

Towards a more diverse and equitable physics graduate program

Danny Caballero (he/they)

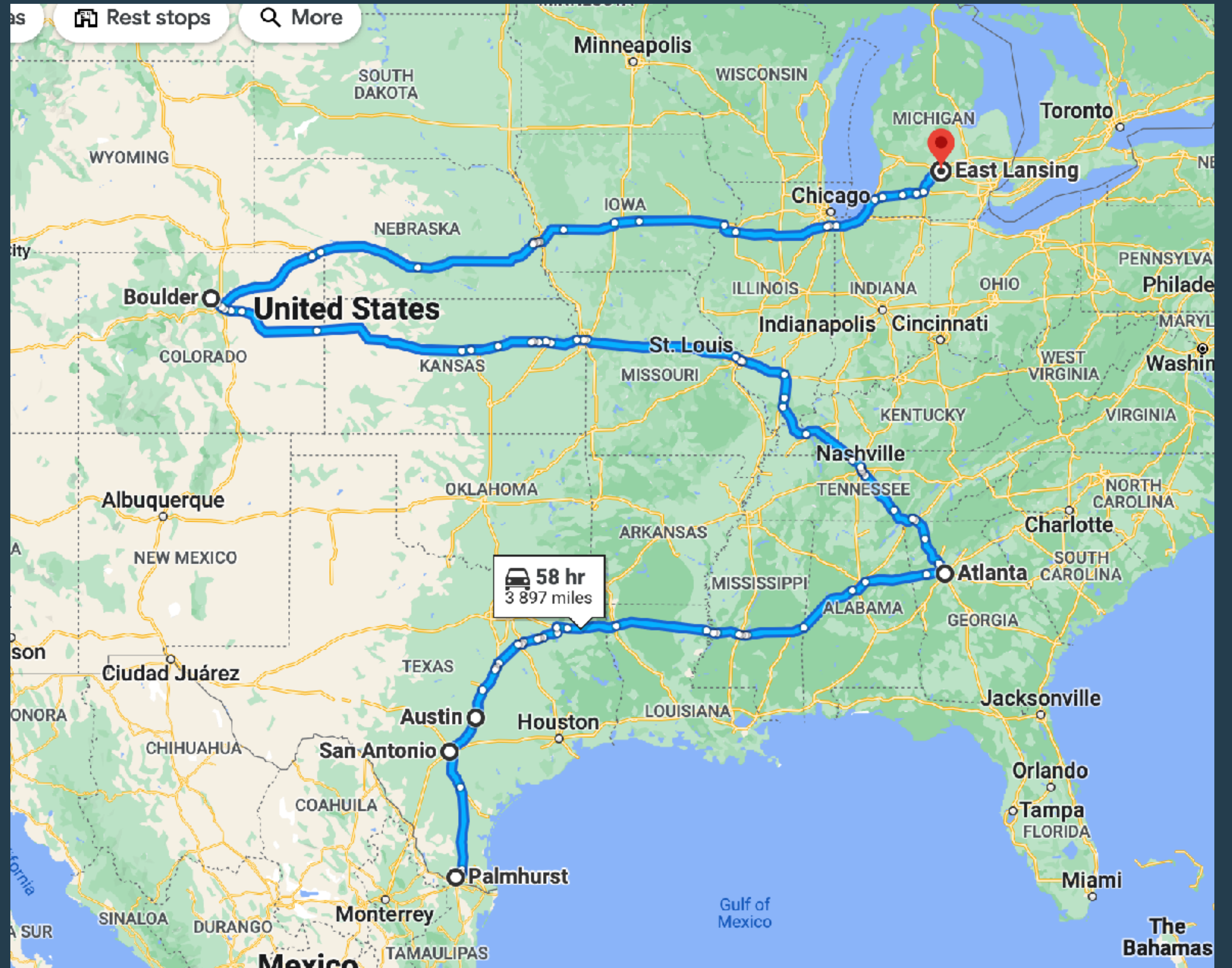
Department of Physics and Astronomy

Department of Computational Mathematics, Science, and Engineering

CREATE For STEM Institute



In summary...



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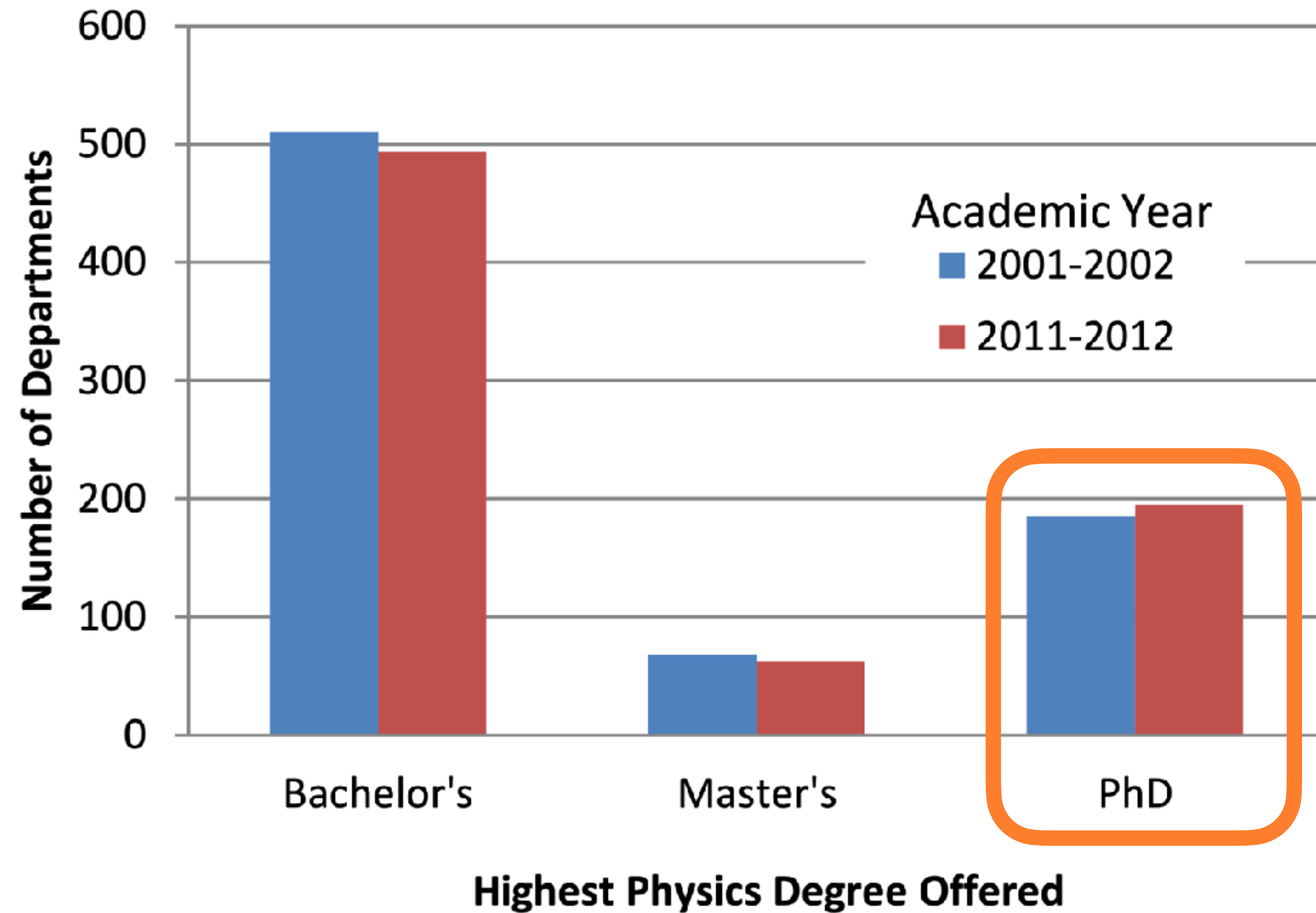
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- Finding a career in science, science education, science policy, etc

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- Developing the knowledge and skills to pursue scientific interests
- Joining a community interested in the enterprise of science
- Getting paid to do science
- Finding a career in science, science education, science policy, etc
- And many more (and some very personal) reasons...

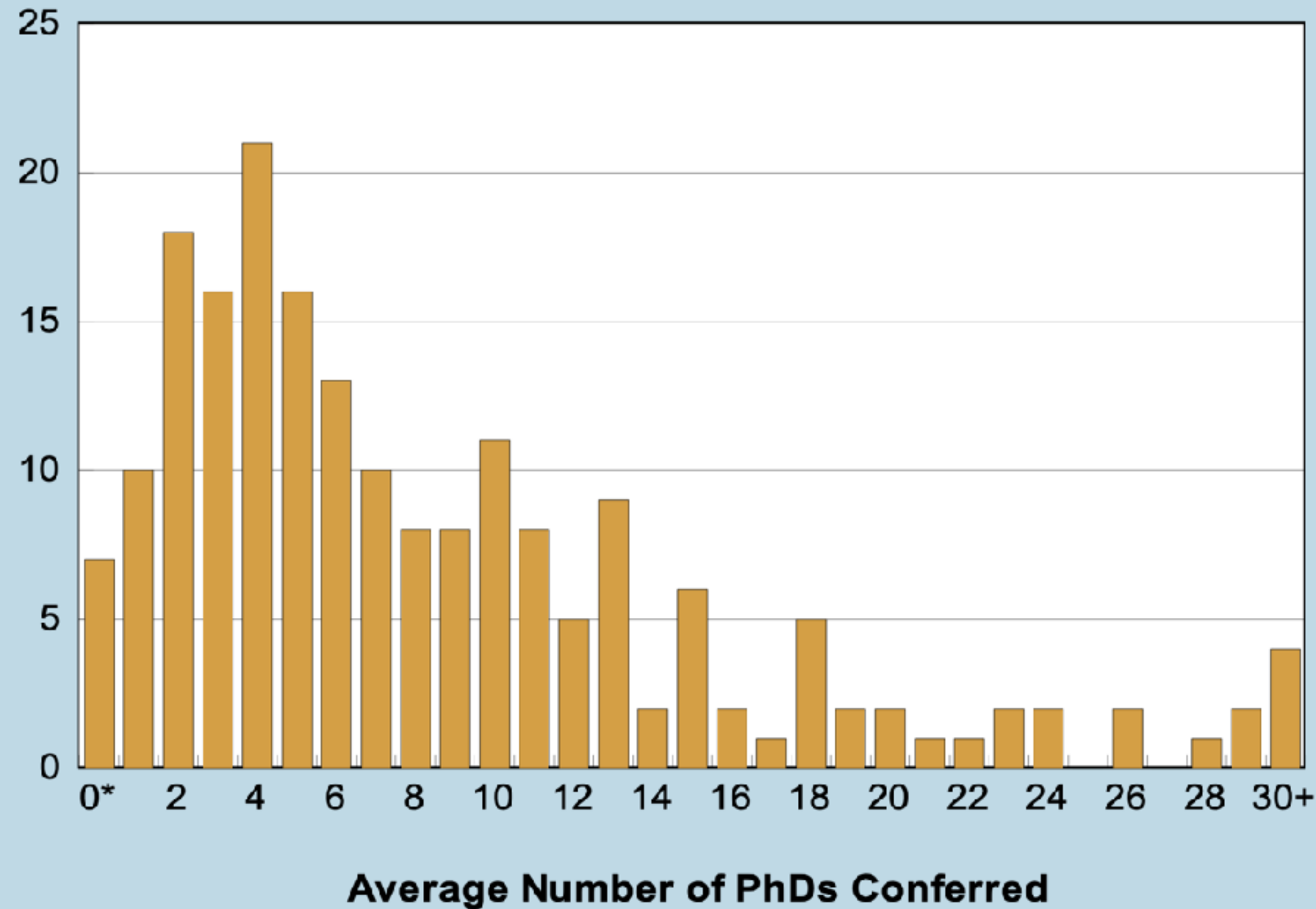
There are nearly 200 programs in the US granting PhDs in physics.

Number of Degree-granting Physics Departments.



Number of Doctoral-Granting Physics Departments in the U.S. by the Average Number of PhDs Conferred.

**Number of
Departments**



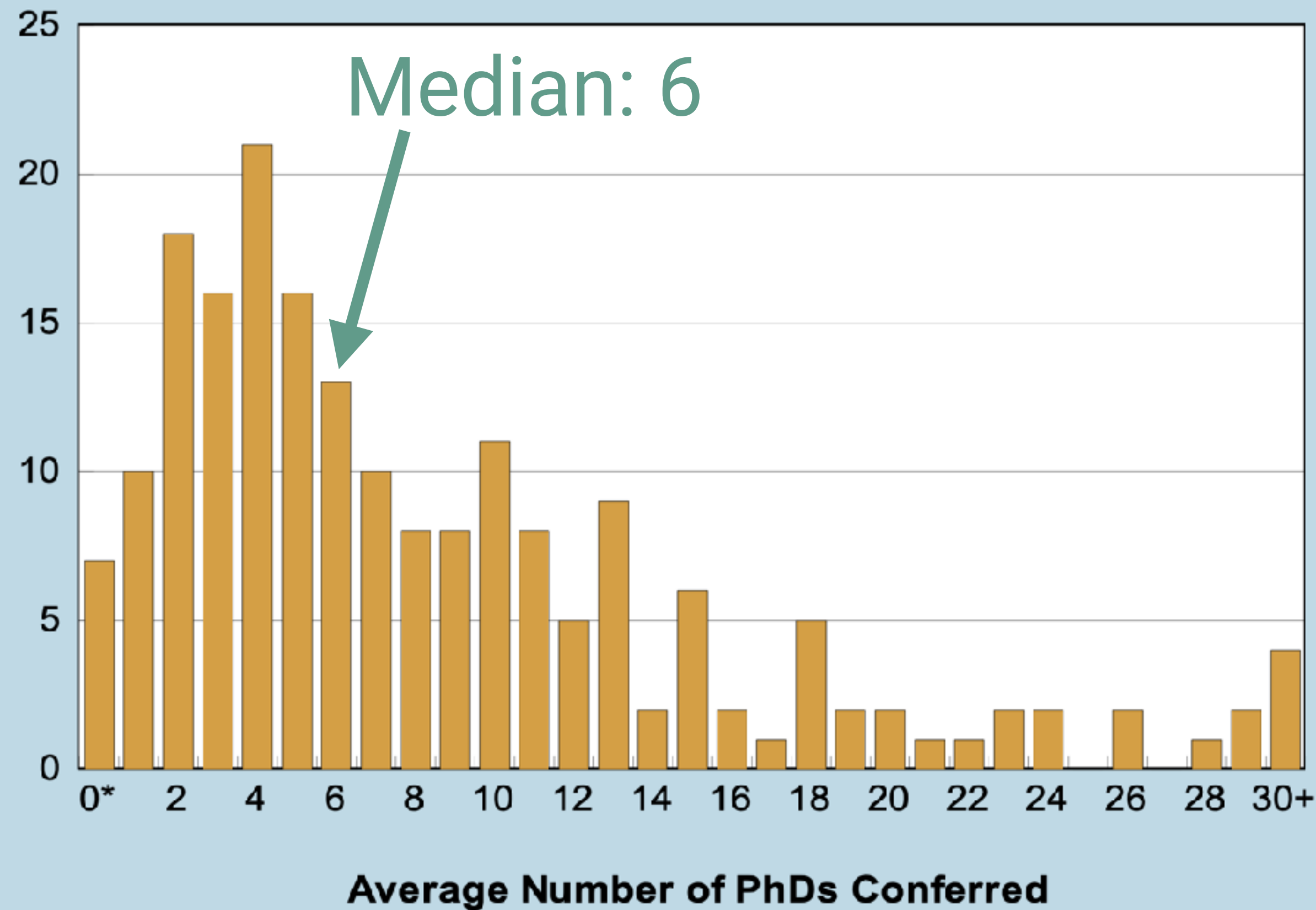
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<http://www.aip.org/statistics>

CU Physics has one of the largest PhD programs in the country.

