

U W X Y Z [\] ^ _ ` a b c d e

b ! f % g Oh & ' i j k

OOcdefJq, ?gAhi xH
l =j Tefg6kIlyp
BC?fDbcb %%%gAJ'
lmnj ocpppJ' 1qDFTr
dsgOtu%@10vqwxjj 6
y pgA[HSzlyQ| 6j T
efgDw}mfTQ7l =?bQl
=' |j UVp
Lp! =Szwg?~ Vy! " U
jy pQ##\$j \$E1w\$F\$R
%%&D&D' / -j j () j *
_s+ 10v\pst?, EZ[- .
/gkeDvQ\$z* Bz - u. Oy
\Qqw?123J' gA4>. r3
] ^ p

l mnoY] ^ 38.6%abc

gA[] Fw`ly?cl. 5,
6?7pV, lj ocp: 8gEMT1
Qew}pfD?, twg\$-l B7j
ocpH9p?D300: a 1200: 6';
<=l \&?c>I??#?C+u%
#<wxj|y p
7UV| Hcd6@ABCOD
9SMR: O1HE? ; <=l ?/BAT
6BC[7E, @AD)j * [VI F
U?VCJqgAewxjj pptu?V
D]j \$FUwG1yHgA6j y<
l m12yHp
Jcl Vy! Q* gAJ' T6j
y RS?gl { | 68j KHeQ7
l =p
%&ETPQ\$R#%\$&aLM
S-Ig##\$j \$E1w\$F\$RRS
i aNOMS-7NPPQRS#%\$
& Graham.J.Hutchings I Z, - 6L) %
Qi 1oD001?H\Q TQSzZ
. UAp
RShi 7{ VWXE2j CZ6
JEYZHm4?eYZ -, oDFUV
, t6[boD\] 2zH) %Qi 1
oD\] p\$ \] eFU: X^a 270: ?

bHr 36{ ?FUT6j 9wc_J q
wxjj ?C{ 2j HY=p
\$gAJ' w\] cfDcy w
xjj 6DBI ' (J' gA? [7I
' ' aj \$JY=pDD] FU\] T?
pqYZb[I' 1.3qY=p[H/b
j \$9p?Y=6bc\ 7c<l m 1500
dq?efDHcgp
E, t=>q' ?DO23wg -l
' j \$JO1GH. Lwg] hj]'
=O6i 7_t ?[7" U 38.6%j y
<?H[j k6gl &l - Bv. bw
Q* =mpqr RSqw- uOvQ\$zp
pqrstuvw 1000xy
Dwg; <?) j * 6L' j QOE
L' M; QQn] . { dQSp
) j * j Qe) %Q{ n<kQl
6; oWs?>DI m\$| UVT?M;
Op{ ABJ' j kQe&l Q6r 3
| g? 5r_) j * l <q#l =#>
nUVp
DBZ - , oD9MSR: ' g) j }
_T? j Q) j * [7BC] j FU(
| ?>DFCGUf Tr - Lf W(pqr

RSst?, t) j * 6_} uvvw
200x7p
W' ?y' j QEM; Q6) j * ,
gl 6J' eUVzHopp
D] \ { B6veT?%&- =?|
' / } Ej j (l - j (: j Q | } GH
6 &) j } _ [7DF8; Xl wgp
! wj " TUV\$- =?py#) j * 6
j QE' M; Qp
H' ?%&B>] Fw- y#6) j
* M; no\$D) j * u&G%&Q' (
xj E6) d* + j ?>q) d6X6
L56, Q756 &) j vG?hDc
AB &vGI ') j j Q6DBI B
C) j * M; Qp
- pl qvw? \$w() j * DMSR
wgFUT` =>l m 1000x76M;
Qpb7?) j * l =. l m 1500d
6) j 2j 5?5j . l ' j Q?+ . .
BZ - , wg) j FU/Op
%&1 2vTPQ\$z? \$RS` 3
n. &) j * M; Q&l V[4Qp,
- =? TnoD5I6: ' (7s7N
8I9: ; ; ' / T?) [l l =MN(
wpD] ' j Q' g) j * M; no' @
veUVDbO' Ql) j *) uTpq

