

From Data to Decisions

Machine Learning–Enabled Personalised and Risk-Adaptive Cancer Screening in Taiwan

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Riga · 7 October 2026

01

Data

Registry + community screening

02

Models

Machine learning + multistate

03

Decisions

Who · how often · what next

04

Delivery

Navigator for people and staff

05

Reinforcement learning

Adapts as new data arrive

Toward CRC Screening 2.0: From **One Size Fits All** to **Precision Screening**

Original research

Long-term effectiveness of faecal immunochemical test screening for proximal and distal colorectal cancers

Gut

Chiu HM et al. Gut 2021



Advanced-stage CRC

-29%

aRR 0.71 (0.68–0.75)

CRC mortality

-35%

aRR 0.65 (0.62–0.69)

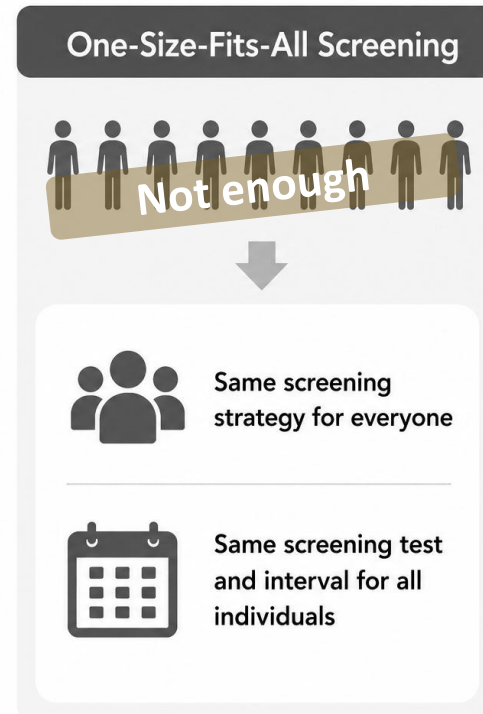
Advanced-stage CRC incidence and CRC mortality, adjusted for screening rate