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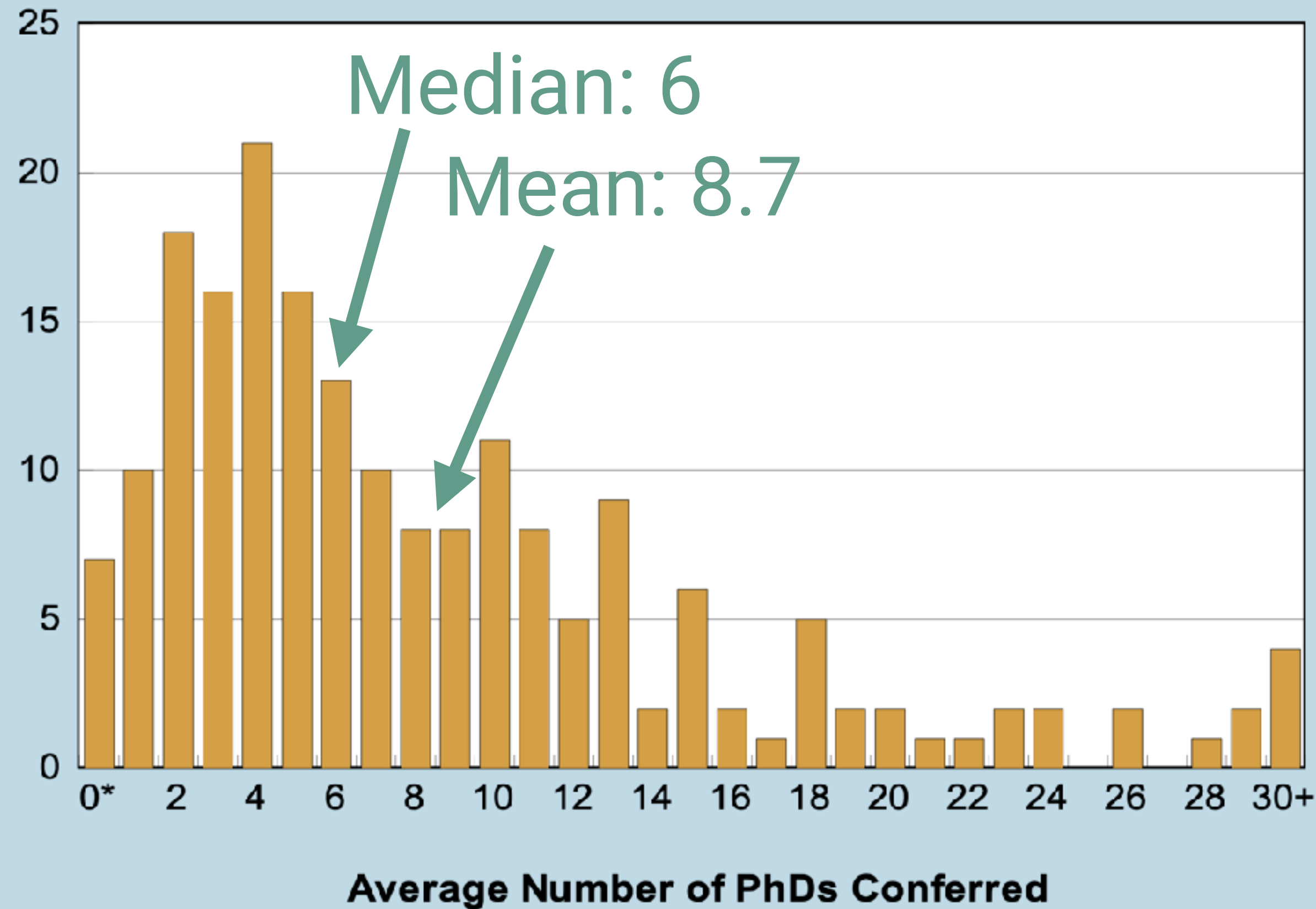
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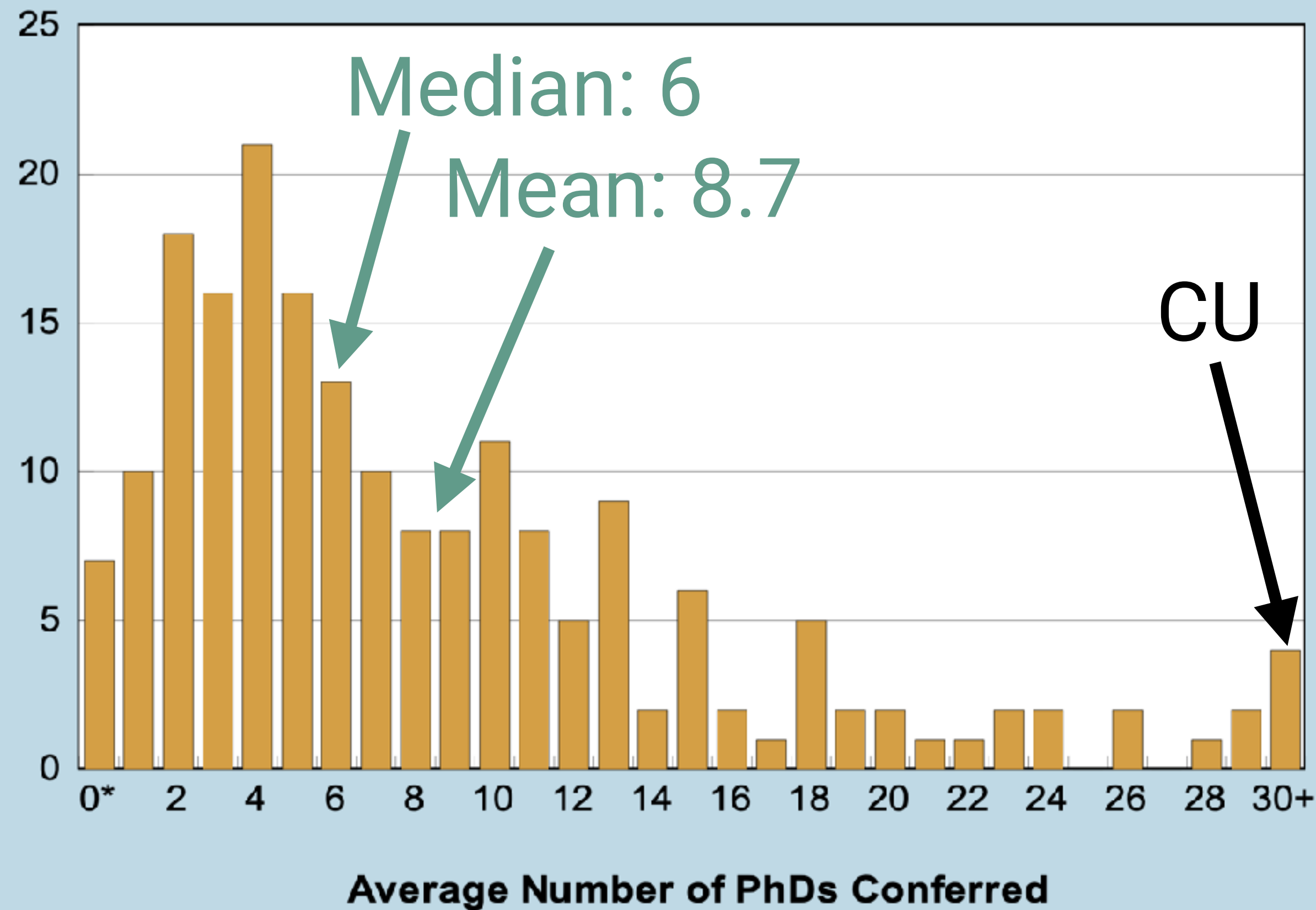
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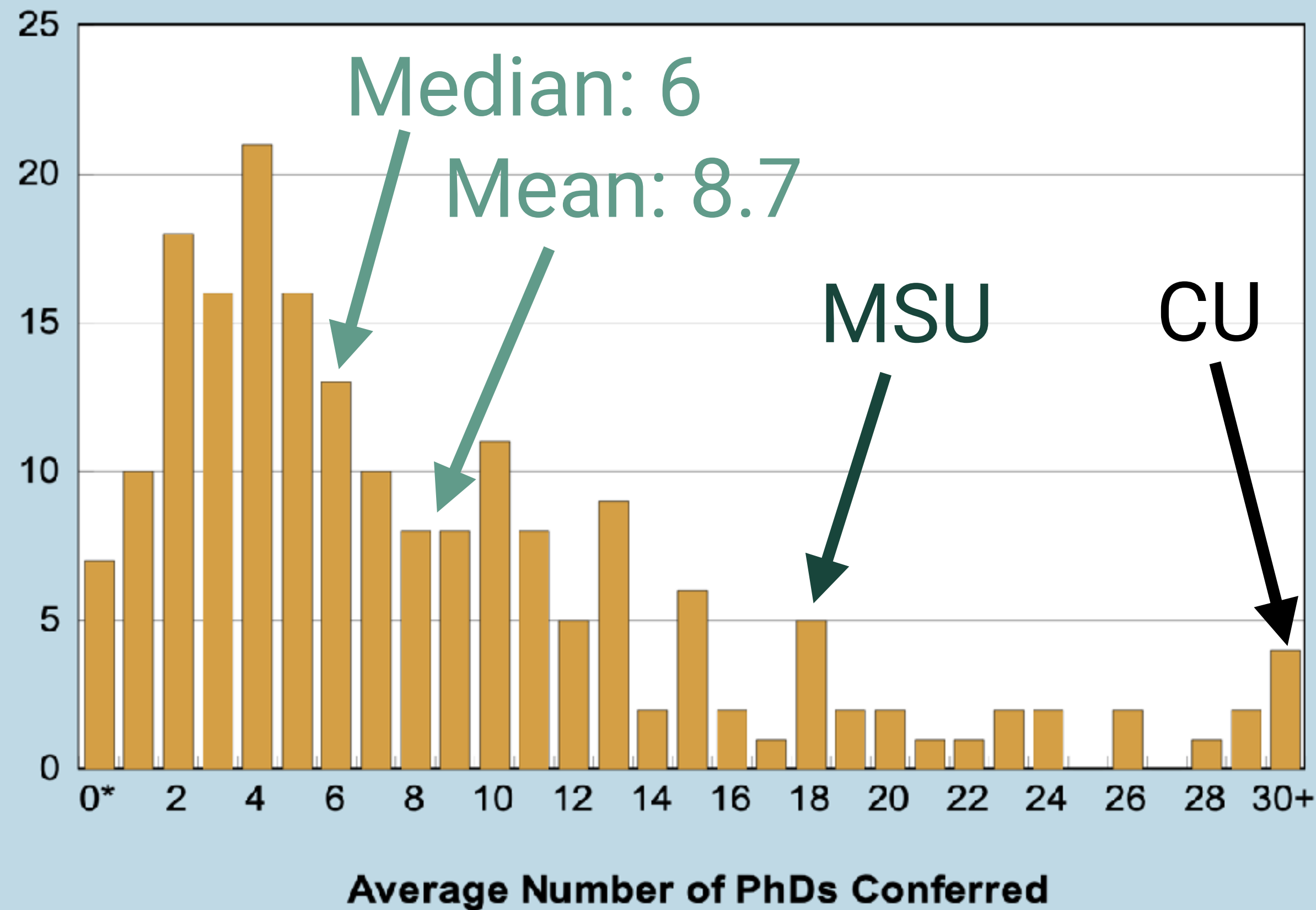
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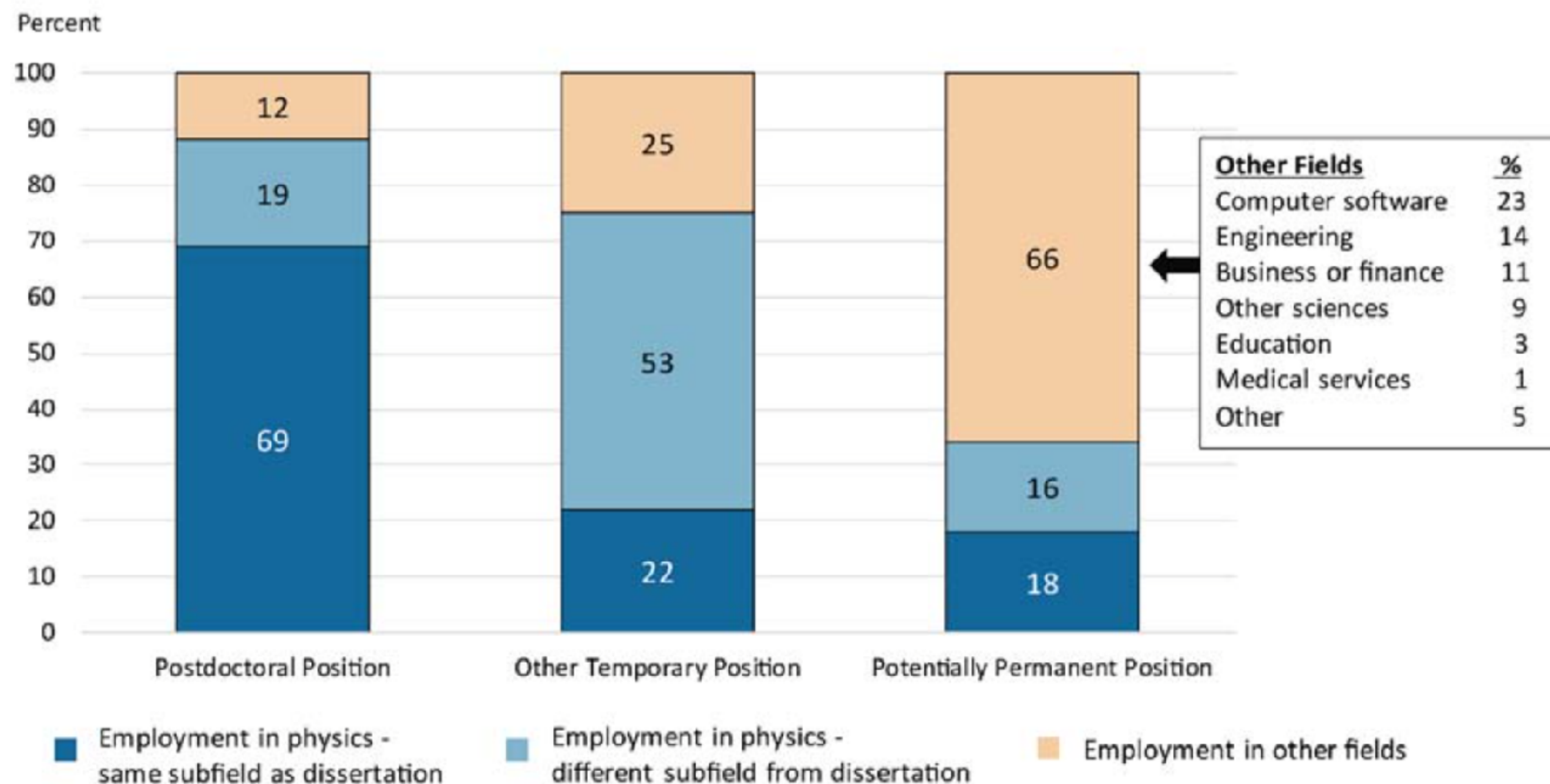


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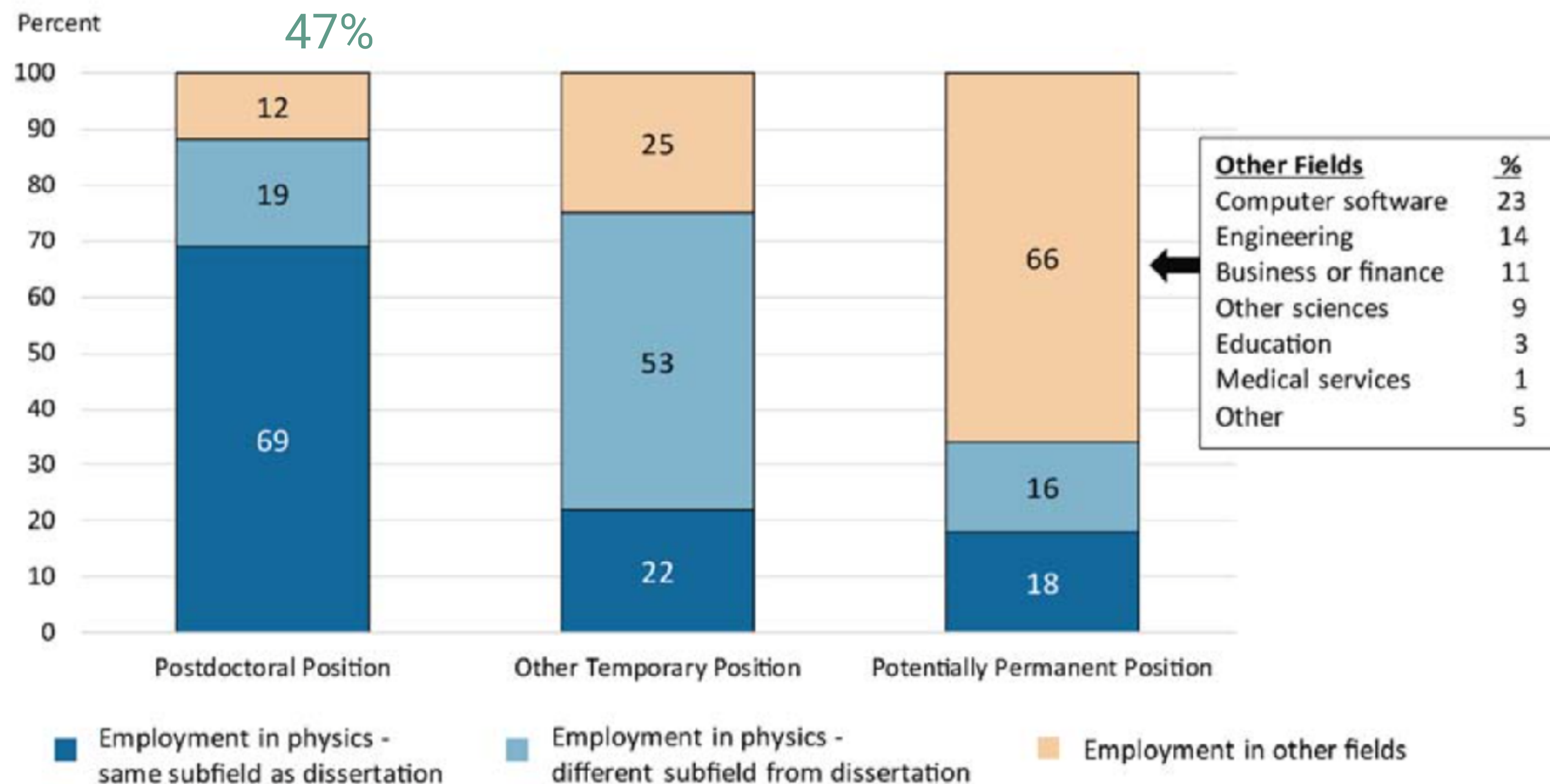
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Employment Field of New Physics PhDs, Classes of 2015 & 2016 Combined