r RSqw- uOv* Bzp
Yz g{ |W} ~ ! " Z
f D?gl O1<=O- ` 7=7k
#>n' | j UV<YI =?9WDO,
tgl J' <=&>8j l8q8l' M
; QO7y#6?@p
%&* +) . AAOB3gA' |
j 6[l Qp2014\ ? , C+qr RS?A
Q23wgQSp10v\ Z?%&* +N
Z[- D' / j j E) j * VOgAJ
' =&s8RS?] ^ ^ DEl qF6-
=?Hk' | j z ZUAp
\$* +l m) j *] ueFU\]
i j ? Vy! ^ 8. wgmf 6j y G
b7? mD) j * u&G%&Q) d*
+j ?] ^ y \ .) j } _ 6M; Q^
_>? q. ' (IM; 6wgO1p
Lfd?j \$&| &>6r 3HI {
l m[j k6=>?] ') J t KJ j T
q# 7p6' JpQ&R2DDORS
T? j l m23wgO1?^ 8. l ??
\Q. gAhOQS?Hj \$l LM: b
O' | 68j 2[zZ. [l QpO
%&u5? DDnqwl =O/b
RSO# ?ePo- . ' gmf 6Pj Q
\$?H' | - ` eUVBv.L\$` Qe
LRSTQ, UARSqwl KVI qF
LU>VQH' ?%&#D\ &qR WXp
L) J, - . l qF>n6YY'
gZ[?hD>q\ T?Bv. l qF>
n6) j * #HX_9?]) J b^
sgAUV6=l fHpQ&| >2q
#l =23wg` @P<6\ pUpp
l = ' | j ?' 7' \$RS8Z[eq
r_n' j pl m_nLa* +b' |
bcB- ?p l =gl 6>nj l8
j j UVpO
! " # \$ % &
<https://doi.org/10.1126/science.adt0682>
<https://doi.org/10.1038/s41586-024-08483-w>

! " # \$

HI J \$KL! ! " O1M

NO PQRS! " TU

! "#&' LMN+TPO\$RS! ! " RSTRSi UVW
* +ERSi XYD* +Z[?\] H5p^_? ` a5. bc
zde! " Lfgh, i fX?h- =j v6% (UE j 7F
6LfkI mn. ar op6[Vpqr RSqwt Dr - uO
vQ\$ \ ` zp
gh[Hs! nt! l <, u6opvw?l Kxg5yz{
h| } D#~ ! e" ! #<~ l <pgH6\ \$e%&' J6
(F) Z* +. , ; 6- . / O?, bc! " 127Fmn. r 3
[VpBC?746RSO5TO#<6X778xXF9?Yl a5
bc: ; g6<=zj >?p
@RSux?%@ABz dLC? j ! " 7F! " Lf ?D
=E[l , ! " gF+Amf' JABp/OD] GH?TPO\$R
S! ! " RST* +B>.] dr 3l J?Kbczd{ <eL-
gh6MNBUp
Oogh6] H5p@P7HQ* D] Q\$RS?RS* +TV
UV' PmWznX' FuY9CMP6 nX5p?VZbc' 1Z
| gh&qn[9HRET: ?LM. 1901\] 2100\ 8bcU] nK
gh, i f X6^zkl pwwx?bc_ } gh, i f XD` =
8aL. b 10?b 20cd/e: ?hDfgh_ " lgh_ " Tl
Sh_ " : ghj k! <--=> ! " 6LfkI p
E' b7?DbczdGHI ?hLfkI Omno#91901\]
2014\ : 6p 10\ aL 04cd/e?a<aYZqH2015\] 2100
\ : 6p 10\ aL 20cd/epI m, ' bcgh, i f XER! "
ps86qr Q?RShi r l . ghLfkI EptWObczdL
- 6 j ! " j va?C j 7F6LfkI , kAB' &p
\$RSj ` a5. bcgh, i f X6<=LfkI ?cS.
bczd, ! " gF+Amf 6suAB?HLMABzj IgF(
F) Z, ! " 7F6AB: Bv. wx\ p
! " # \$ % & <https://doi.org/10.1126/sciadv.adq4577>