One-size-fits-all

Interval for everyone

2 years

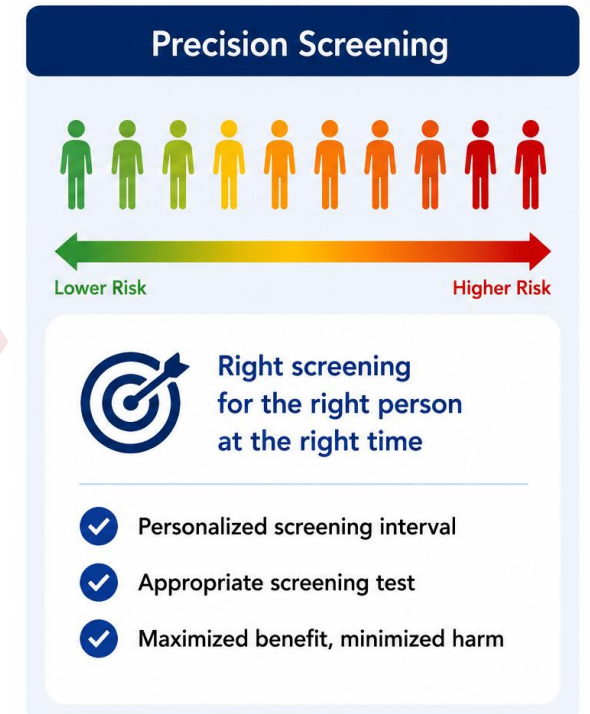
Regardless of f-Hb



Complete colonoscopy

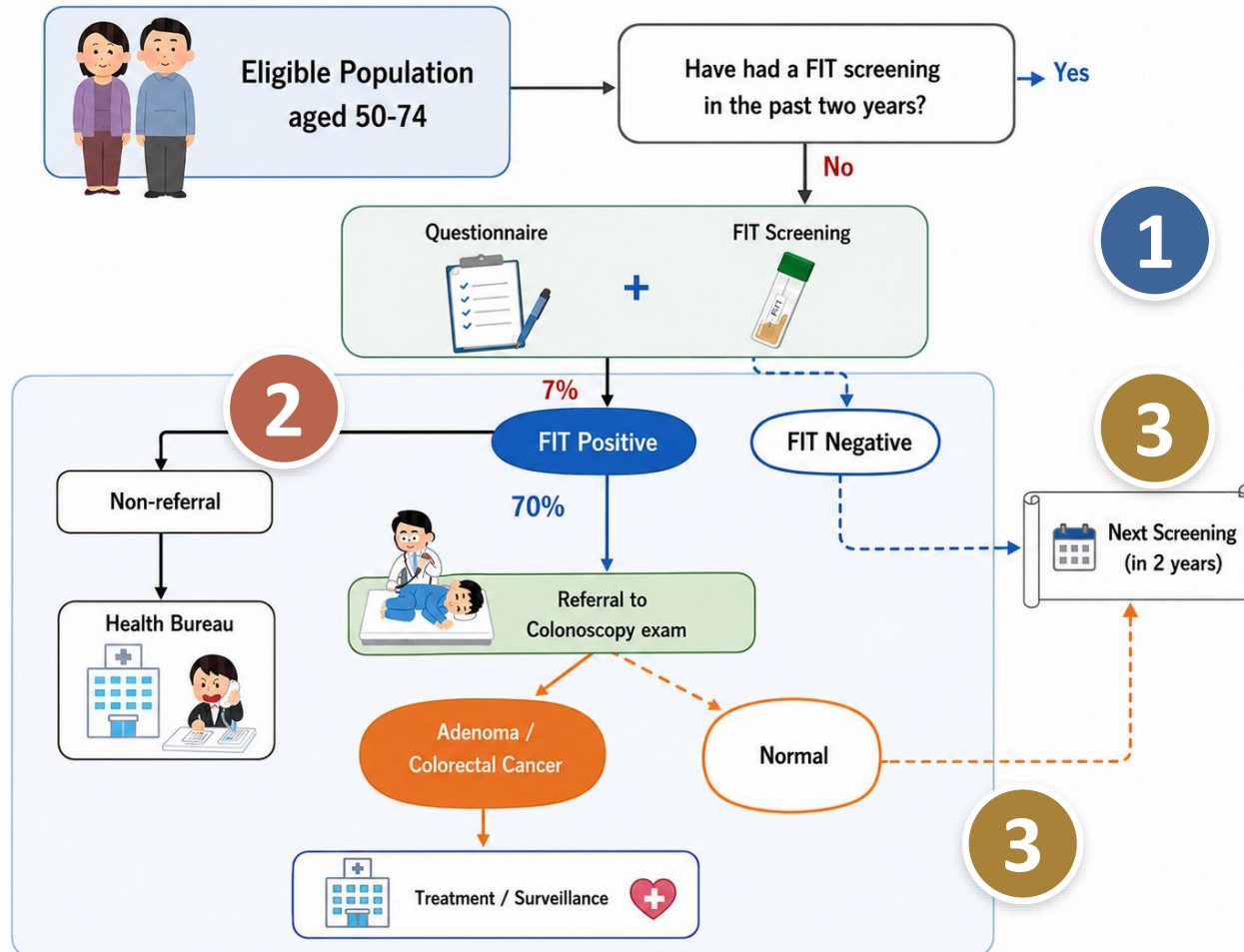
≈70%

of FIT-positive people



From Data to Decisions

Three Decisions Along the Screening Pathway



1 Who is at higher risk?

Personal features + f-Hb

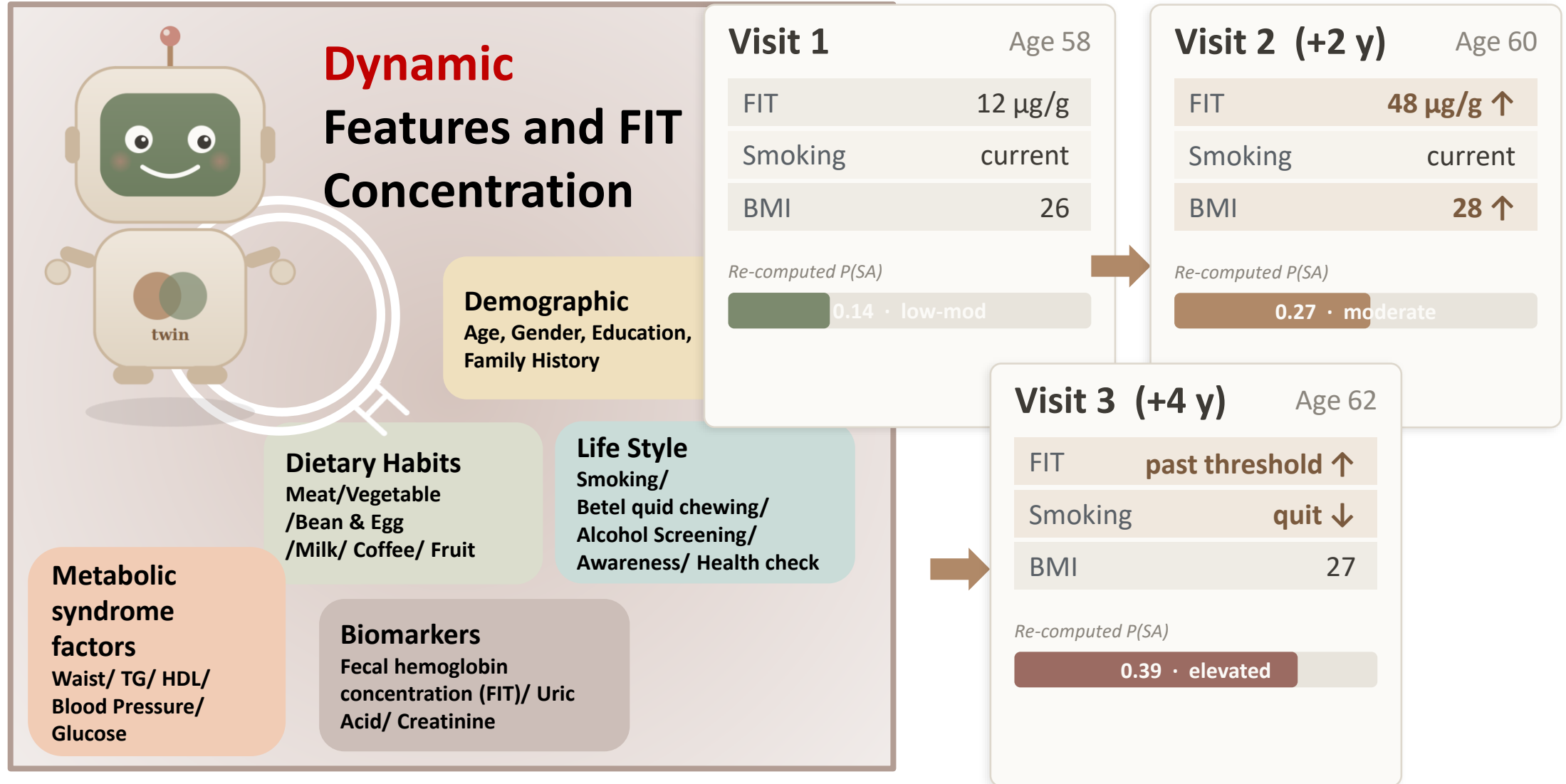
2 Who needs a reminder?

Referral after a positive FIT

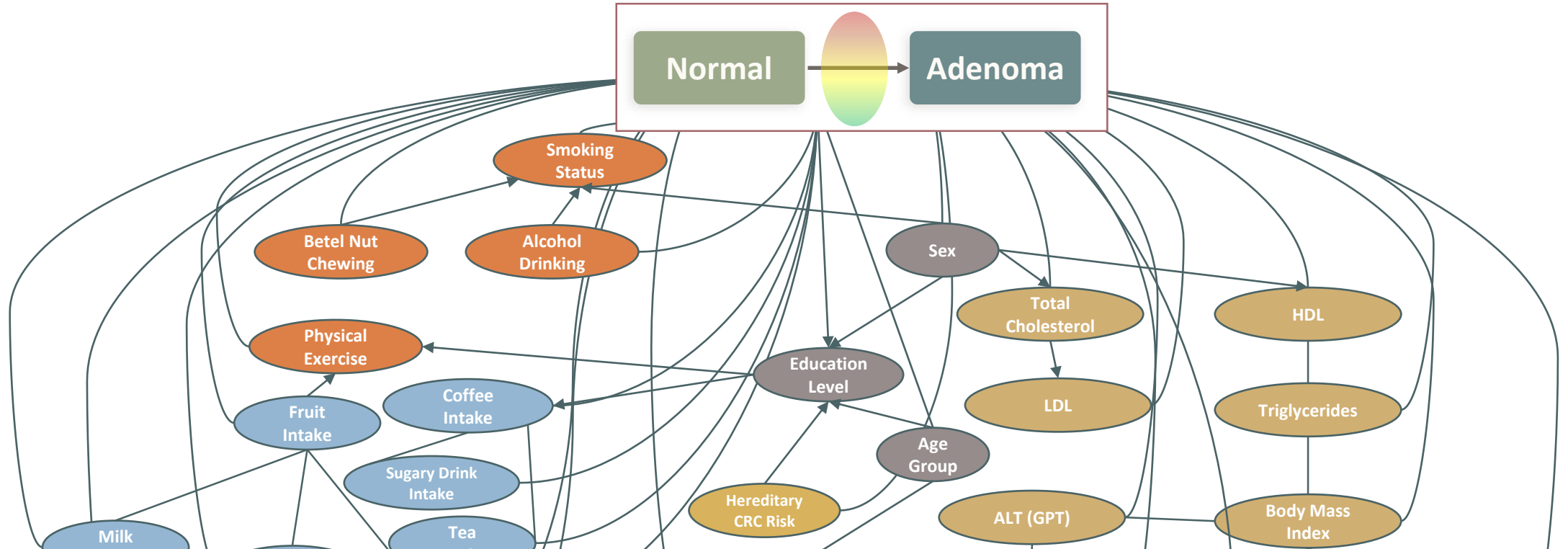
3 When to screen next?