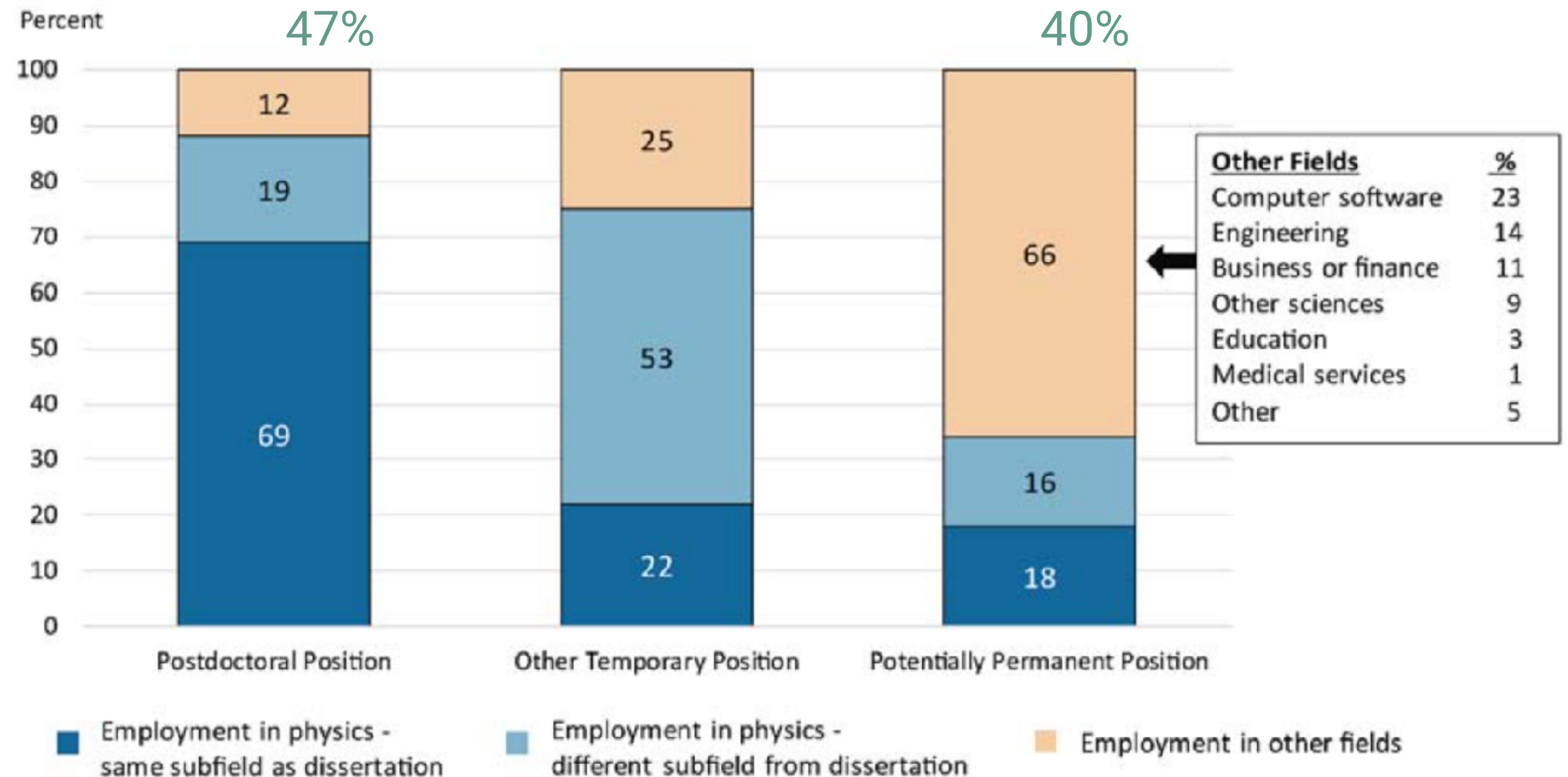
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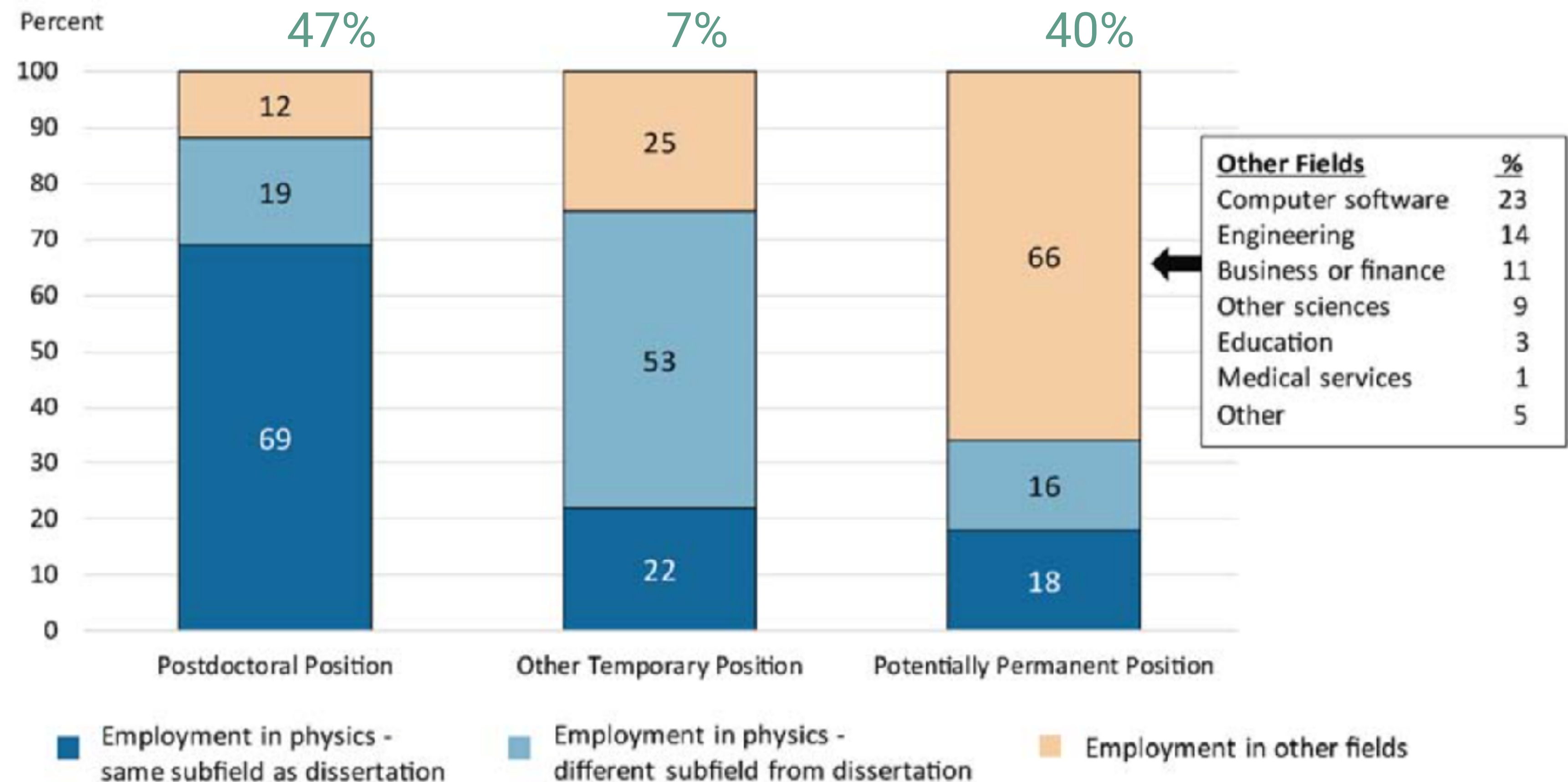
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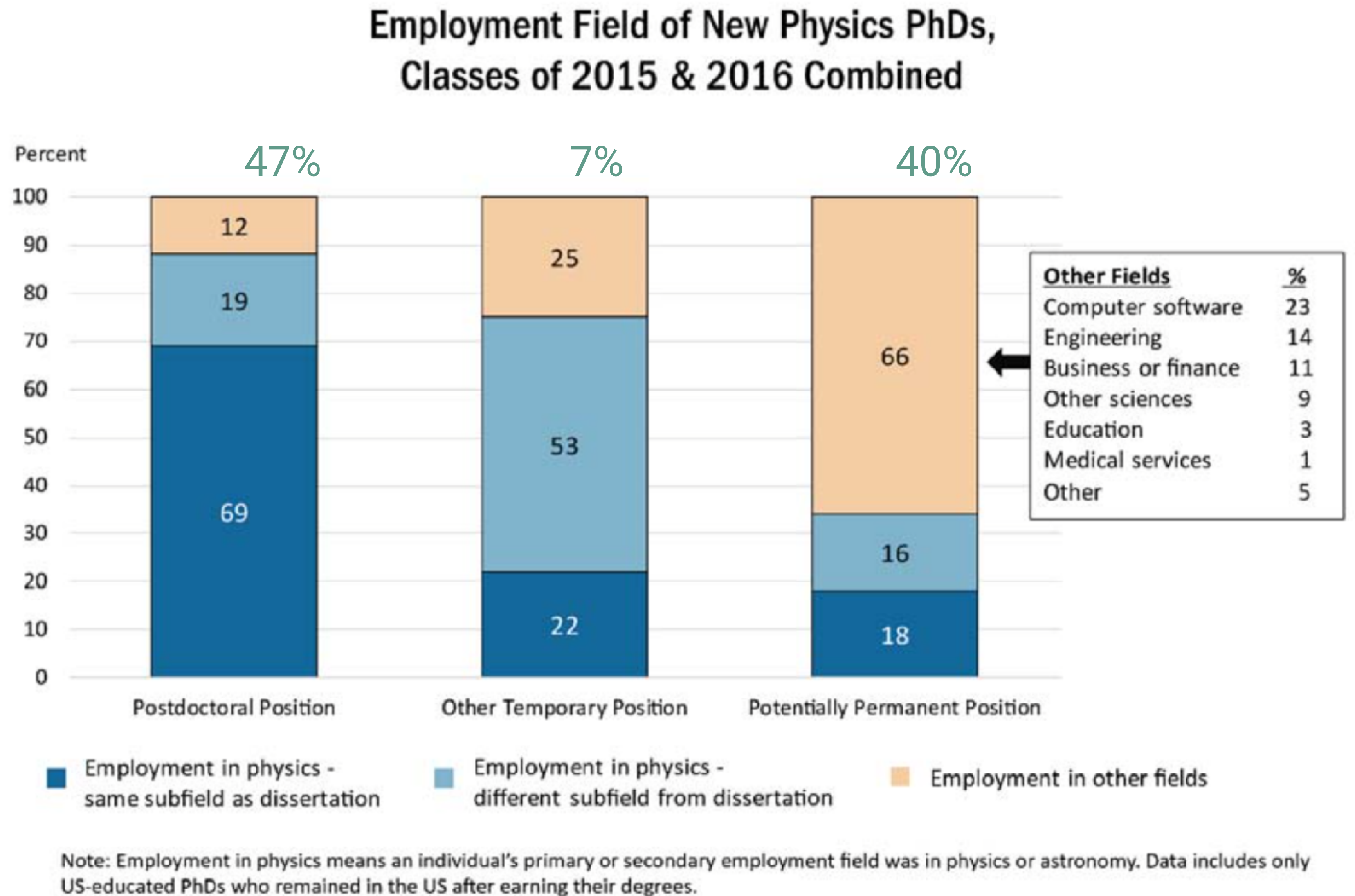
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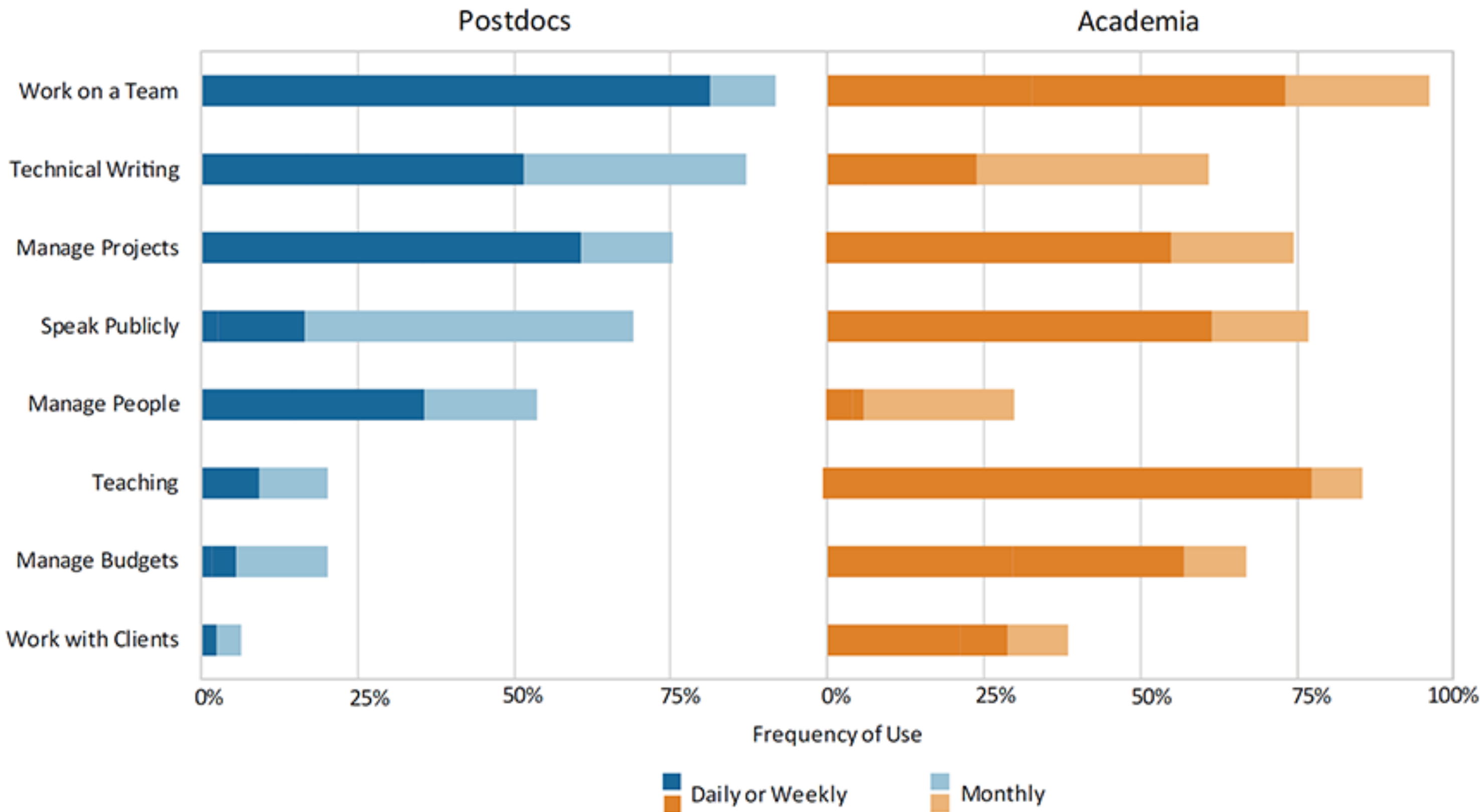
~33% of PhD graduates are not working in physics

~40% are working in the same subfield of physics



A wide variety of technical and interpersonal skills are used by employed PhD graduates

Interpersonal and Management Skills Used by New Physics PhDs Holding Postdocs and Potentially Permanent Positions in Academia, Classes of 2015 & 2016 Combined



Percentages represent the proportion of physics PhDs who chose “daily,” “weekly,” or “monthly” on a four-point scale that also included “never or rarely.” Data only include US-educated PhDs who remained in the US after earning their degrees. Academia refers to physics PhDs holding potentially permanent positions in two- and four-year colleges or universities and university affiliated research institutes. Figure based on 380 postdocs and 52 potentially permanently employed PhDs in academia.

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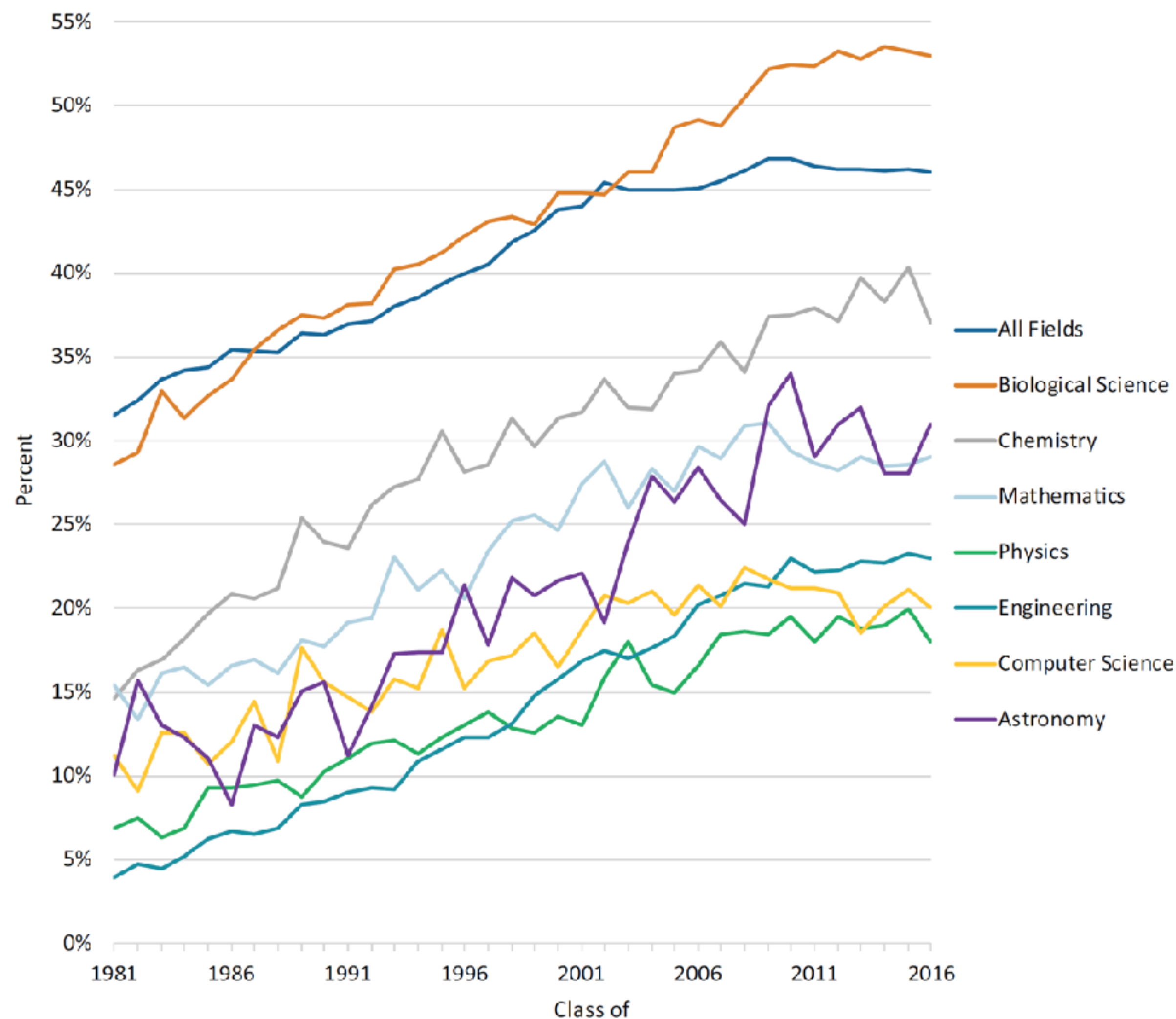
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But earning a PhD is
not the only marker
for success!