HI VWXYJ \$KVW) Z [\ O1M

] ^ O _ ` abcdefg

! "#&' OPQ" R: ST+TPyz { | Q\$Ryz J
EO1RST} l / W-E1w F* +, - > ! " 35K#q F
\$ " ?D! " } l / W-RSE/W-) % F=&' @op' (?
\] AB' .) P! " F6* E+wI Apqr RSqwt
- uOv, - RSzp
! " { #. Q! " / OE? bc1#op" M[E&] ? @
2l 3l245l ' ' : i 67Qp, -] F8q8l' l <l') j
Qe' (| 6/W1[_9?, O! " } l / W-RSE/W-)
% F' @op' (p
; ; <=OKO\$NP. \$ " [H] Fq>6/W1[O1? VO
' l <?H/W-T6 SNP 34pSNP\$ " 6i l @A' l <l WB
Ql[oCQeq, F86q8pD{ | ; <?NP\$ " DcdVOW}
+ , \$1s1+, EFGHib/W-r l 1seJFK56: p
RS* +/O377L " Fmb/W- SNP gNI2980 FOP
E QTI95<QQ/WR: e 23dS8{ - QQ: TU? () > /
W- ' OKQIRVW[l 1X] Y6 35369 d SNP [HGH34p
kT? QOZ[r l 6586d SNP[HDH34&] \) u? *
+q} R- >bcj ^ ! " # q F\$ " L GenoBaits Cassava35KQp
\$/W\$ " DW} OPQ1s1_t- 1s1b/W-r l 1
sT` @F_6(wp\$ \$ " 6R- @%O' 9! " Fa =?BC
F(| ?] AB') P! " F6* E+wI Ap
! " # \$ % & <https://doi.org/10.1093/hr/uhae305>

r l s t _ uH) v w x y

! "#&' i 5+TPO\$RS#
OMdJERST=O-OJK_t m
yRS* +st. DyeJEW- =6
TJOfj o]] ghyefpD' &
D? } Pfst. 3i fMj opD(y
eJEWj ` st- =fj o? k.)
PTJOfj o6l mpqr RSqws
t- uOvQ\$ l szp
&T7nHlghyef O' O\$ j
oZ* yeJEW?Fo| 5#ng86
phO/Oqrstuegh#pyeJ
EWW- =OF7[vwj oCi xH
_20y/bc| op6dJE- =&] Q
ghyefg8/8[D? 1D] V
W?spOsz3[| Tpk] ~ ?w!
" E# " F<?%&- & >? 21\ V
<? t8() f x f Buthida?WVU* X

N+): 7, ?O- : 7Y; p
ghyefj o} >Fk, P. T
JOfMj ob#p- p1s? \$fj o
<X[/ 10cd? >q, F#?JD
l { yeJEW=EOT6' - 11-
23- ?1745167H=?8a[l 9
=x[: ; +E<] p=>[l {] NT
[: ; +E6=E? ? =@MeAB
+E?7NCg: p
QRhI l mD^oHyeJEW
6=EO? =ghyefDJ KOET
' @P' d.F5ToQQux=[l E
C7-OJK_t 6OdeF' JCG
6JkH+pD] RSH. QyeJEW
=EO6CGQBv. wr pp
! " # \$ % &
<https://doi.org/10.1016/j.scib.2025.01.035>



z { V | w } ~ ! G 67801 z { V | w } * " # \$ G 9: l ;