f-Hb-guided intervals and surveillance

Longitudinal Personal Features and Repeated f-Hb



AI Model: Bayesian Network for Adenoma Risk Prediction

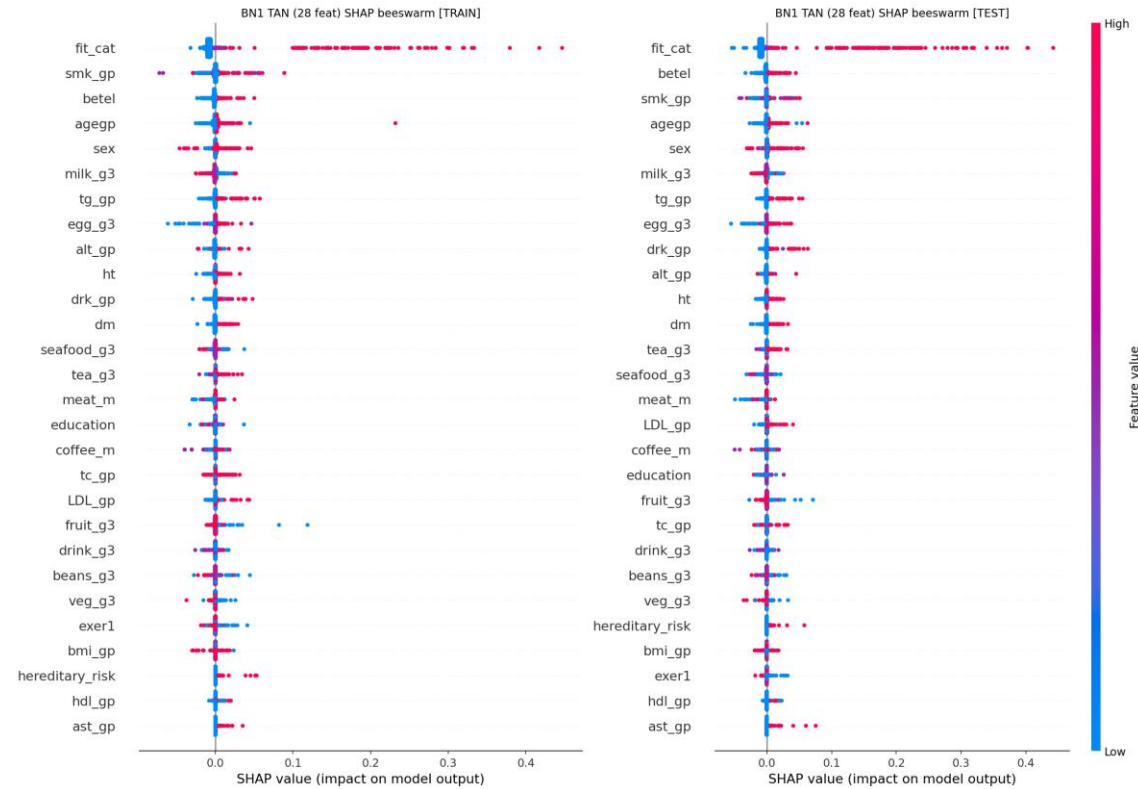
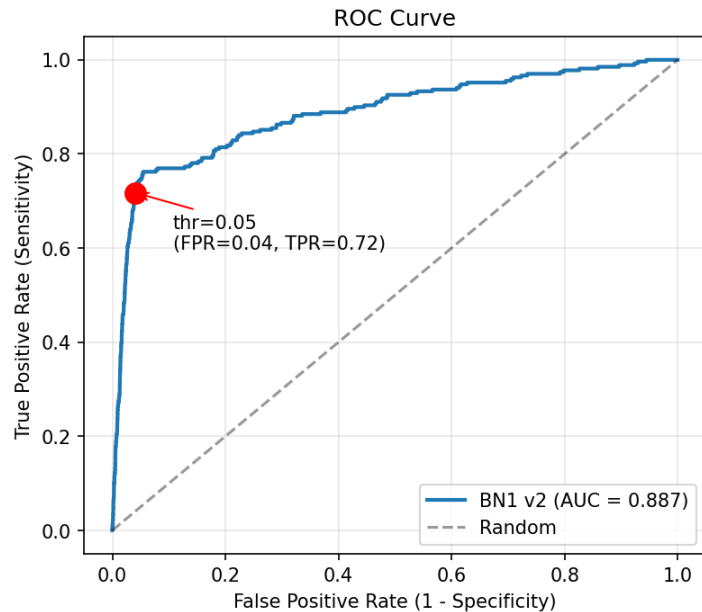


BN learns how **all factors relate** at once — revealing both how factors connect to each other and **how changing one propagates along a path to the outcome.**

AI and XAI: Machine Learning Identifies Higher-Risk People

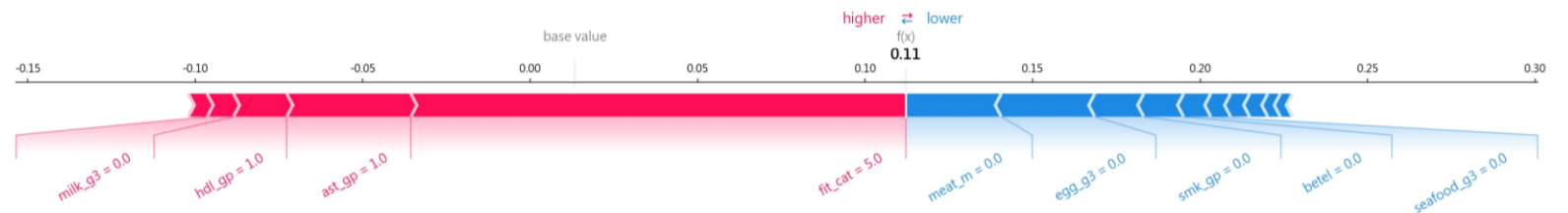
Metric	Train	Test
AUC	0.89	0.89
Accuracy	0.96	0.96
Precision	0.18	0.18
Recall	0.70	0.72
F1	0.29	0.29

Test ROC curve



Top Prediction Features

- 1 f-Hb
- 2 Betel quid
- 3 Smoking
- 4 Age



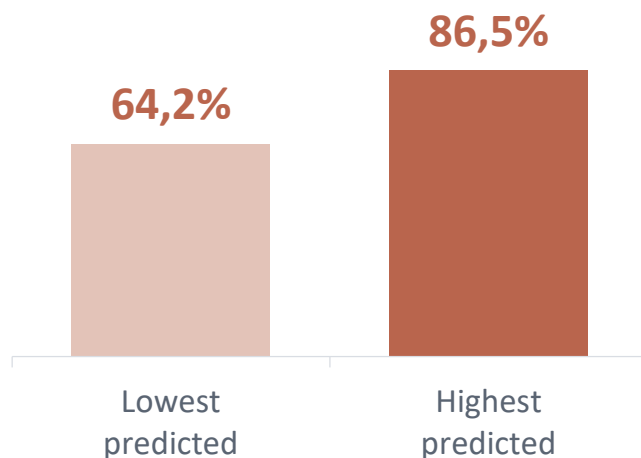
Predicting Non-Completion of Colonoscopy After a Positive FIT