Percent of PhDs Earned by Women in Selected Fields,
Classes of 1981 through 2016



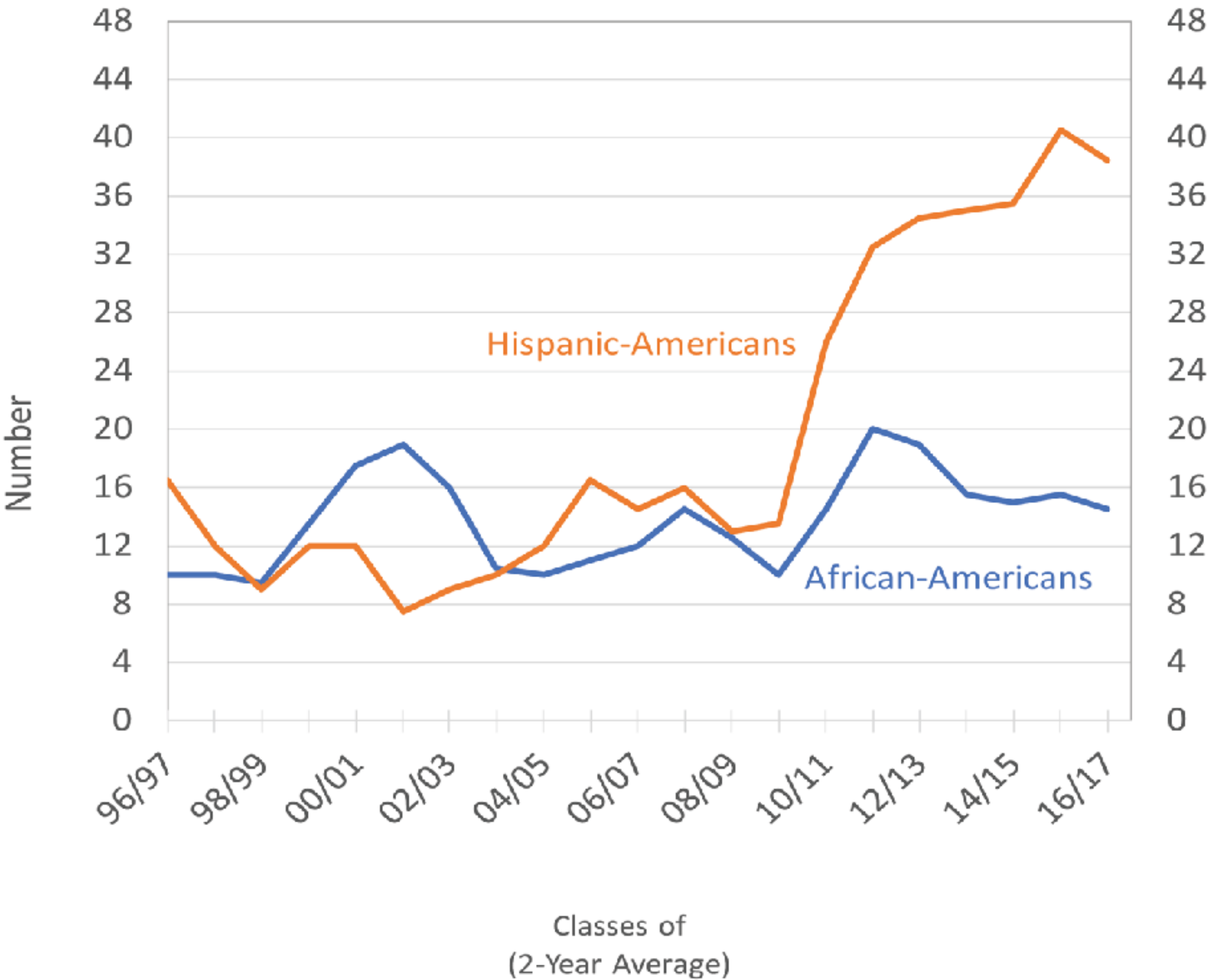
Source: National Science Foundation, National Center for Science and Engineering Statistics. Data compiled by AIP Statistical Research Center.

About 20% of PhDs in physics are granted to women

More women are earning PhDs in physics (and in STEM)

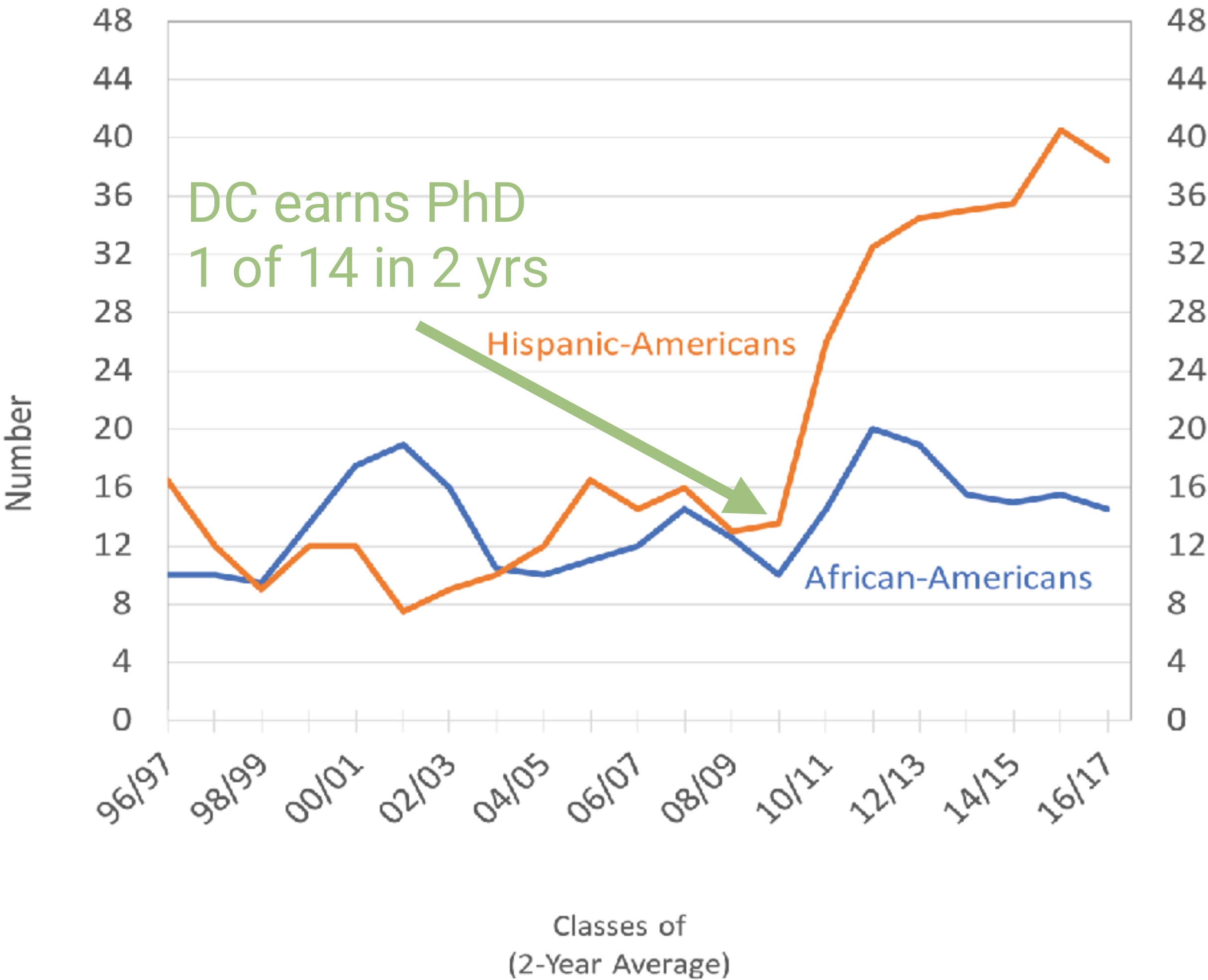
Few PhDs are granted to African-American (~14% of US pop) or to Hispanic-Americans (~20% of US pop)

Number of Physics Doctorates Earned by African-Americans and Hispanic-Americans, Classes 1996 through 2017.



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Reshape the culture of physics to bring traditionally excluded folks into critical activities and decision making

Sustain these changes over the long term

“DEI”

Summarized from UC Berkeley Division of Equity and Inclusion (<https://diversity.berkeley.edu/>)

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- **Equity** - The guarantee of fair treatment, access, opportunity, and advancement. Striving to identify and eliminate barriers preventing full participation.
- **Inclusion** - Authentically bringing in traditionally-excluded individuals into activities and decision making. Sharing power and ensuring equal access to opportunities and resources.

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DEI in Graduate Physics Education

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- **Equity** - Changing admissions criteria to remove barriers for applicants; Creating structures that support the transition to graduate physics programs (e.g., the APS Bridge Program)
- **Inclusion** - Creating a governance structure where graduate students participate in and vote on departmental decisions; Implementing a departmental code of conduct and the associated accountability practices

Generating Evidence

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Quantitative Research: A research tradition that provides evidence typically from large groups of individuals; statistical analysis and modeling of this data leading to claims and counter-claims

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Mixed Methods Research: A research tradition that blends Qualitative and Quantitative approaches to generate complementary evidence

STEM Education Research

- Studies by STEM professionals of:
 - how students understand STEM (concepts, practice, identity)
 - curricula / pedagogy
 - tools / context
- Theory, experiment, and applied



learningmachineslab.github.io
github.com/learningmachineslab

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The Learning Machines Lab focuses on **generating quantitative evidence** for understanding issues in STEM Education.

