da sakamakon da samfurin ya ba.

Manyan iyakoki: Rukunan ƙwayolin halitta huɗu suna wakiltar dukan jiki; an kulle mace-macen asali a matakin shekara 30 har abada; kansa da sauran hanyoyin tsufa da ke ƙaruwa da lokaci an cire su ta zato; hulɗar gaɓoɓi an saukaƙa; yawan maye gurbi ya fito daga nama na mutane masu tsufa na gaske; thresholds na gazawa da yiwuwar mutation mai kashe ƙwaya zaɓuɓɓukan samfurin ne; kuma ba za a iya gwada babban counterfactual ɗin a yawan mutane da ke daidai da shi ba.

Yawan amincewar da ya dace ga mai karatu na gama gari: Babba cewa lambobin da aka ruwaito suna bin zato da parameters na samfurin kamar yadda aka bayyana. Matsakaici ga babban bambanci tsakanin nama masu ƙwayolin da ba sa rabewa da nama masu iya cike gurbin ƙwayoyi **a cikin waɗannan zato**. Karami sosai ga duk wani ikirari cewa shekarun da ke kanun labarai suna hasashen tsawon rayuwar mutum da za a iya kaiwa.

Majiyoyi

Efimov et al., Somatic mutations impose an entropic upper bound on human lifespan, npj Aging (2026), article in press
https://doi.org/10.1038/s41514-026-00421-6

Computational Aging Lab, model and analysis code
https://github.com/ComputationalAgingLab/somatic-mutations-simulation