FIT-positive people
modelled

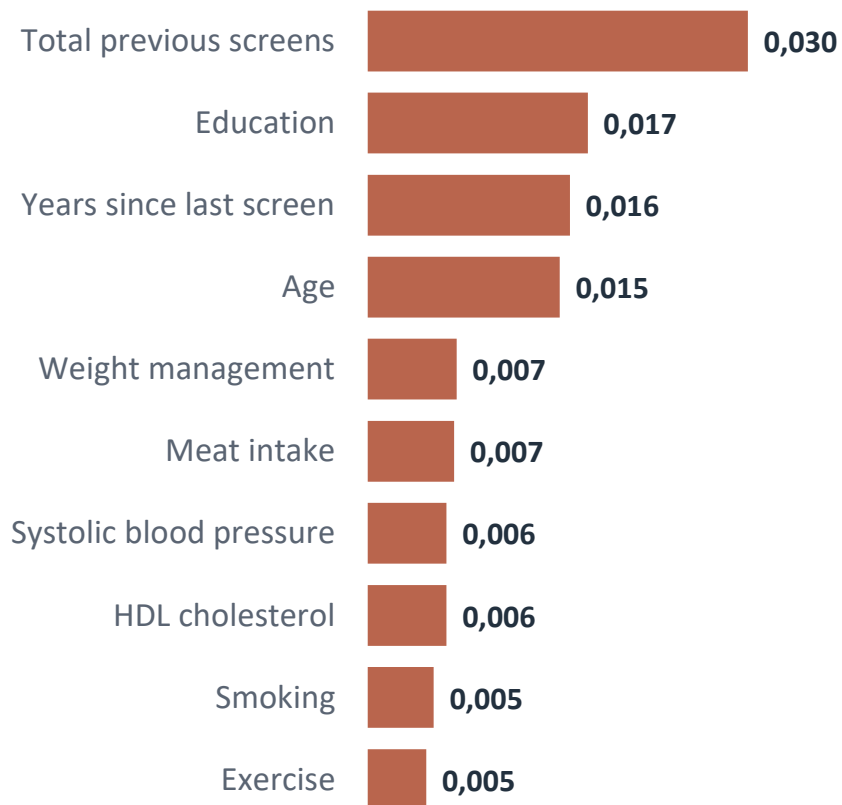
14,673

Changhua 2010–2020

Colonoscopy completion



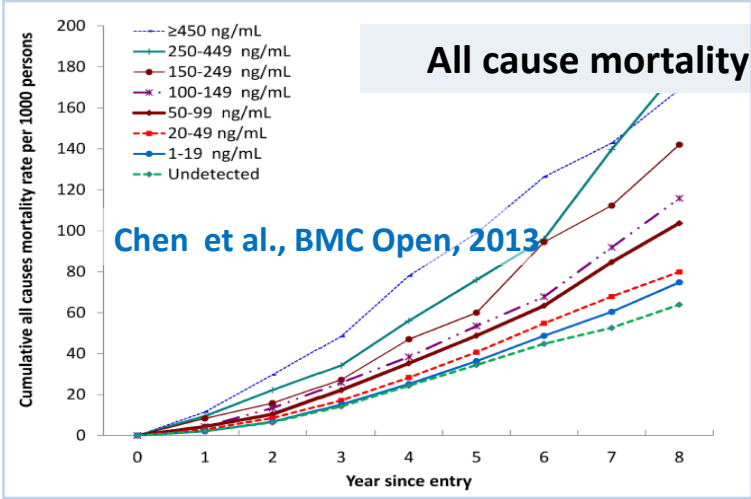
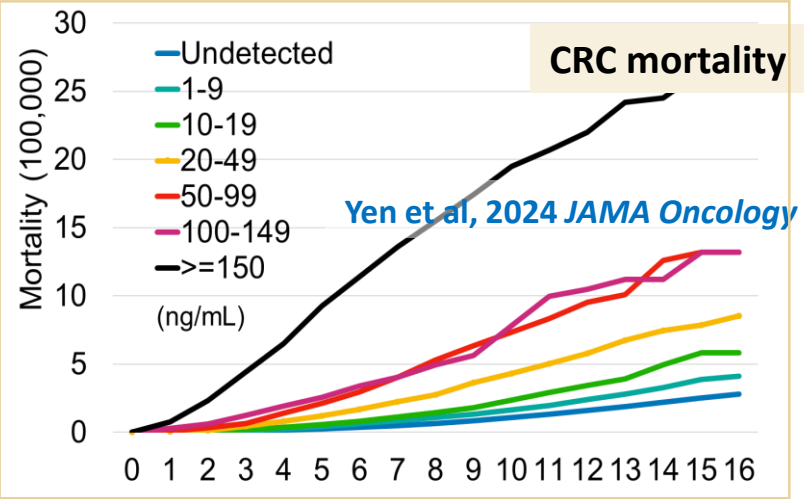
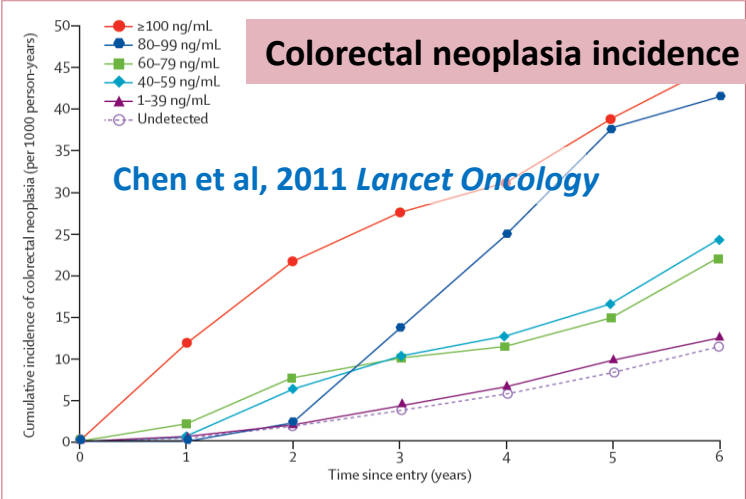
Feature importance



Less likely to complete

- Fewer previous screens
- Lower education
- Long gap since last screen
- Older age
- Higher FIT value

f-Hb Concentration as a Dose-Dependent Risk Signal



Chen, 2011		Taiwan
Chen, 2013		Taiwan
Digby, 2017		Scotland
Grobbee, 2017		Netherlands
Gibson, 2019		Ireland
Burón, 2019		Spain
Kim, 2019		Korea
Senore, 2020		Italy

Senore, 2020		Italy
Balamou, 2021		France
Meester, 2022		Netherlands
Breekveldt, 2023		Netherlands
Deding, 2023		Denmark
Digby, 2023		Scotland
Ribe, 2023		Norway
Yen et al, 2024		Taiwan

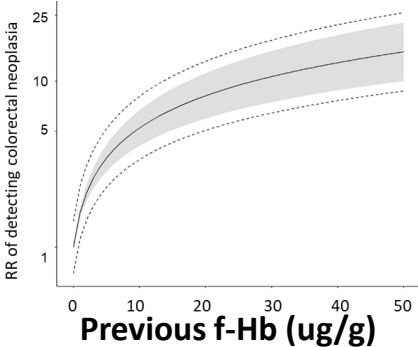
Prior f-Hb concentration	Pooled RR (95% CI)				
	Any colorectal neoplasia (all 13 studies)	Advanced neoplasia	CRC	Advanced adenoma	Advanced adenoma + early-stage CRC
0	1.0	1.0	1.0	1.0	1.0
5	3.4 (2.8-4.1)	4.3 (3.5-5.3)	3.8 (3.0-4.8)	4.5 (3.3-6.1)	4.4 (2.9-6.8)
10	5.2 (4.0-6.6)	7.0 (5.3-9.3)	6.1 (4.4-8.2)	7.5 (5.0-11.2)	7.3 (4.1-13.0)
15	6.7 (5.0-8.9)	9.5 (6.8-13.1)	8.0 (5.6-11.5)	10.3 (6.5-16.4)	11.0 (5.2-19.4)
20	8.1 (5.9-11.1)	11.8 (8.3-16.9)	9.8 (6.6-14.6)	12.9 (7.7-21.6)	12.5 (6.1-26.0)
40	12.8 (8.7-18.8)	20.3 (13.2-31.4)	16.2 (10.1-26.2)	22.7 (12.1-42.4)	21.9 (9.0-53.1)