A Graduate Program in Physics

Applicants

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Graduate Students

Applicants

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Graduate Students

PhD Graduates

Applicants

A Graduate Program in Physics

Graduate Students

PhD Graduates

Employed Graduates

A Graduate Program in Physics

Recruiting

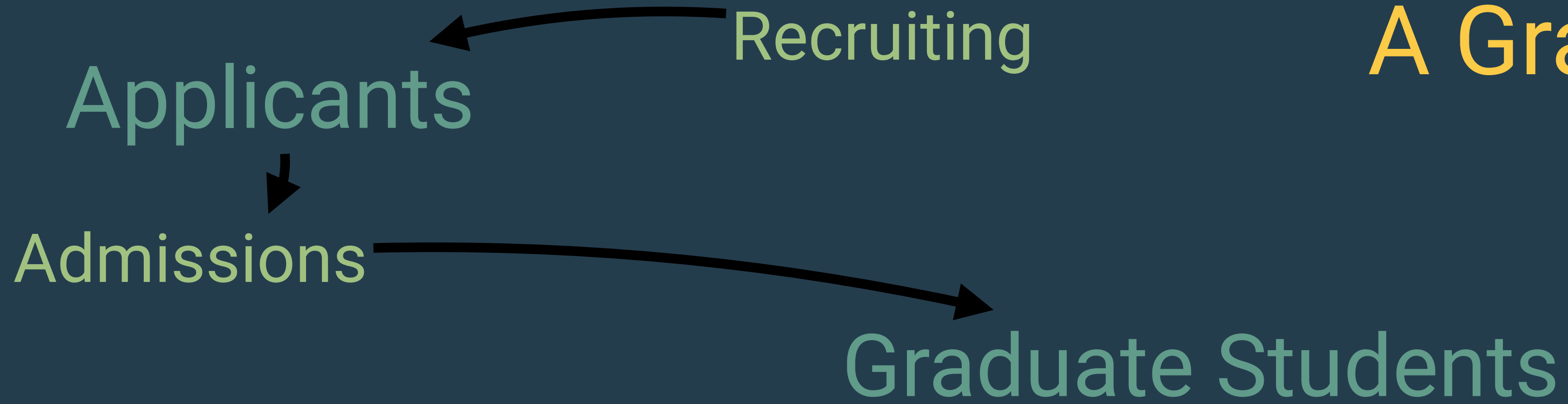
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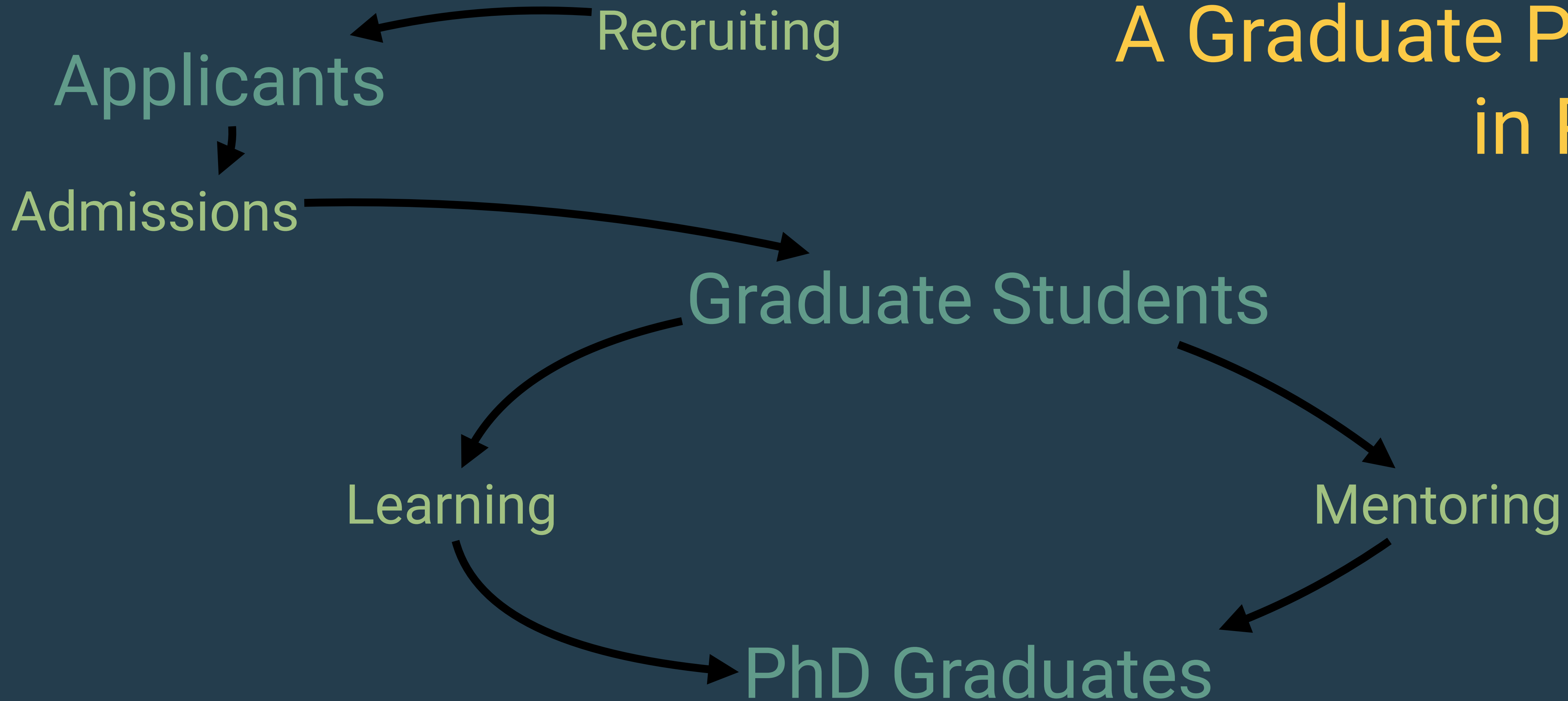
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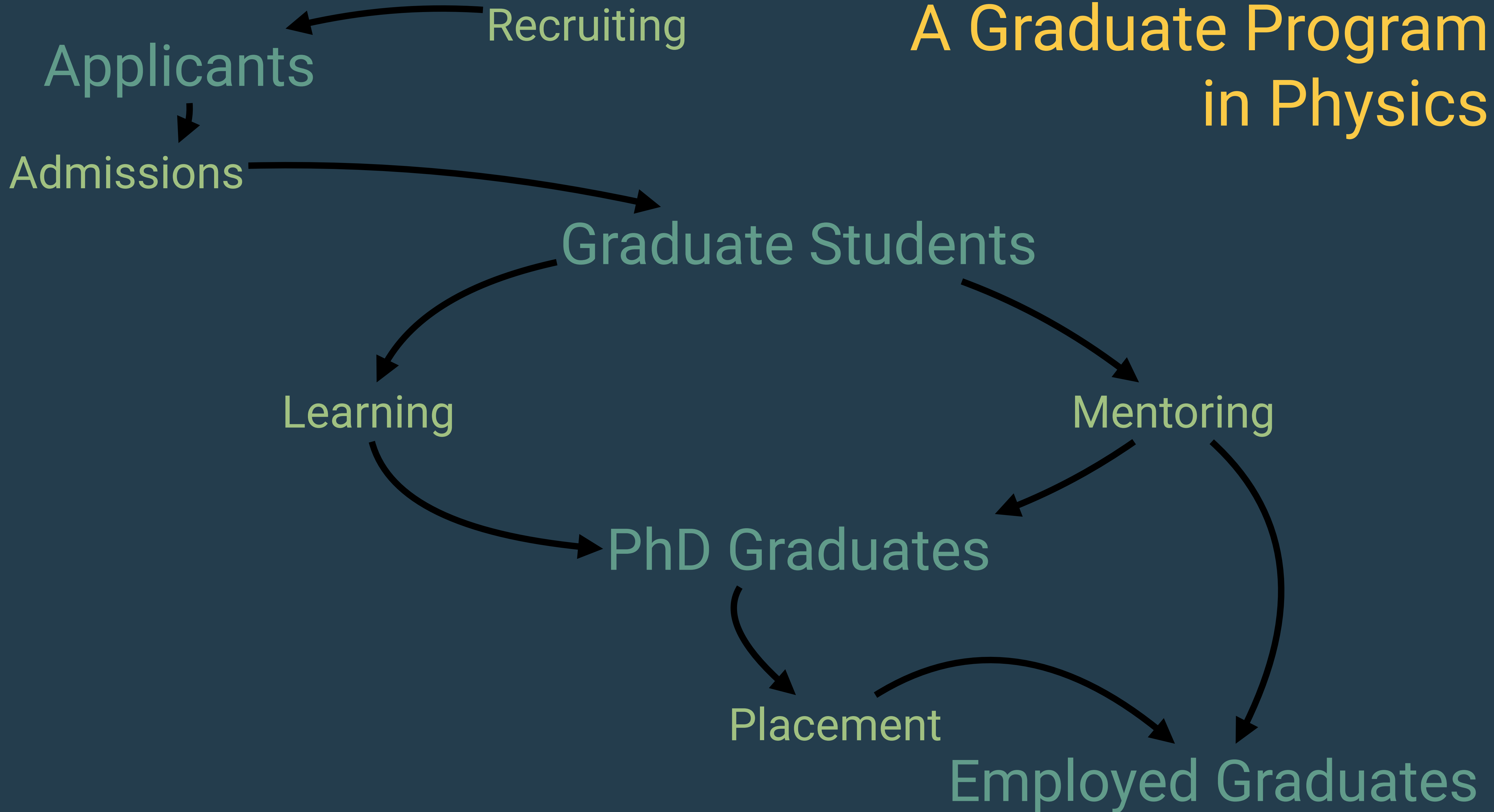
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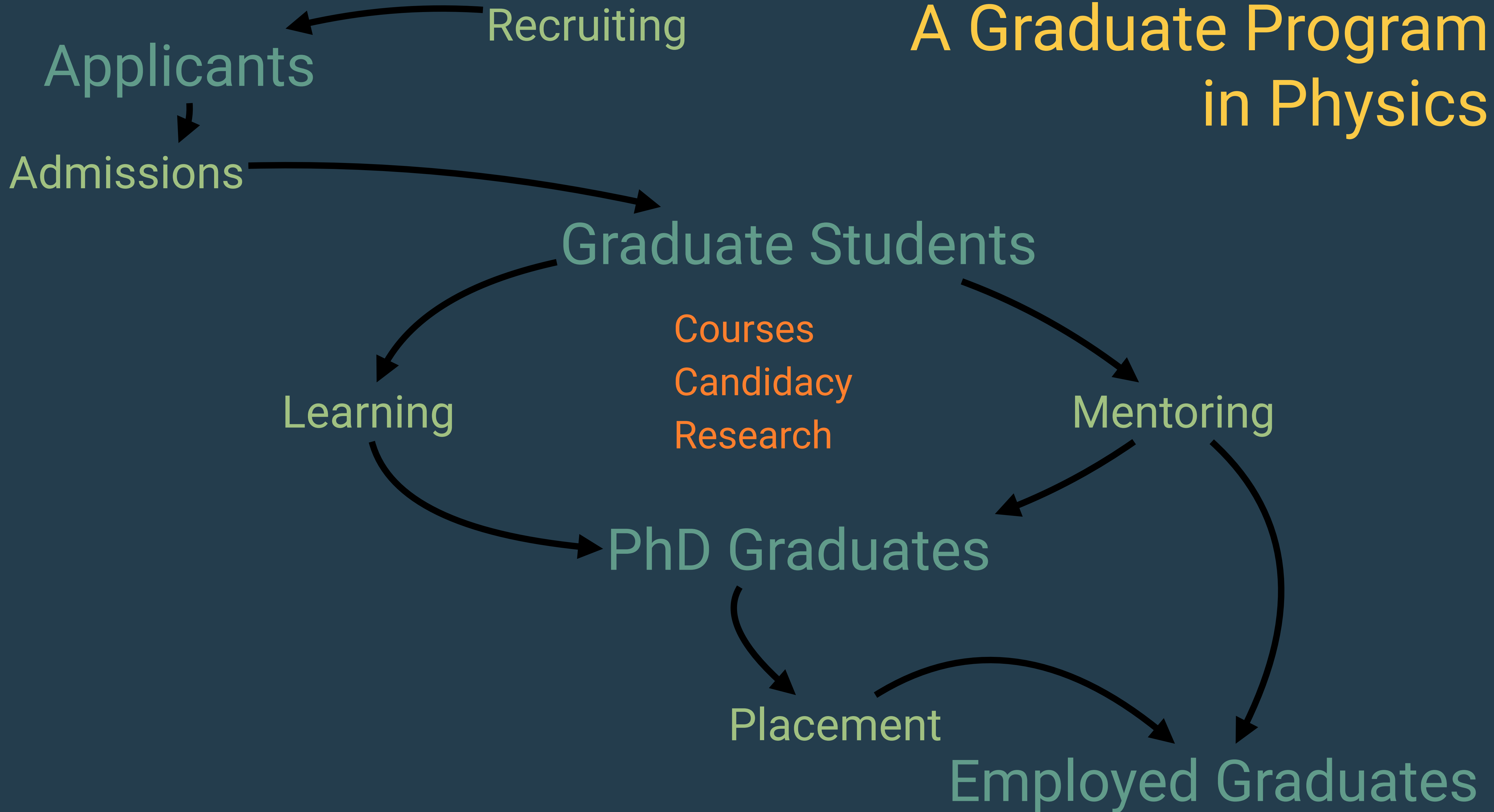
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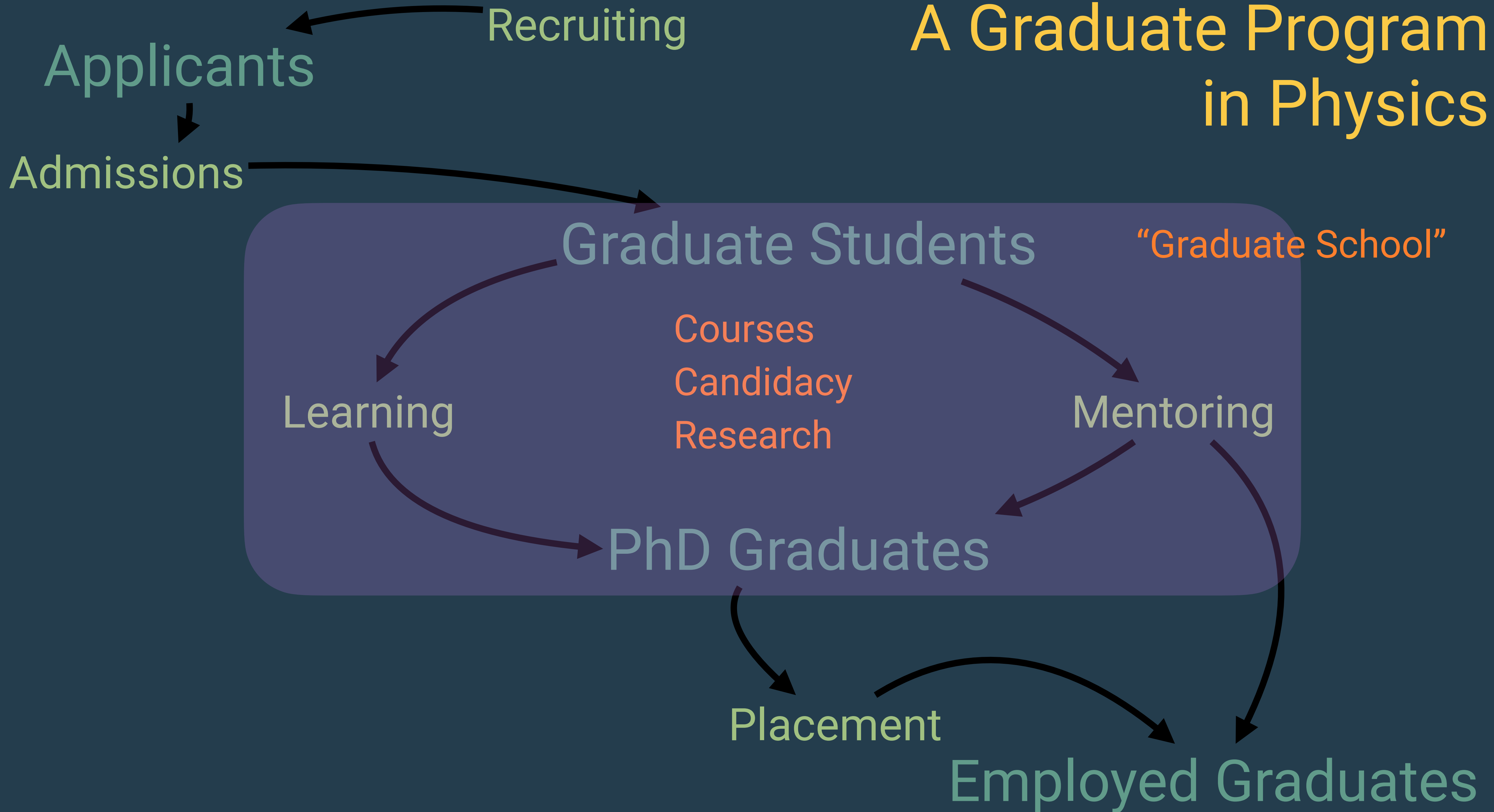
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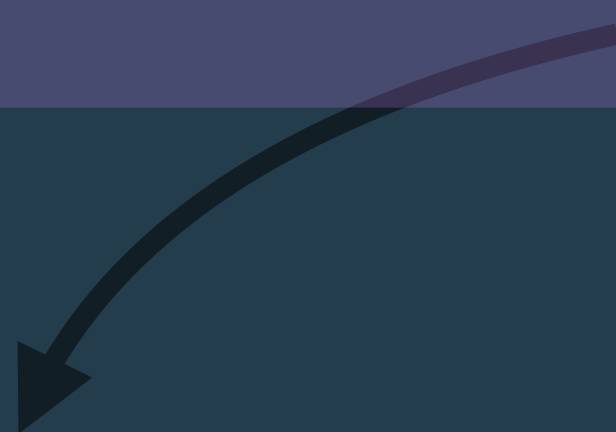
Recruiting

Focus for
Today

Admissions

Graduate Students

Holistic
Rubric-Based
Admissions



Admissions Package

GRE scores

GPA

Personal statement

Research statement

Letters of

recommendation

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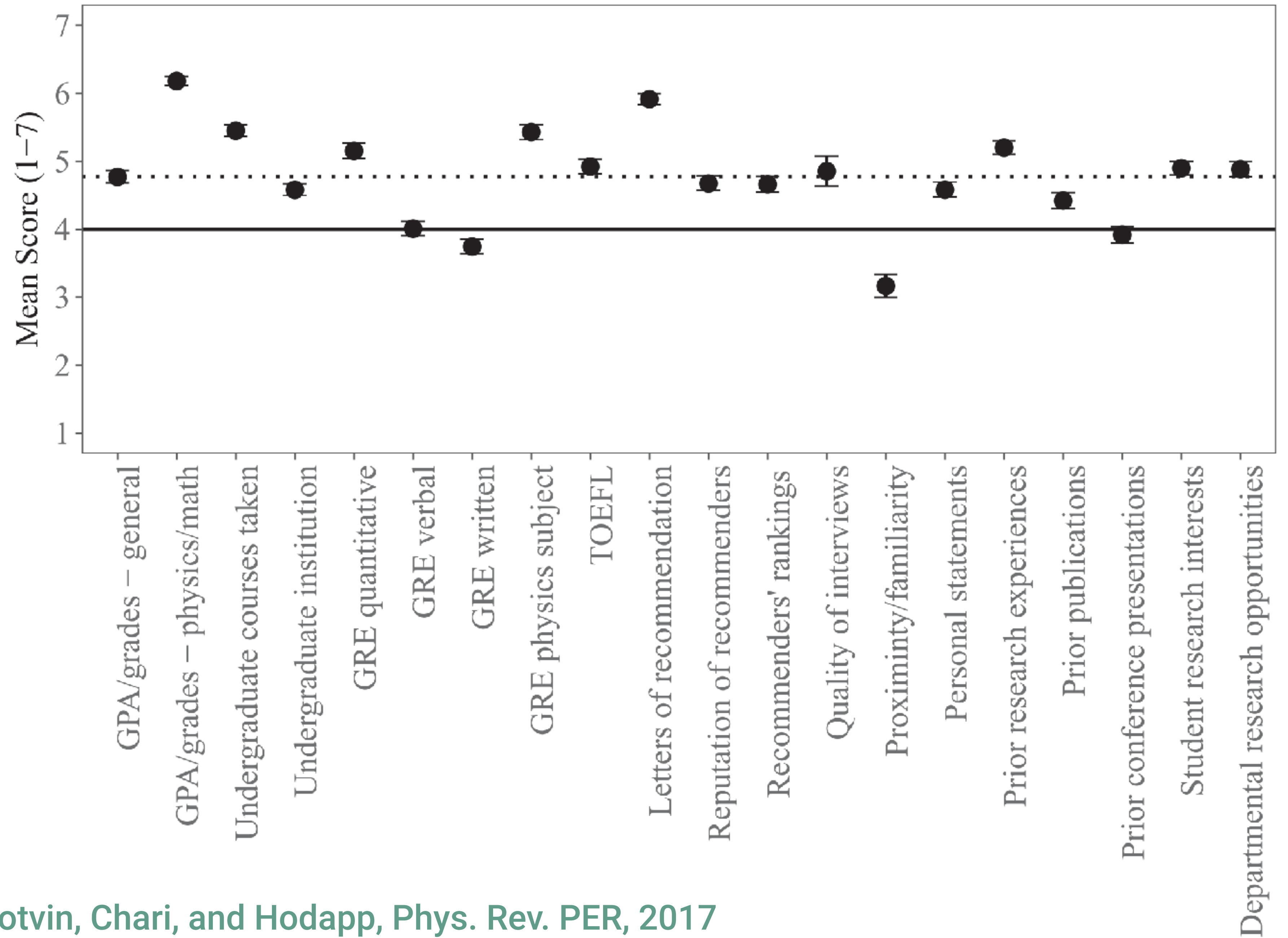
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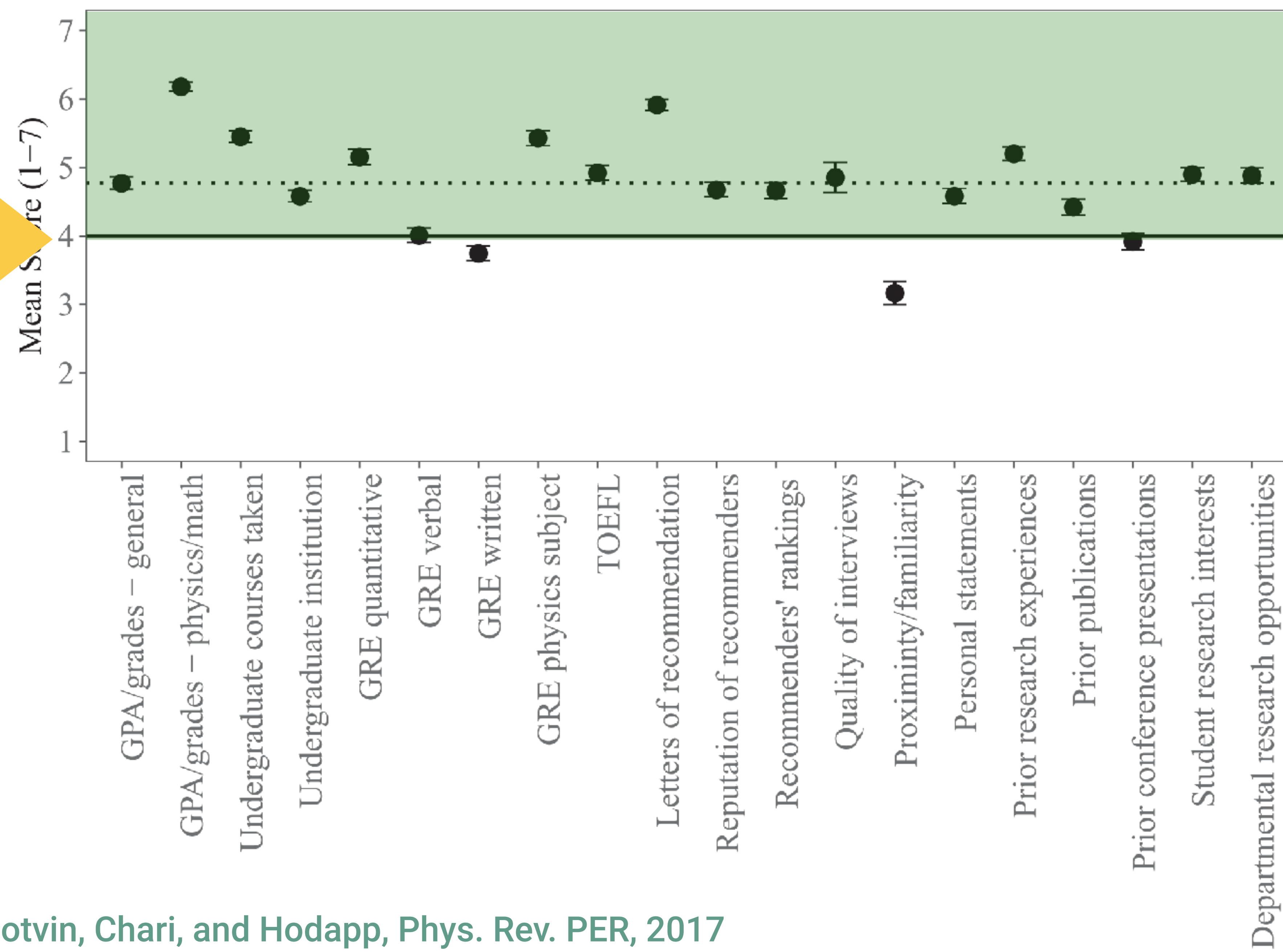