! ! " # \$

%&' () * + , - . /



O123456789: ; 9<=>?@A eDNA BCDEFG
- . . / O1

hi Ajl k l mWn Do Np q

b # \$ %

' () * +, - . / , O12345
! 678' 9 ; < 2024=>? 80 @AB
CDEF 5.2%, GHI 20J? 80 @AK
L' 1MN- OPQ 80 @A9BCDN
- RS? 70 @AT U%, VWXYZ [\]
^ _ ` abcdefgVhi j k l m
n9op
hij k l q r s t u v a b c , g
w x y z { | M } f - A! " # \$ % & ' &
() , e f m * X + \$ % , - . /
O1]
23456, Al&' 7H89: 59
; <=>Q@, r' hij A[efB
CDE, FGH4f l J K9hi j k
l , L DeepSeek, Jefv? Al&' j c
* + , AI - MNO9 Vectara HHMM |
} f &' PQRS, DeepSeek- R1 9&'
Dx 14.3%, TUH- MVWXY]
[U, YZ? @es[l U \ ,] ^
_ [l U] Lphi j ` ab` c + 9
de| f, gg hb#Qj k. l Ym,
v? Al&' _n() [h] eg, Lpo
qbxUpqr | f 7st 9\$%u7,
Al&' () \$%2C, gyz{ Al39
9: ; +7<=+() , >? - Zhi j
^aA@ABS_ () ,
GC, \$v4* X+() D, , hi

j EF- Gba] H'] ~L, l <Ja
DeepSeek KL: MNO, PCQtv? o
bRVbl 5STU i VWX` Y' 9#
ZVbR, s[. O, - \] ^ 9Y
Z, _g` bxNOKL9ab+cd7
=S, ef gf 3g- . hkba9j i
9u6, \$l <j k, BC , \$ DeepSeek
=l 9bc\$%, [` @AmX=U] b
pD, nFt# { opiO7qr }
^ _ 6, - JbstuU9Mdef t
Dv Al' a\$%9 wQ_ G<dxMb
stu[U,] yz \$hi j k l]
2025={ l su, DeepSeek | H\$K
#() D, 9- ! ? , ' #K#hi j
a\$9%&' () r (* +K#hi j
kl , L#h, i- . iKmiil / O129
34] 56[78M9MP, , a\$] e
s; <= " # DeepSeek Kh9H4f
l ef Rsdx>? @AH4f l BC
9DEM] FG, DeepSeek HMI J qv
f' K#! 59#K, dxM: L*
: MNOPQYmQ#RQMYSD
T Q U5 AlVWX Y9Z [\] ,
DeepSeek ^n_dxM' l Ha, [lb'
>?cd, efggh9cd] Yi Hj
j 9 Alz O\$ @]
-L, kO! 5v? [ma DeepSeek
: L: Rinbi" #7) opqXV9r
X, steumv<wx, esVuMYi!
y7Ni Twt 9z{ | Y | Ma] Al, h
ij <5, oq~ HM9! " q5] * X
5, Z[E- 9: M: #D{ g' - : #,

] Lg| 8Mh' - , - : M: L] 2\$%
56, hij k l [47M^bl 9&
' , ` gES() i: * i53#+D,
- 7i { . / T9Mok yz \ } , %
c5gl 5\$%ibc7\] 9 1XQ
2 VW3QR, l 5\] h45[8
Mi[67i[v<, LF8#9 Alyz
\] -AIGC 9: es; <' - : #=>
wF, BCs&' s? 9Alkl bxpq
\$c, \$: M5@[-]
FG, l 55A9` a\$%, BAl&
' C5UD, wx Al\$%H' Wa9+
E, FH' uv\] VWXPGHI \
J9KL]
MNsul OXPQR, SZT, i
UV' Wv[X, #vg YZ [Q5u
L\] iv^iv_ , 3@ \$c6` XQ
BCH' ab] [cdefW gg: ,
: zLB(QHg, l 59U% [" nh,
(Q-ij k9kYfl m] ? \$' (y
z{ Al| f, vn[o] Ni24h([p
[q9AlXPl { , W FURsst
FZuZ, ' Mi ox @W uZQ5
l OPGJ uJH' W , dxMJ uJ
>?W , vd() iv4() i: L()
JuJwxJMYmizyz<z\$]
Al&' s? 9hi j k l Lpz {
W| i() , h~aU%ia\$%t !
yz] " U5v# 76\$9%&l ! u,
s[* () 9OKb(i nNO+ ,)
. thhUk@W (<Al' a\$%5
A] Jahi j hkyzSZ#%9:

yi#* 7+, M*, LpM- Ja Al&
' s? 9hi j k l , t / O12! " "
l , z<' 8' K3{ 6{ ! l OPL
es, gWga[?K]
G* X+uv' () (, [4Al |
f9H4f l xKh, sqr * Xx: ;
b8+AgFQ} y9] GC, [e56
t': 789#B: XQYzV? , _ +
D; n* ; , wx<: 8+s=7FBg
9\$%KLx<=] ' (8+m@SD,
9\$%, >f=v' ?m+9@ADB,
8+R>f 2KCADJ ZYi* Y98
+DB] wF, kOxyxW] * +9h
ij kl aHEFGGr, HI K6W: J
kl 9\ &f+>-]
K: , L? L\$ Al&' ef# { 9
\$%2C() >? j kHKM>Shi j
NM] HI , eOHI P{ MI iQl iR
l ST&' D, JqU#2CV3] * W,
K=Uhi j k l JaM* 9bst u,
[z \$ Al, Xys Alhkqr 9 hkQ
xZ, BAlxMr a, sL AlnvxZ]
' W, mH- | 8M[\ 9hi j] a,
#%yz 6OK' ^ _ ` =, z{ <K,
- saF' ?m+9&' D: J, m[e
bqSc] k8, 2MTud, hi j \$%
2C() 3SDJ b, - e{ Ff {
9g: <pp, 3zy8(L\$DB, '
hi i' j Bi' kA6H, hi j k l
\$S- SM9eO^aA]
#&' ' () * +, - . / O12
34+

! "#\$%&' () * + ! ! " # \$ % &' () * + , - .
/ O12345678 DNA?eDNA: ; <=>?@ABC eDNA D
EFGHIJ KLMNJ EOPQRST 6UVWX?YZ [\] ^
_ ` abcdeJ 8efgEF?hi j kDI mJ KGHT 6U
Vnopqr RSst- uOv1wJ Kxyzp
eDNA { | J E } ~ a } ! 78T 6 DNA " # p\$ % eDNA
\ & J EGH?] F' (l) * + , J E - . / 6O12# ?DJ
EOPQLMI 34EF 567N89J EGH: ; <' =>?#
6UV@ApBC?eDNA DXE 78T J E <6qr QFG?eDNA
O1HI J kL@M@NQPORSTL@OUNQ
RS* +V/WXYZ [6\ X82?] ^ eDNA EEF5<
6r_p' } Ca?78Tb] EFcbd} 6DNA XYe=>]
; f X6Z [?d] 5<gO?XYZ [g#p
RShi j k l mno5pqr 12345<DeDNA; <1
sT6[&Qpt u1svwx?d3Fcbyz { | 6no5p
T?1 2345<EXY5< } --> ! " 6#qr Q?+ / Wy
z { | g' ?qr Qg%p
&m, ' () ?RS* +* ;) V' @F' + , OPQ+- O
/ 6O1234N, ` \] ^ i qpvw 5?qFO DNA 67
5?1 2345<EP8d] 56#qr Qb%uXZ [45E
N65<9: X! " ' O, t DNADX>?+c; N{ <\ =l }
>?@6ABp
' () u5? * + , - 6/ O1 23456 eDNA; <=>?1
OCDEF 6eDNA 675>?C; EF] >IG=&H: 78z<
6l J7 kBlM: lWNOLmf gEF 65<p
! " # \$ % & <https://doi.org/10.1111/1755-0998.14076>