Gastroenterology 2025;168:587-597

PREVENTION AND EARLY DETECTION

Fecal Hemoglobin Levels in Prior Negative Screening and Detection of Colorectal Neoplasia: A Dose-Response Meta-Analysis

Danica M. N. van den Berg,¹ Rosita van den Puttelaar,¹ Lucie de Jonge,¹ Iris Lansdorp-Vogelaar,¹ and Esther Toes-Zoutendijk¹



f-Hb-Guided Screening and Surveillance Intervals

Risk-based Interval by
baeline f-Hb at 1st screen

f-Hb (µg/g)	Interval
<10	5
10-14	4
15-19	3
20-49	2 (non-referral)
50-99	1 (non-referral)
100-149	1 (non-referral)
≥150	0.5

Adaptive inter-screen interval by
the updated f-Hb of subsequent screening

f-Hb (µg/g)	Interval
<10	6
10-14	3
15-19	2
20-49	10
50-99	5
100-149	1
≥150	0.5

Precision FIT Surveillance Interval
Positive FIT, after colonoscopy, adenoma finding

f-Hb (µg/g)	Low risk	High risk
NA		
NA		
NA		
20-49	10	3
50-99	9	3
100-149	7	3
150-249	7	2
250-449	6	2
≥450	6	2

JAMA Oncology | Original Investigation

Precision Colorectal Cancer Fecal Immunological Test Screening With Fecal-Hemoglobin-Concentration- Guided Interscreening Intervals

Amy Ming-Fang Yen, PhD; Chen-Yang Hsu, PhD; Ting-Yu Lin, PhD; Chiu-Wen Su, PhD; Han-Mo Chiu, PhD;
Tony Hsiu-Hsi Chen, PhD; Sam Li-Sheng Chen, PhD

Gastroenterology 2026;■:1–12

Fecal Hemoglobin-Guided Precision Postpolypectomy Surveillance Within the Current Framework: A Four-Million- Participant Fecal Immunochemical Test–Based Screening Study

Mark Pi-Chun Chuang,¹ Wen-Feng Hsu,¹ Chiu-Wen Su,¹ Amy Ming-Fang Yen,²
Tony Hsiu-Hsi Chen,³ Chen-Yang Hsu,^{4,5} and Han-Mo Chiu¹

f-Hb-Guided Intervals Reduce FIT and Colonoscopy Demand

JAMA Oncology | [Original Investigation](#)
Precision Colorectal Cancer Fecal Immunological Test Screening
With Fecal-Hemoglobin-Concentration-Guided Interscreening Intervals

Amy Ming-Fang Yen, PhD; Chen-Yang Hsu, PhD; Ting-Yu Lin, PhD; Chiu-Wen Su, PhD; Han-Mo Chiu, PhD;
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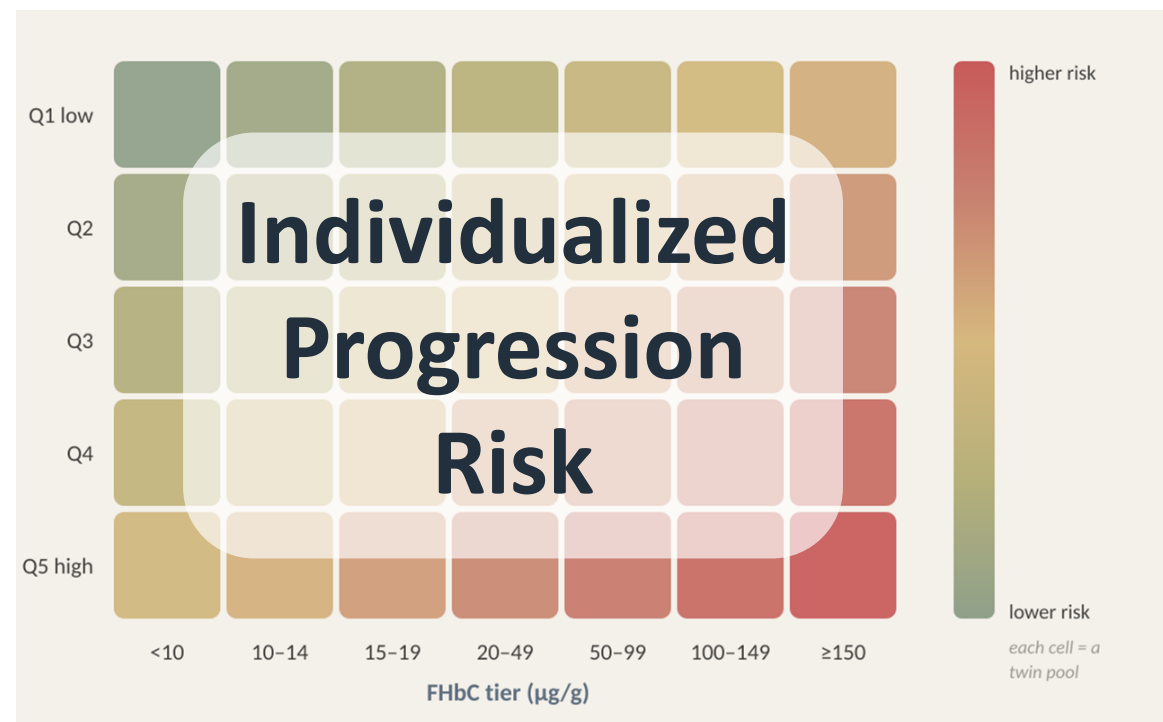
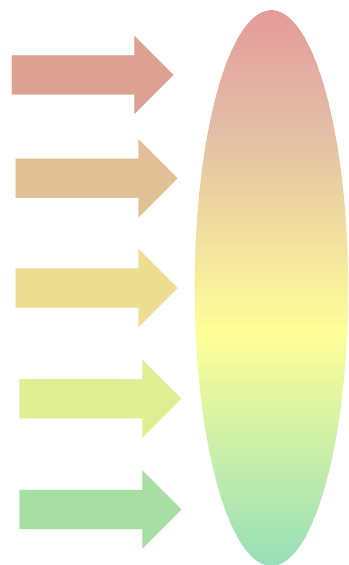
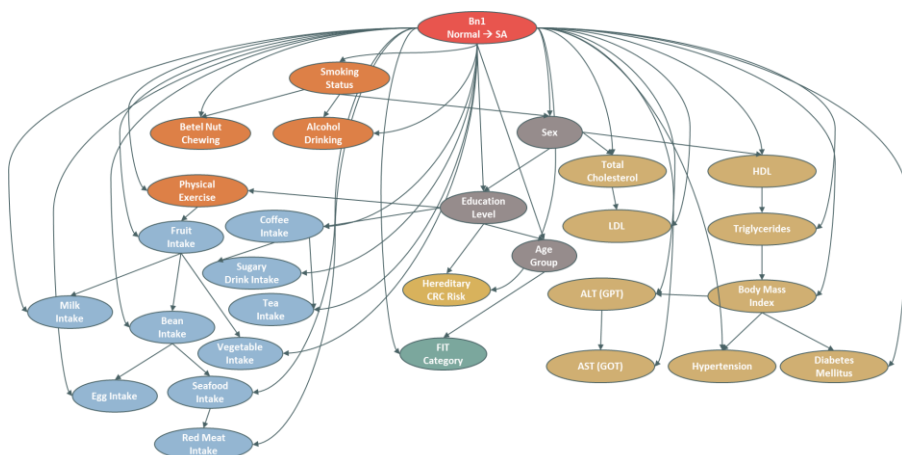
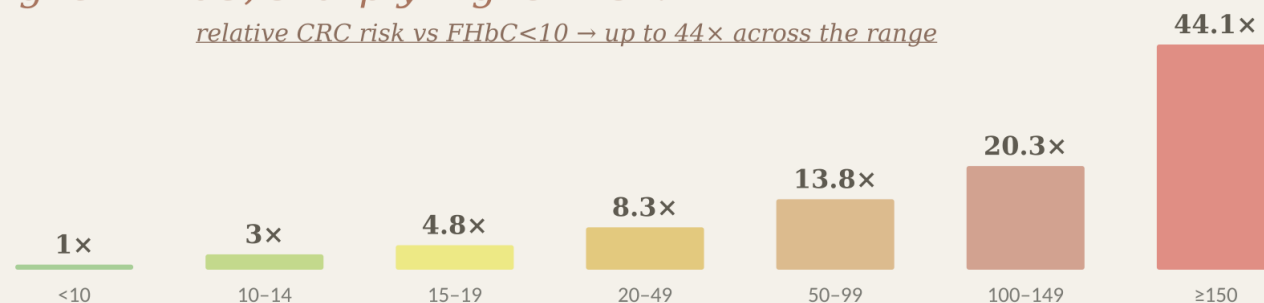
	Universal Biennial Screening	Personalized f-Hb–Guided Screening		
		Referral Rate		
		60%	80%	
Number of FIT Tests	19.9 M	10.2 M		
Reduction in FIT Tests	Ref.	9.6 M		
Reduction in FIT Tests (%)	Ref.	49%		
Number of Colonoscopies	1.28 Ms	686 K	915 K	1.1 M
Reduction in Colonoscopies	Ref.	593 K	364 K	135 K
Reduction in Colonoscopies (%)	Ref.	46%	28%	11%