Potvin, Chari, and Hodapp, Phys. Rev. PER, 2017



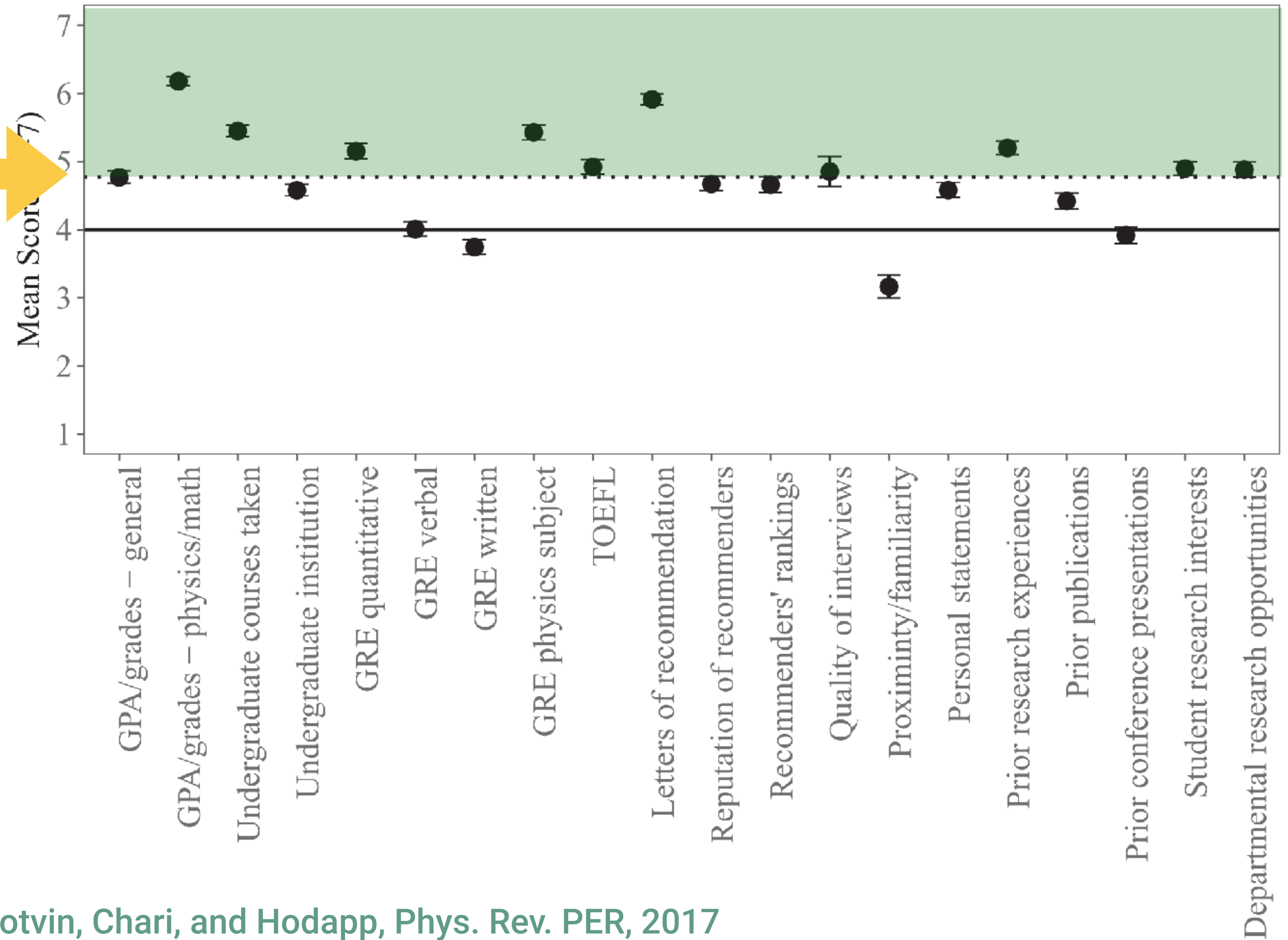
Moderately Important

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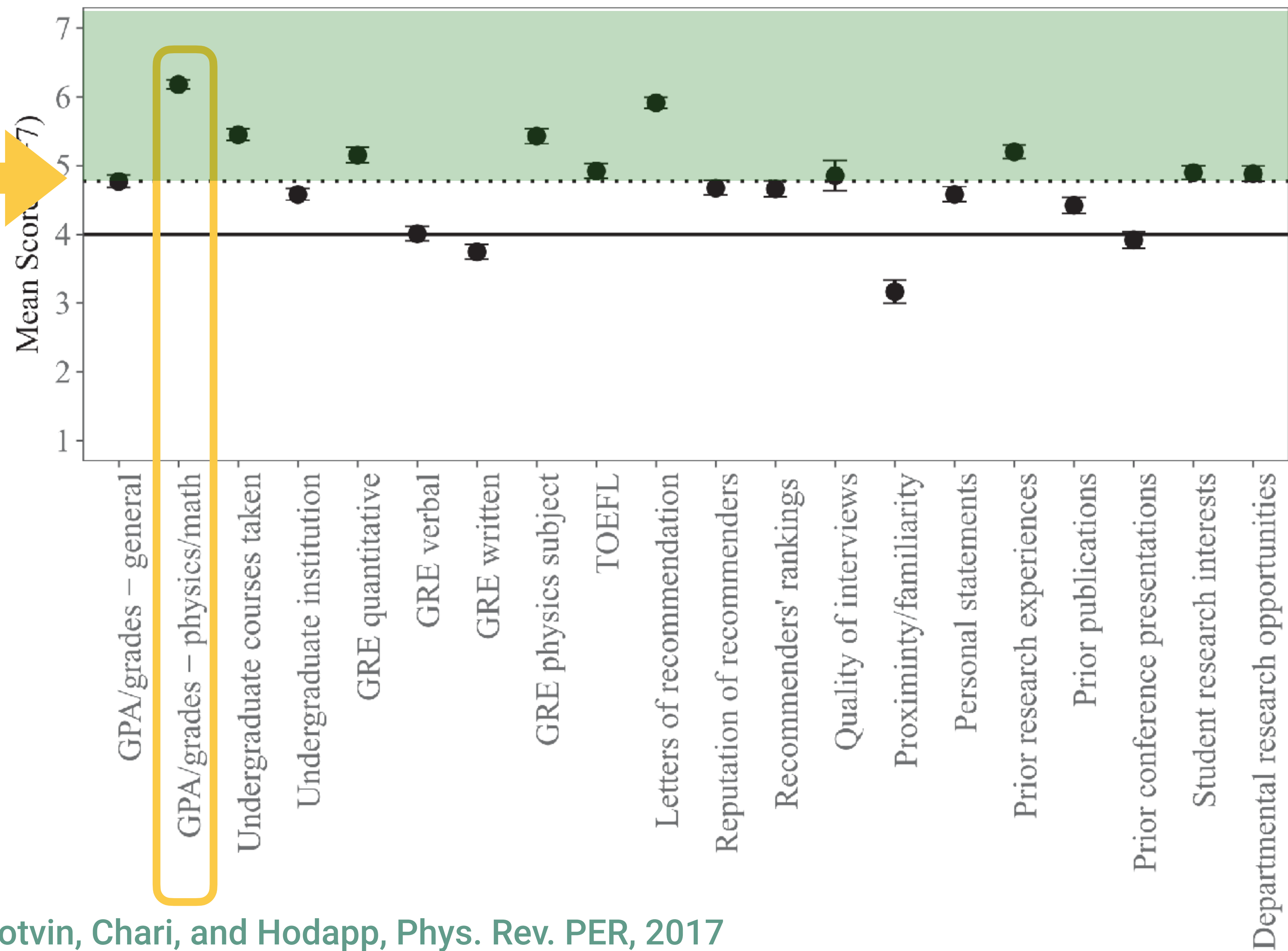
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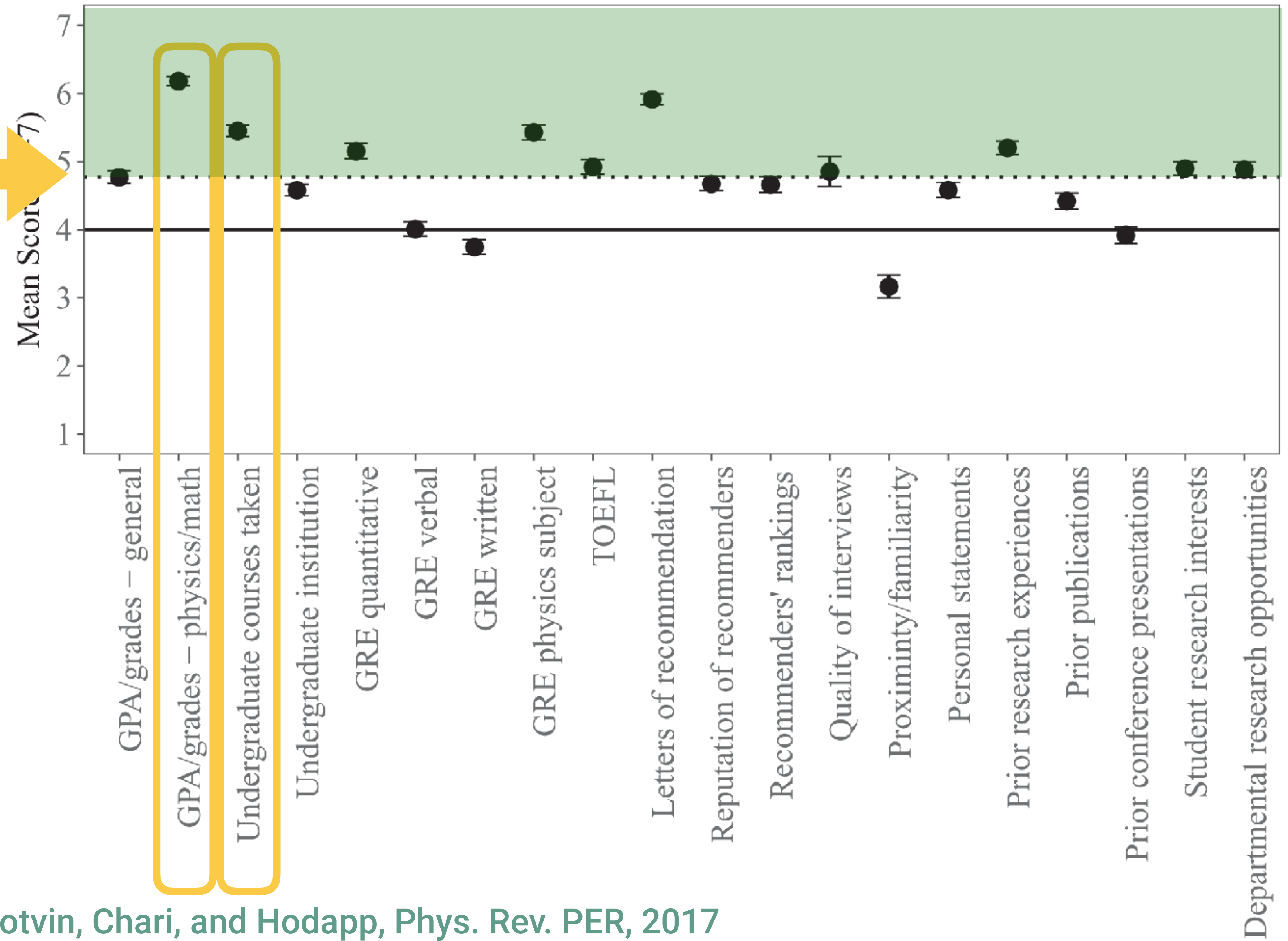
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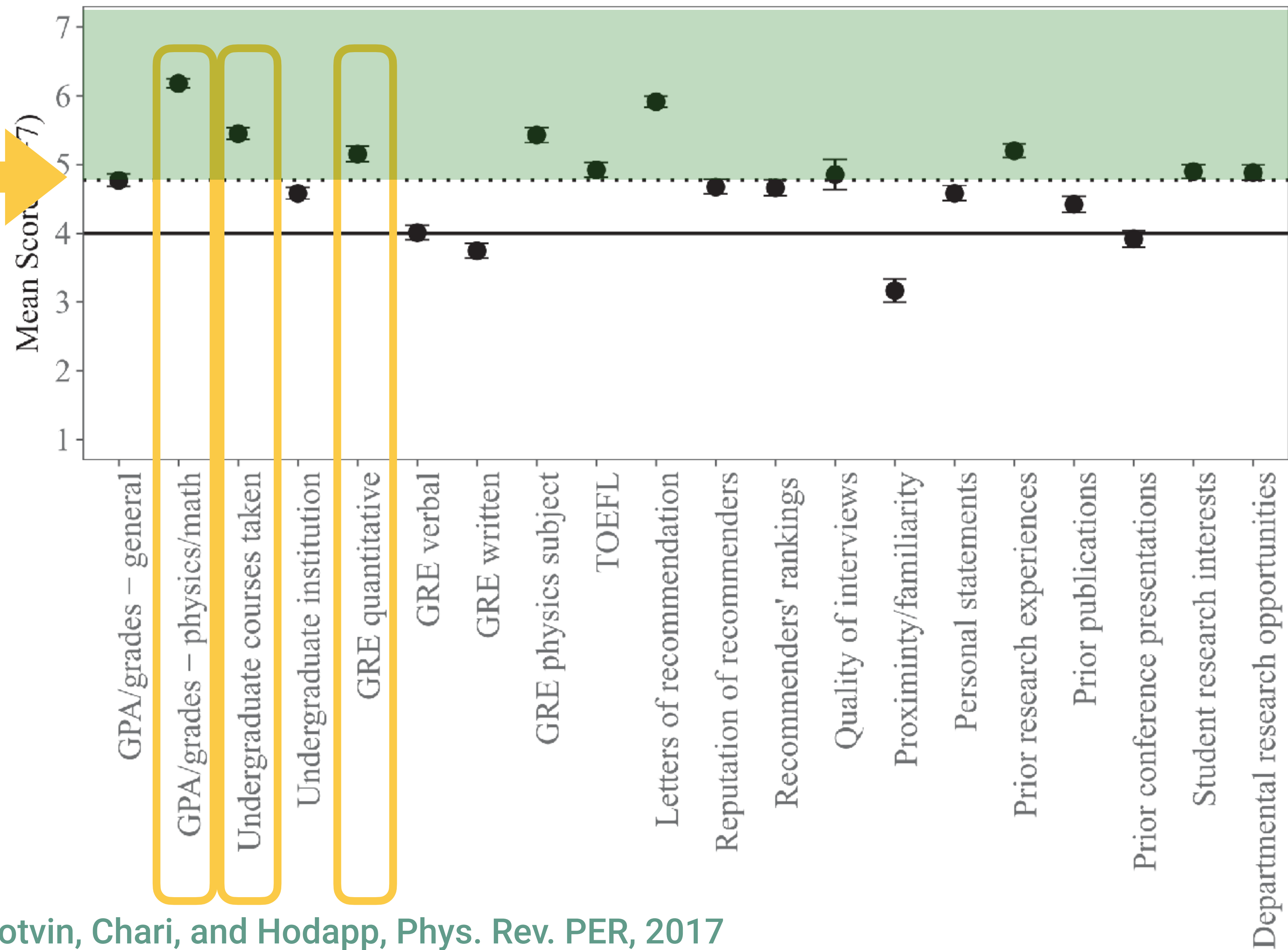
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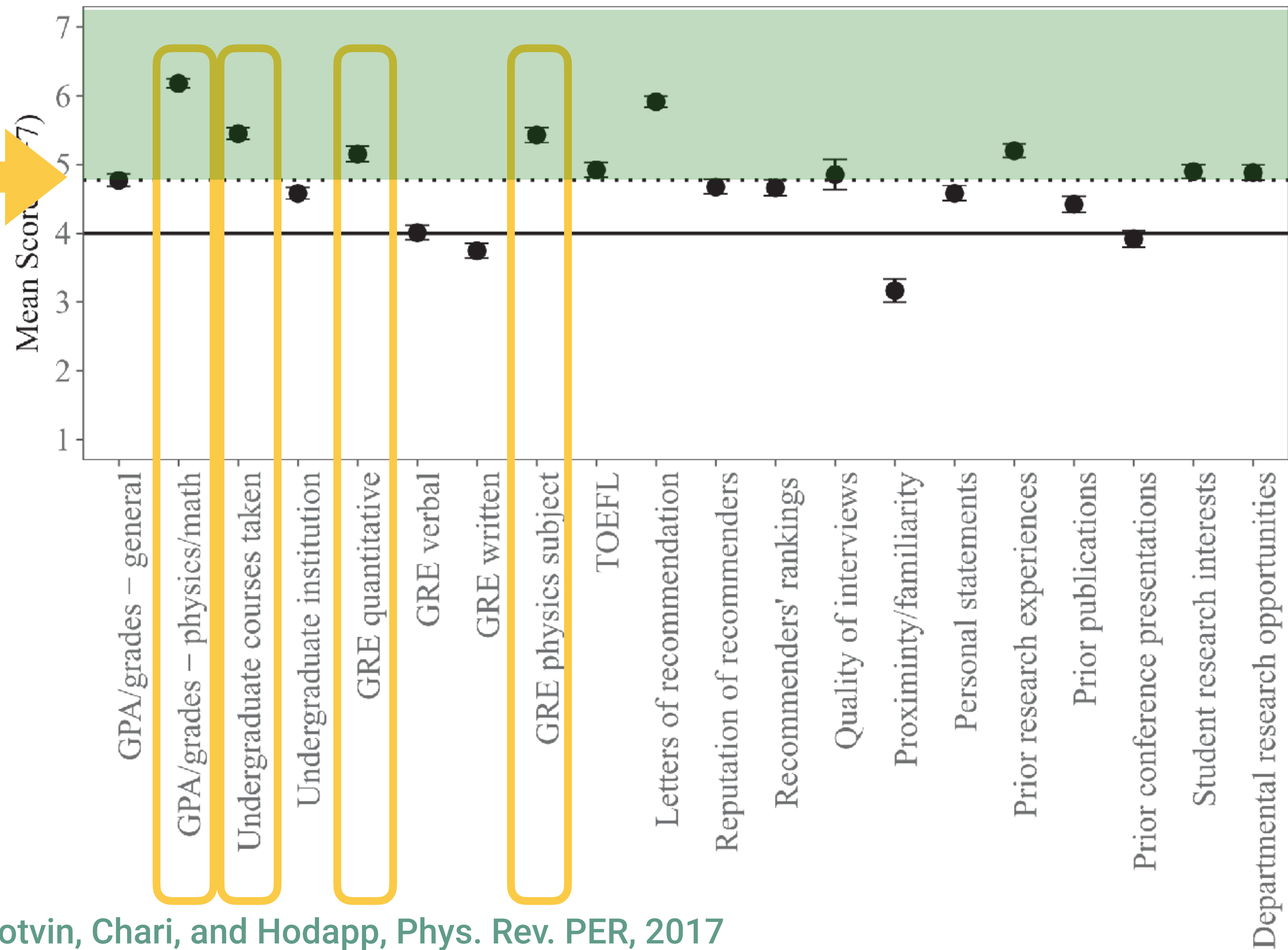
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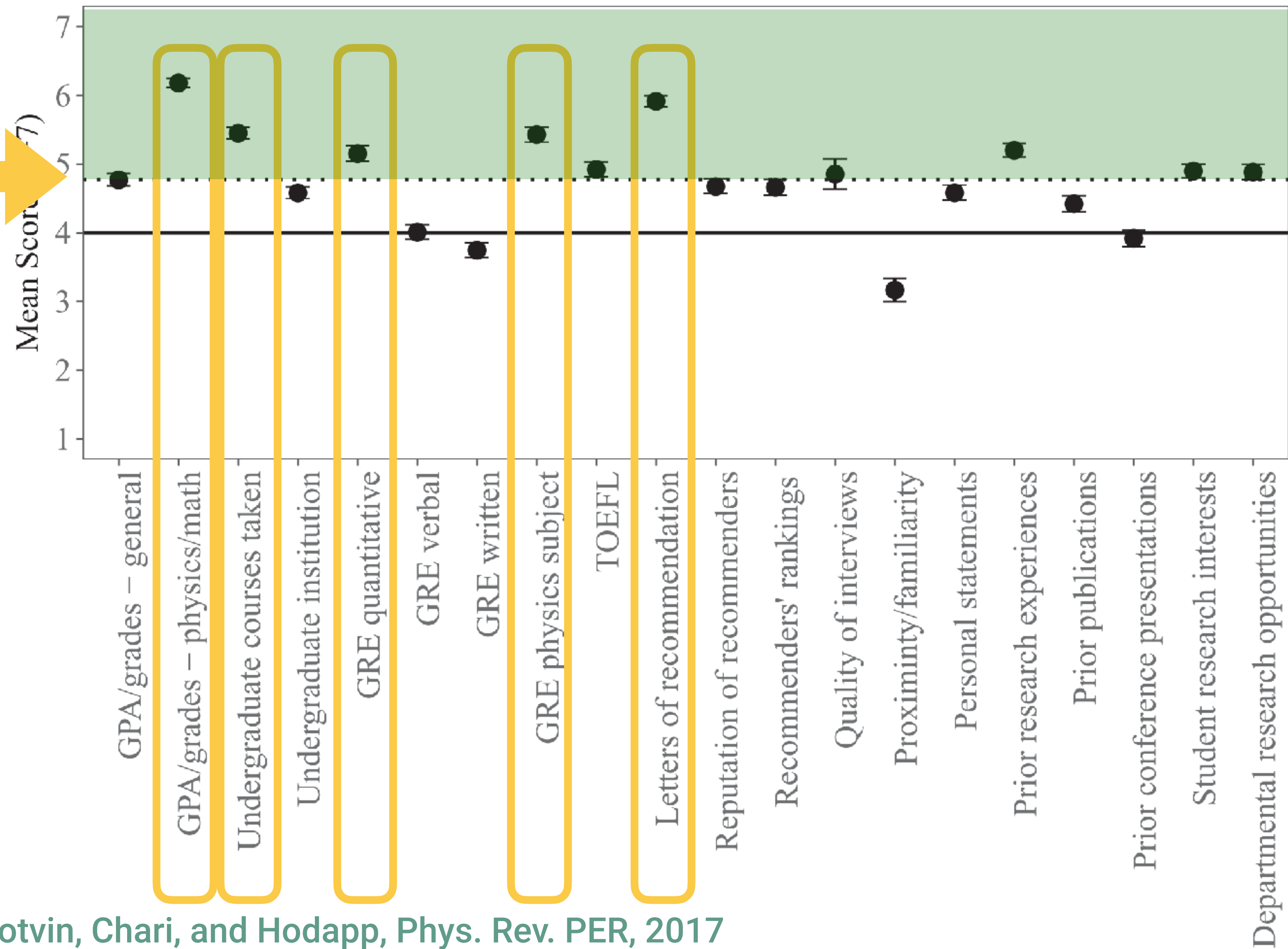
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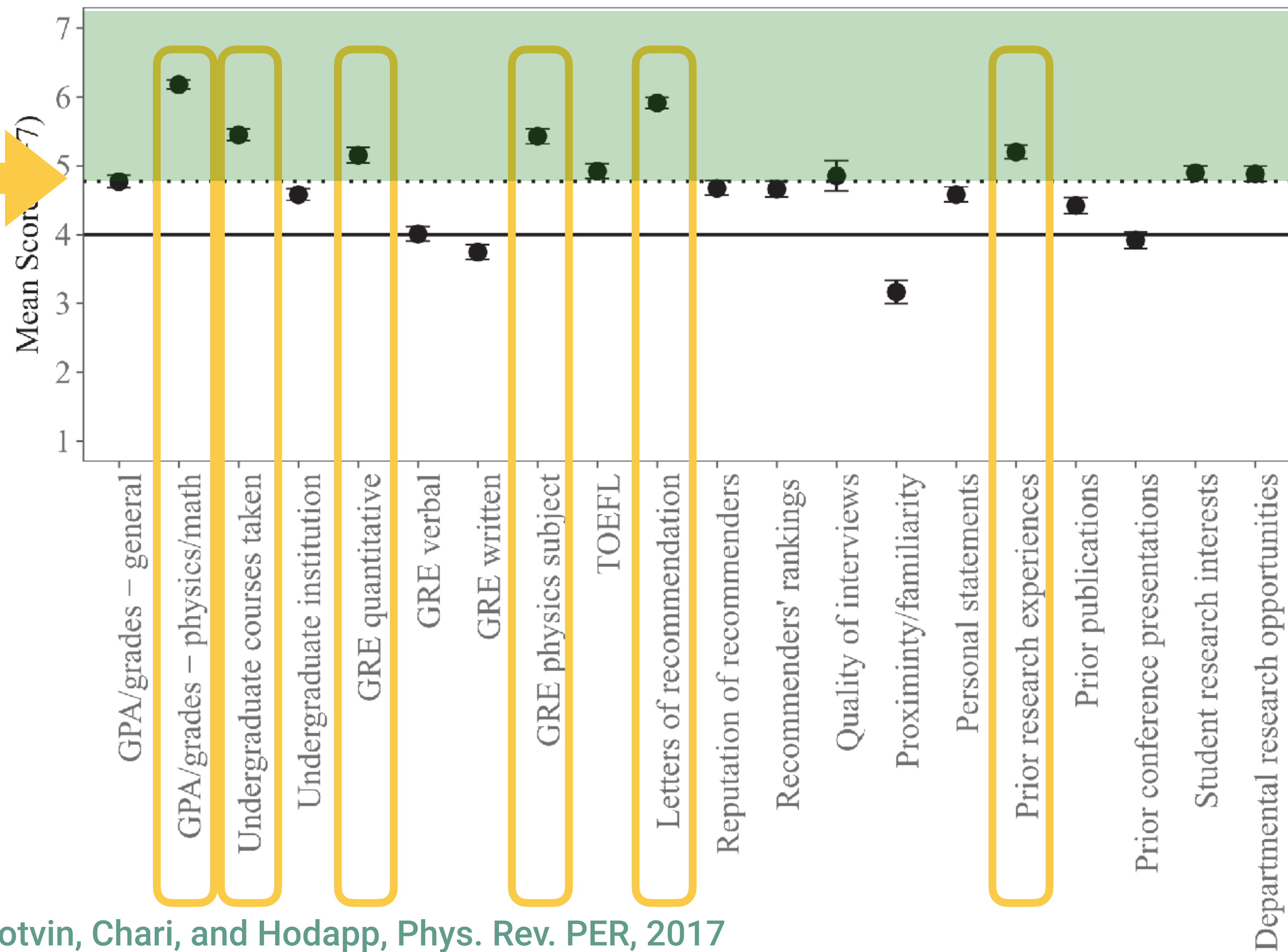
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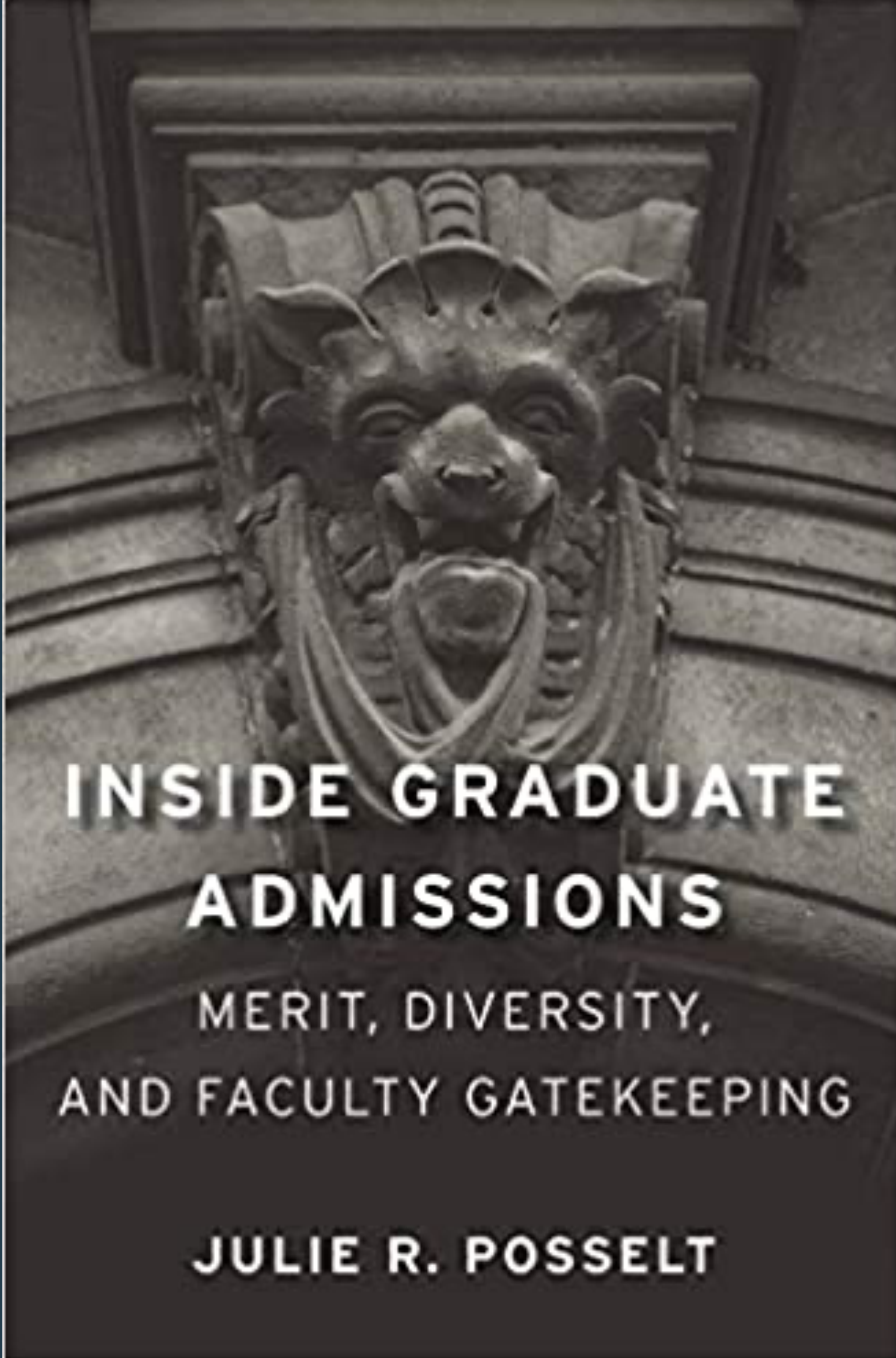