Save 49% of FIT
test and 28% of
colonoscopies

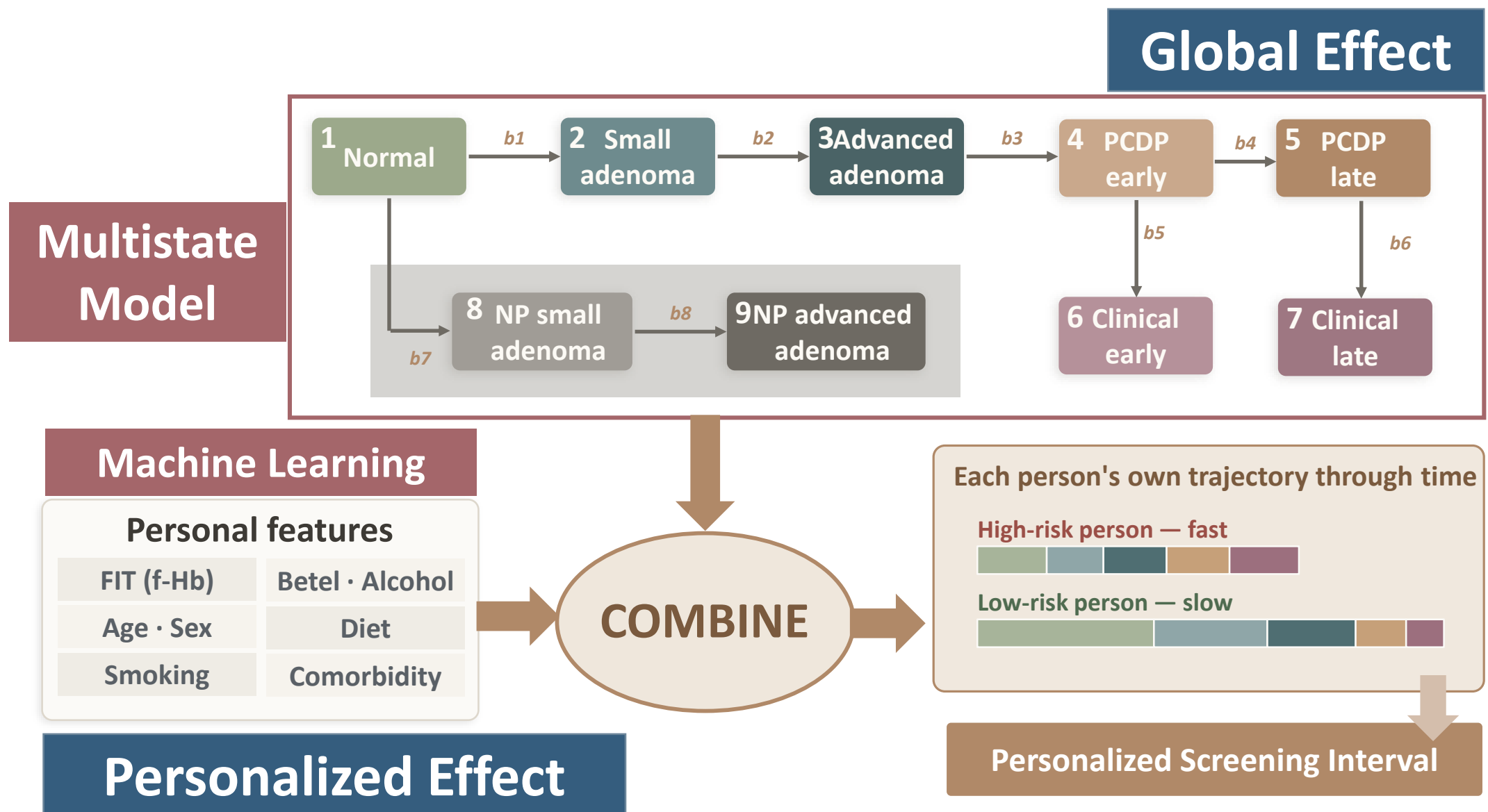
Bayesian Network Classifier with FIT concentration information for Individualized Progression Risk

Higher FHbC, sharply higher risk.