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In-depth research
into admissions
deliberations



The Graduate Record Exam

GRE General Test

~4 hour test in three parts

Cost: \$205

GRE Subject Test (Physics)

~3 hour, 100 question, multiple-choice

Cost: \$150

Perspective (12% income tax):

\$7.25/hr -> \$6.38/hr (56 hrs)

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41. The quantum efficiency of a photon detector is 0.1.
If 100 photons are sent into the detector, one after the other, the detector will detect photons
- (A) exactly 10 times
 - (B) an average of 10 times, with an rms deviation of about 0.1
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43. Which of the following wave functions represents a solution to the Schrödinger equation for an electron in the $2s$ state of a hydrogen atom? (c is a constant and a_0 is the Bohr radius.)
- (A) $c \cos \theta$
 - (B) $c \exp\left(-\frac{r}{a_0}\right)$
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53. A microwave line has a laboratory wavelength of $1 \mu\text{m}$. If the Hubble constant $H \approx 75 \text{ (km/s)/Mpc}$, the observed wavelength for the line from a galaxy 100 Mpc distant is about

- (A) 250 nm shorter
- (B) 25 nm shorter
- (C) the same
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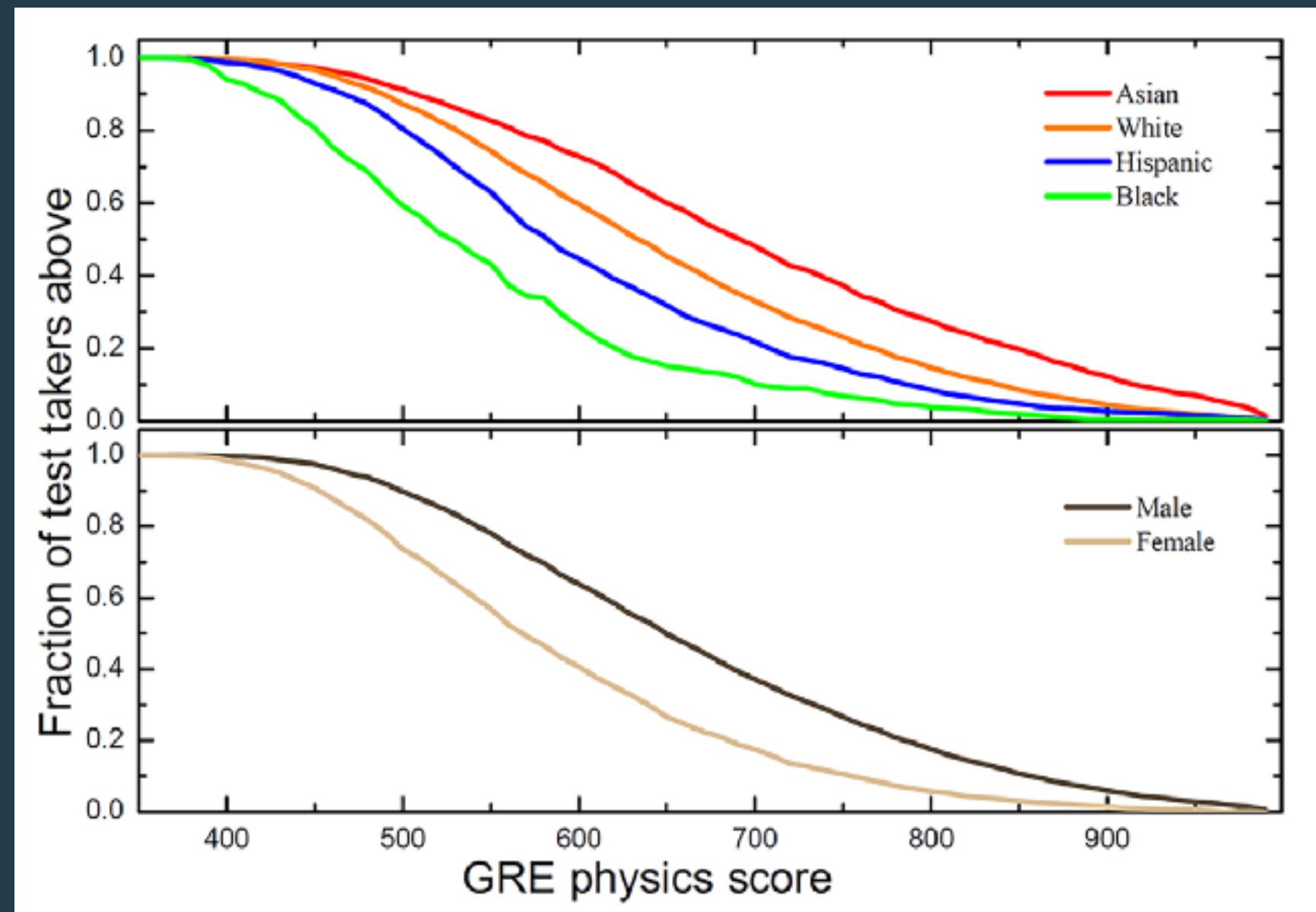
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- (D) 25 nm longer
- (E) 250 nm longer

NOTE: many students will not have taken upper-level physics courses before taking the PGRE

Numerical markers used for admission



This distribution of GRE scores suggests weighting scores in admissions limits the diversity of potential PhD students [1].