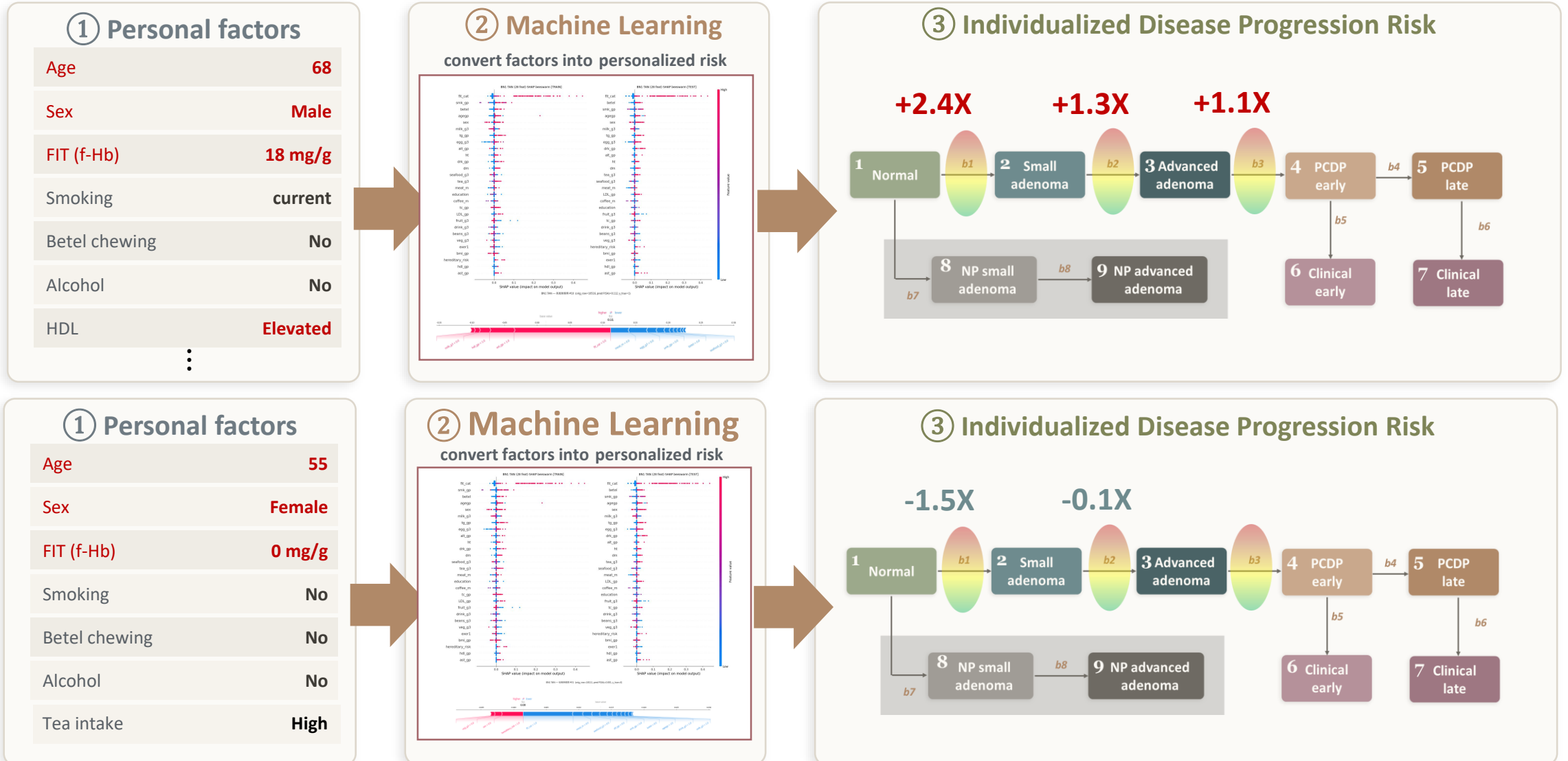
relative CRC risk vs FHbC < 10 → up to 44× across the range



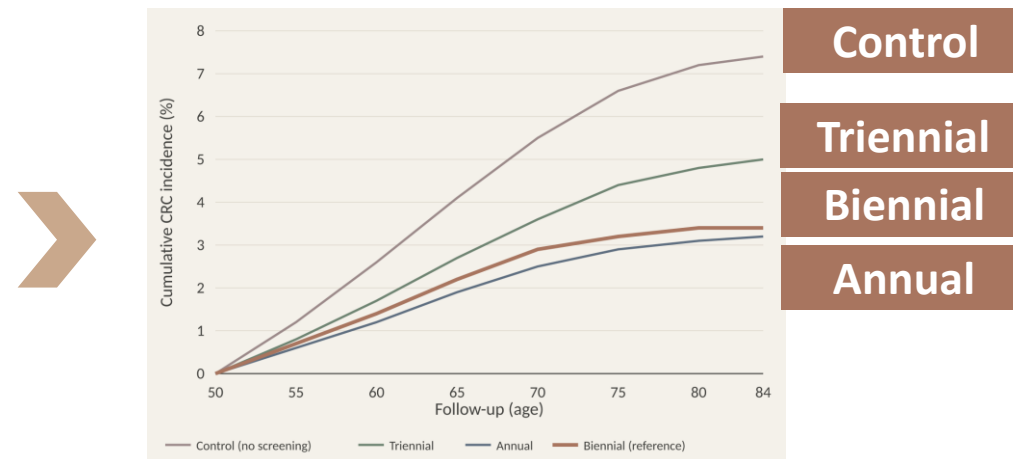
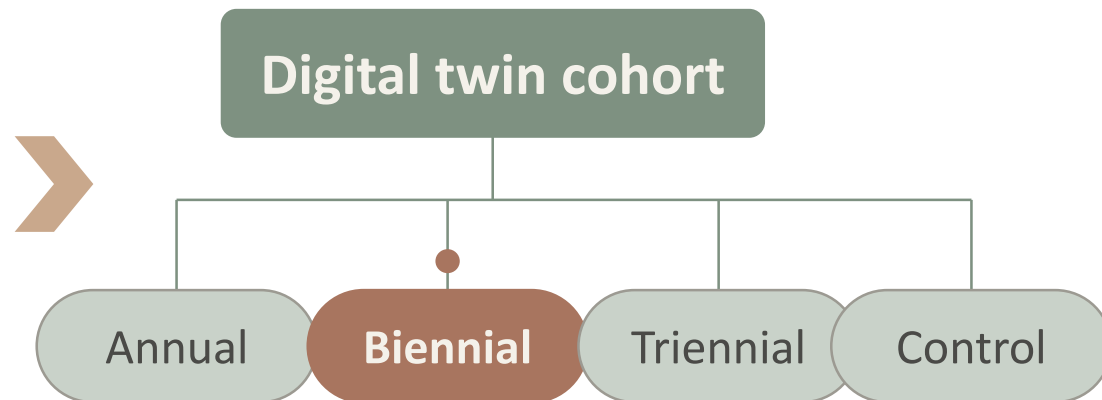
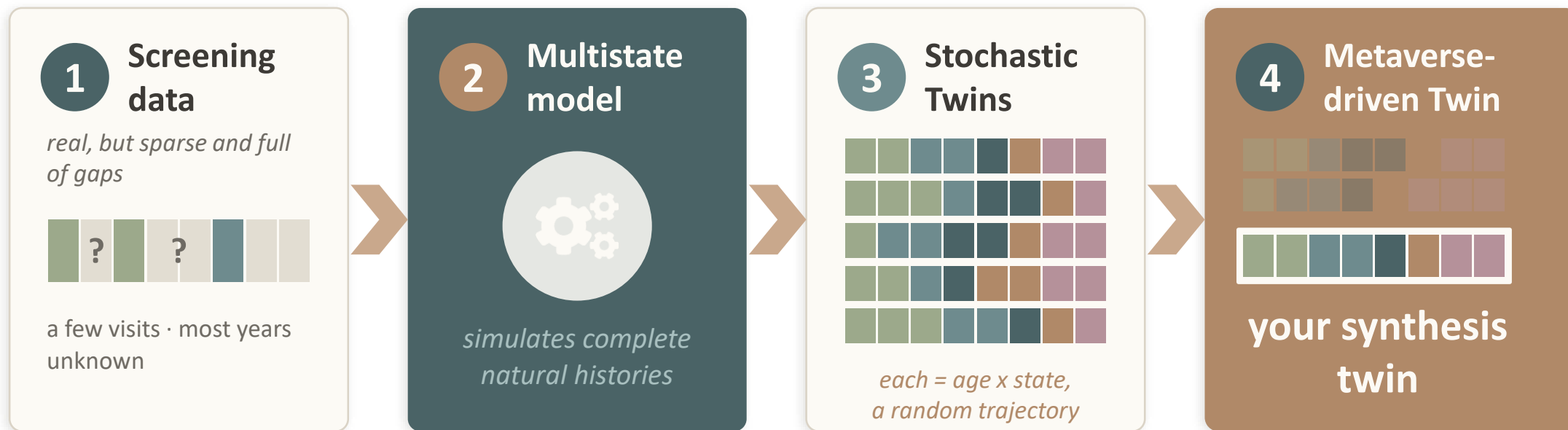
Integrating Multistate Progression with Personal Features



Individualized Progression Risk



Digital Twin Emulation for Evaluating Screening Policies



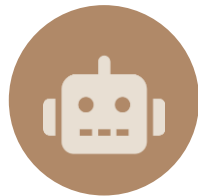
Precision Screening: Biennial Benefit with Fewer Resources

Constraint: Bioequivalence design

Outcome	Annual	Biennial (Current)	Triennial	Precision
CRC incidence reduction	31.3%	22.5%	17.8%	≈ Biennial
Advanced-stage CRC reduction	50.2%	40.7%	34.3%	≈ Biennial
Adenoma overdiagnosis	+20%	— ref	−16%	−20%
FIT testing frequency	higher	— ref	lower	−39%
Colonoscopy demand	higher	— ref	lower	−35%

LLM-Guided Navigator Grounded in Predictive Models

My previous FIT was 5 $\mu\text{g/g}$, and my current result is 2 $\mu\text{g/g}$.
What screening interval would you recommend now?



1 Structured
feature extraction



2 LangChain calls
ML prediction model



3 Risk score
returned



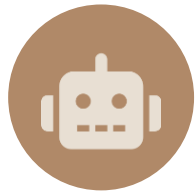
4 Natural-language
explanation

Ans:

Based on your FIT decreasing from 5 $\rightarrow$ 2 $\mu\text{g/g}$, we suggest extending your screening interval to 6 years.

Recommendations Adapt to Individual Risk Profiles

I am a **smoker with metabolic syndrome**. My previous FIT was **5 $\mu\text{g/g}$** , current is **15 $\mu\text{g/g}$** . What interval would you recommend?



1 Structured feature extraction



2 LangChain calls ML prediction model



3 Risk score returned



4 Natural-language explanation

Ans:

Based on your personal features and FIT rising from **5 $\rightarrow$ 15 $\mu\text{g/g}$** , we suggest changing the interval **from 6-year to 2-year**.

Dynamic Risk Profiles Require Adaptive Decisions

Everything we used to personalize the twin drifts over time.



FIT concentration drifts

A person's f-Hb today is not their f-Hb in five years. Baseline FIT was a lifetime label — reality keeps moving.



Personal features change

The BN factors — lifestyle, comorbidity, habits — evolve. The risk profile we fixed at entry slowly goes stale.

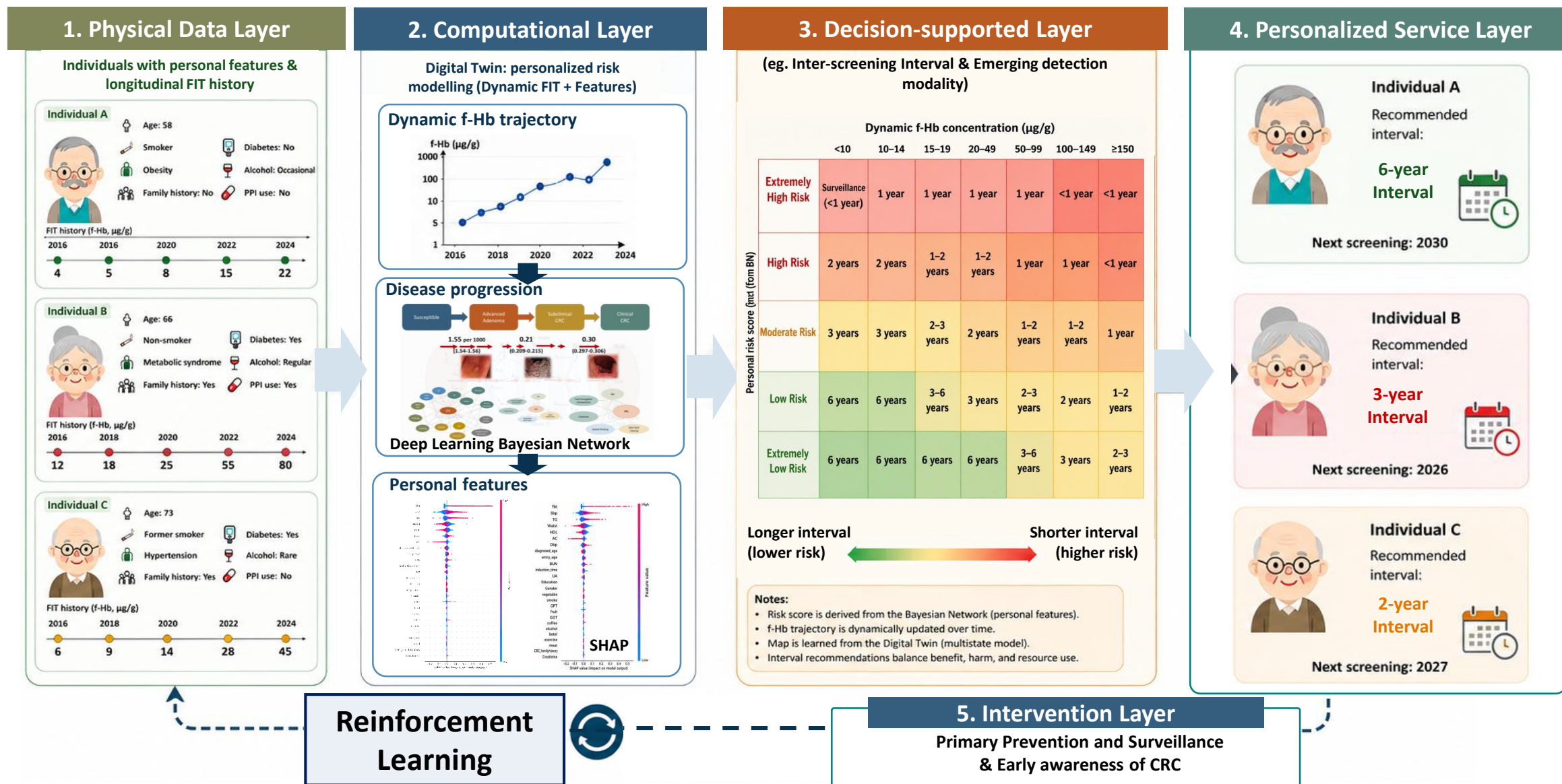


So the right interval changes too

If risk rises, the schedule should tighten; if it falls, it can relax. A one-time plan cannot follow the person.

**We need a twin that does not just hold one schedule —
but re-decides every time new information arrives.**

Reinforcement Learning Framework for Adaptive Screening



Thank you for your attention!



Thank you, Riga — from the Taiwan team