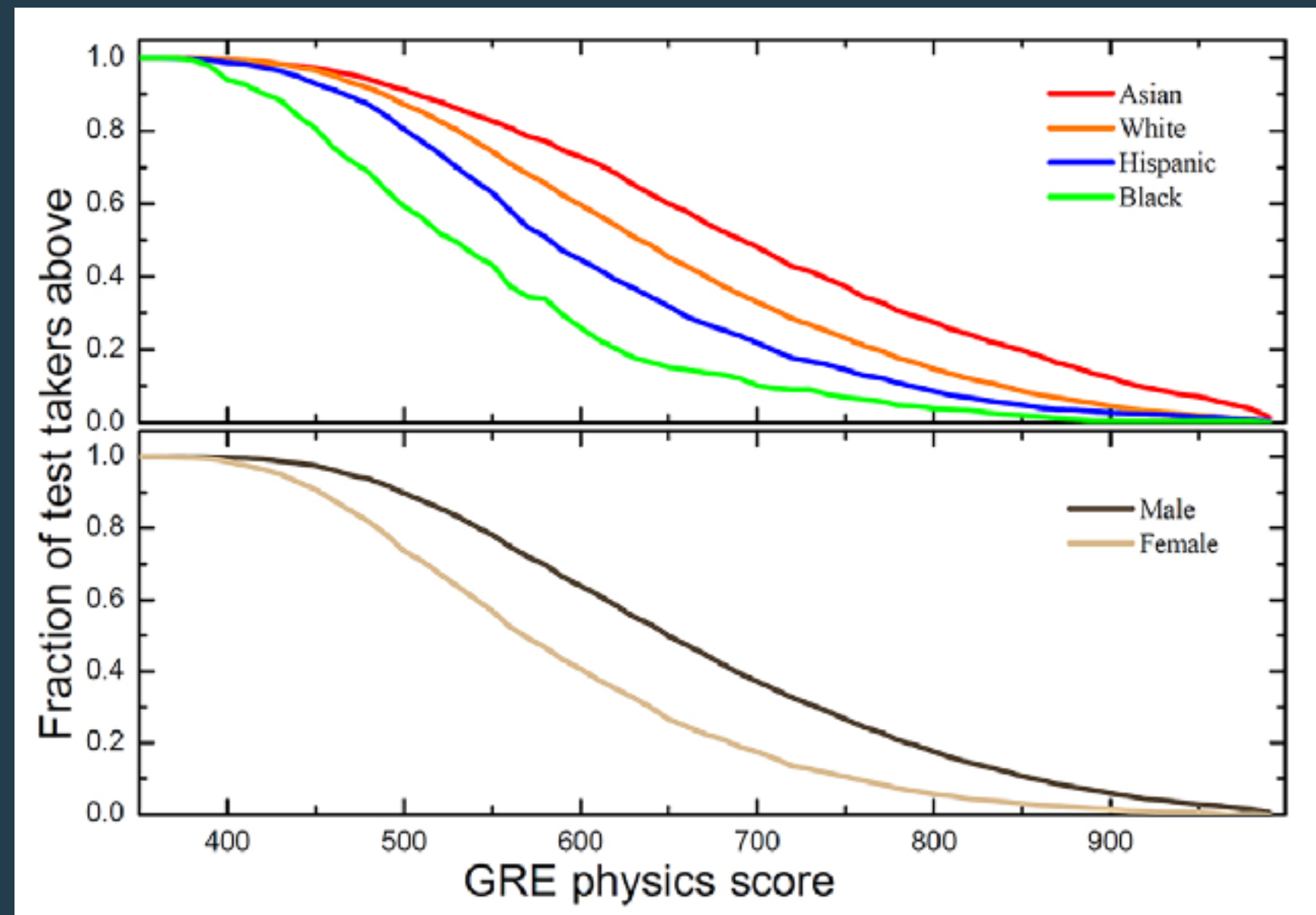
[1] Miller et al., Sci. Adv. 2019;5:eaat7550

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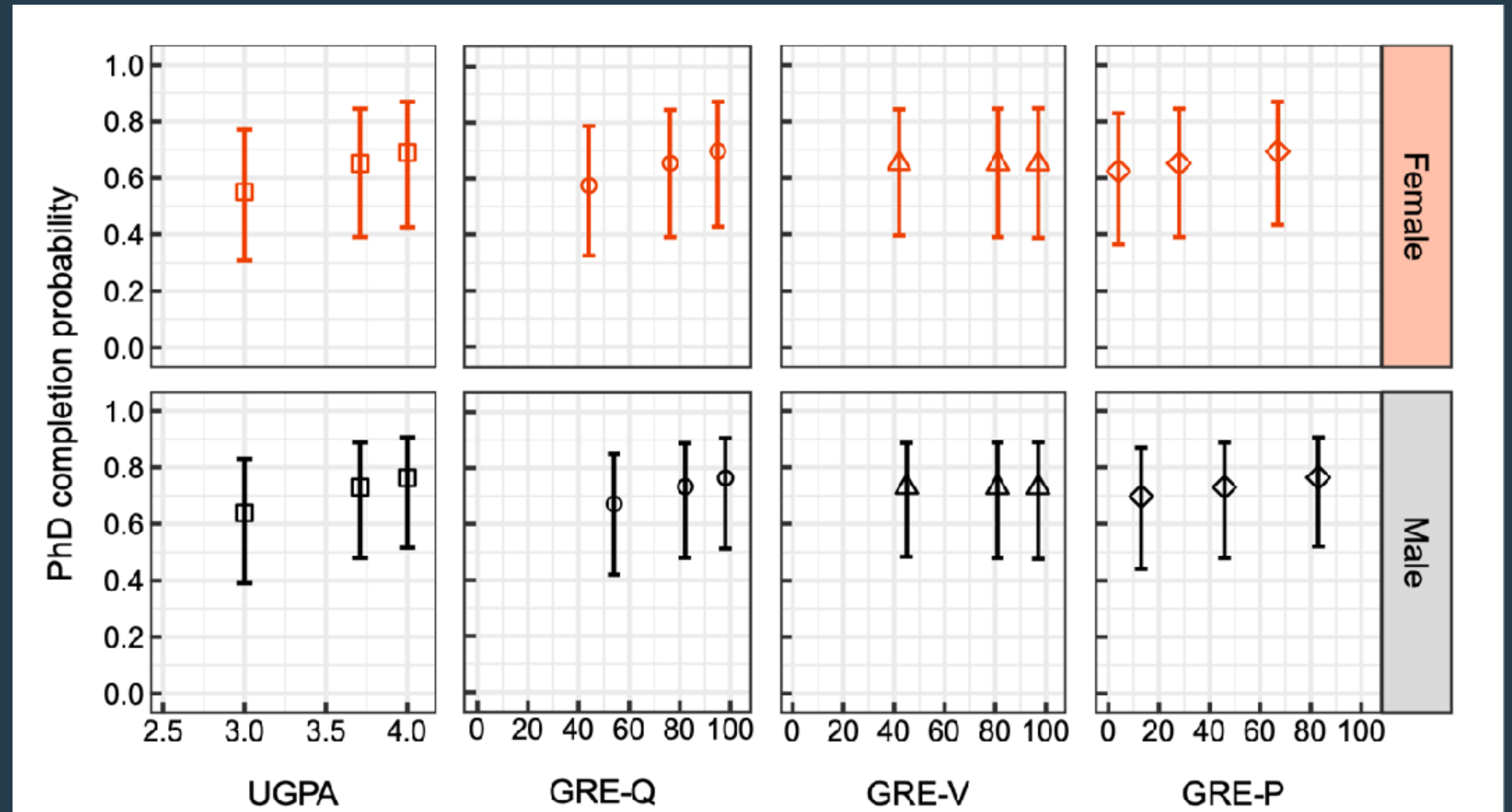
[3] R. Wilson, PhD Dissertation (2020)

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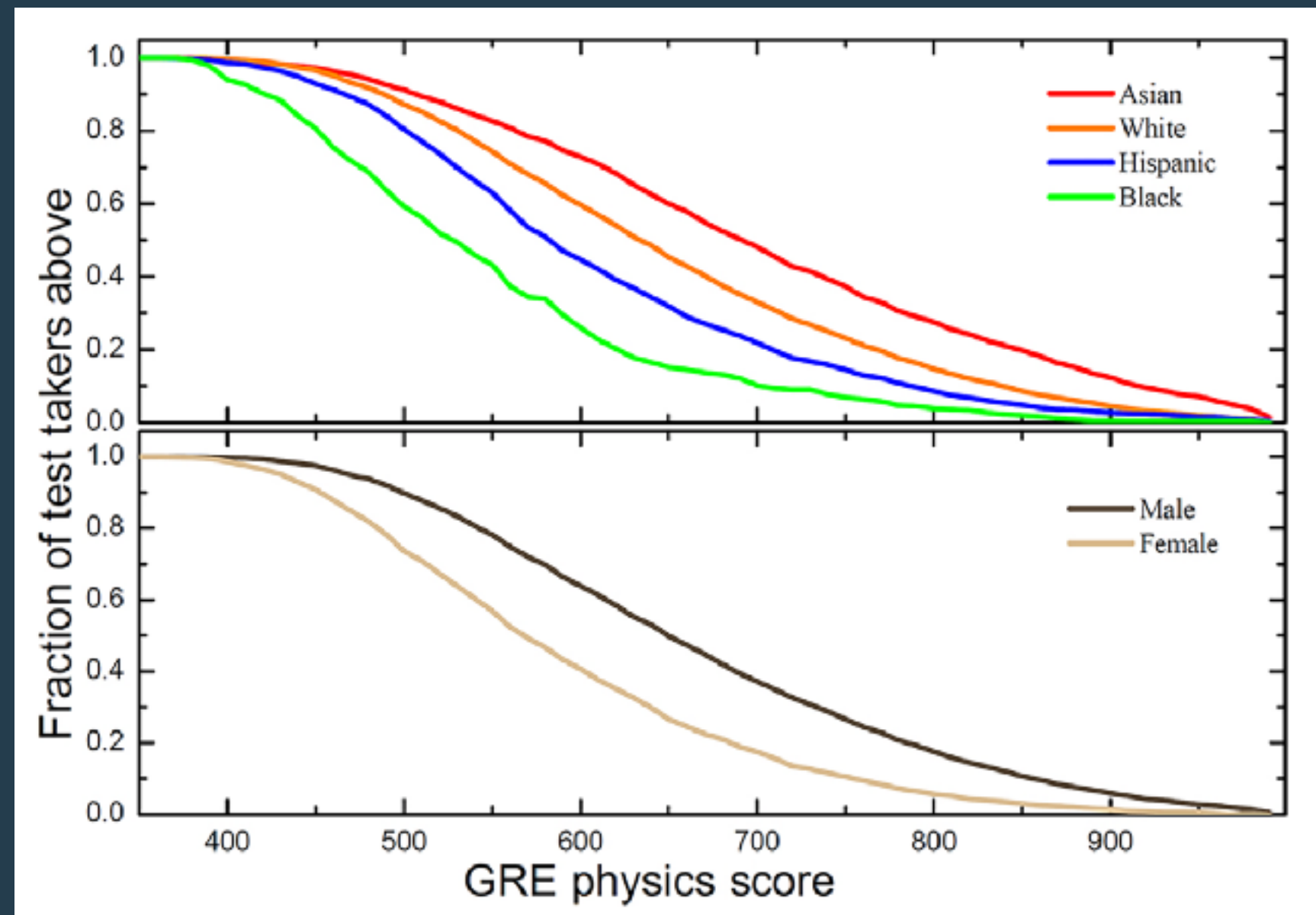
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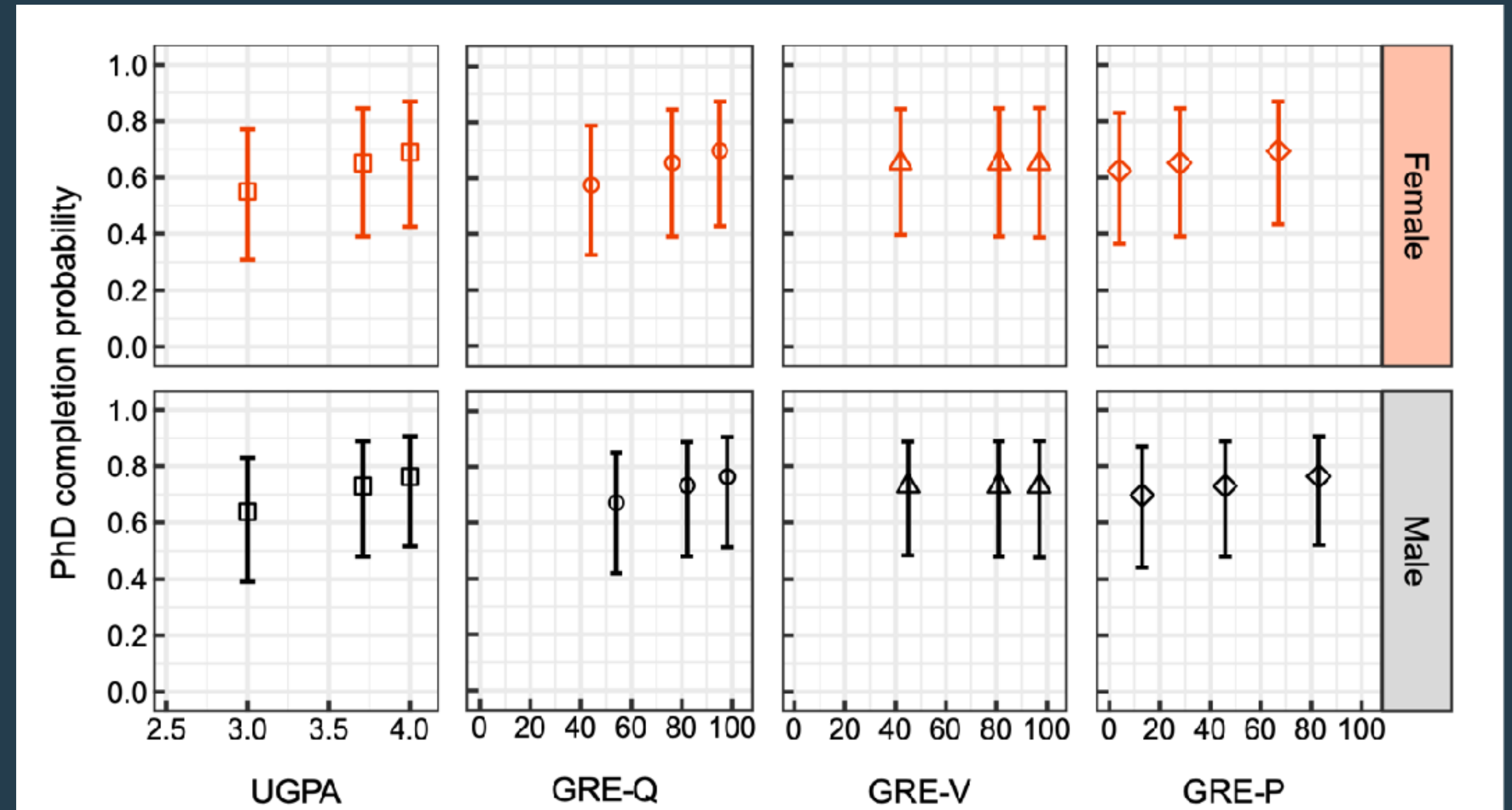
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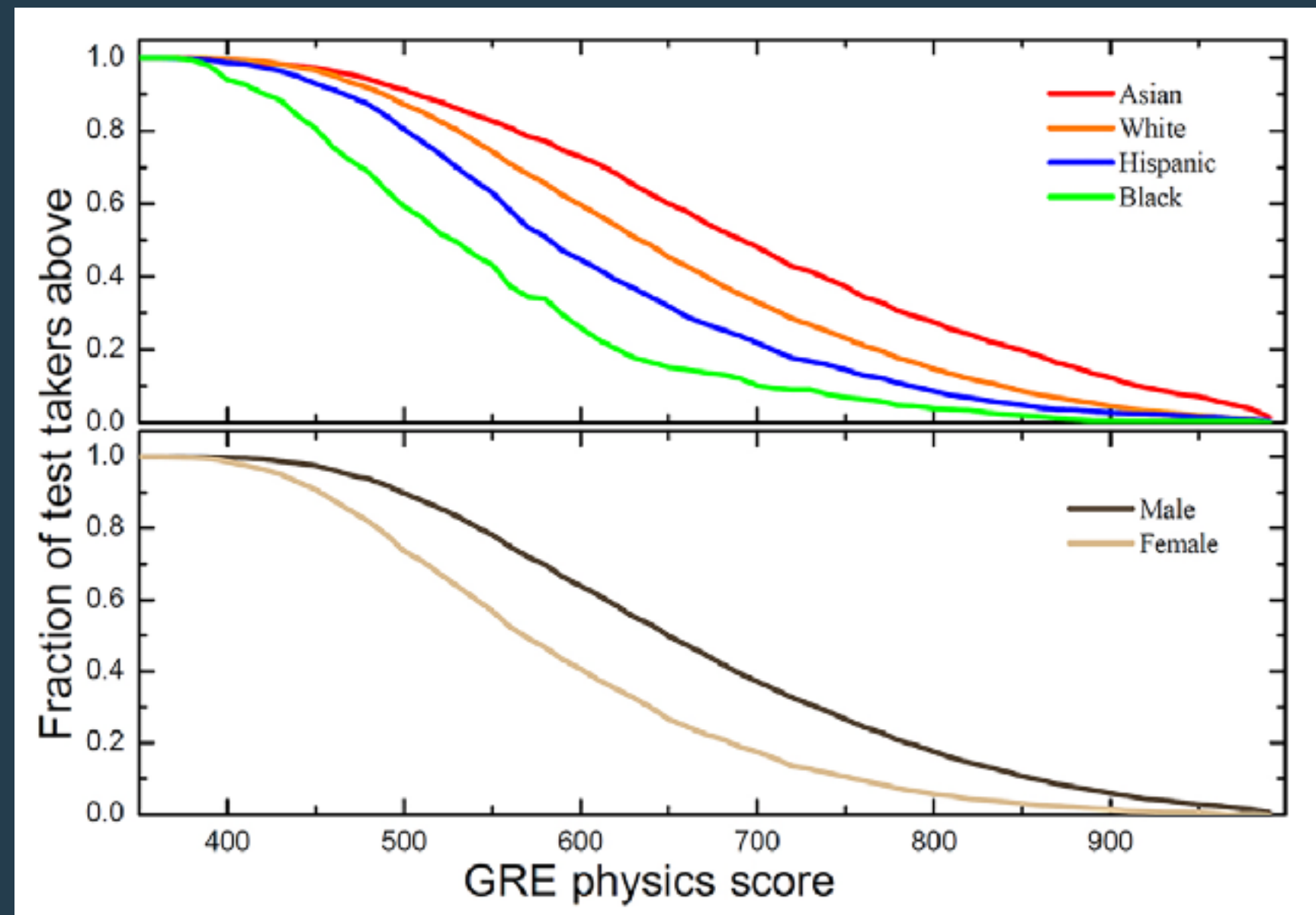
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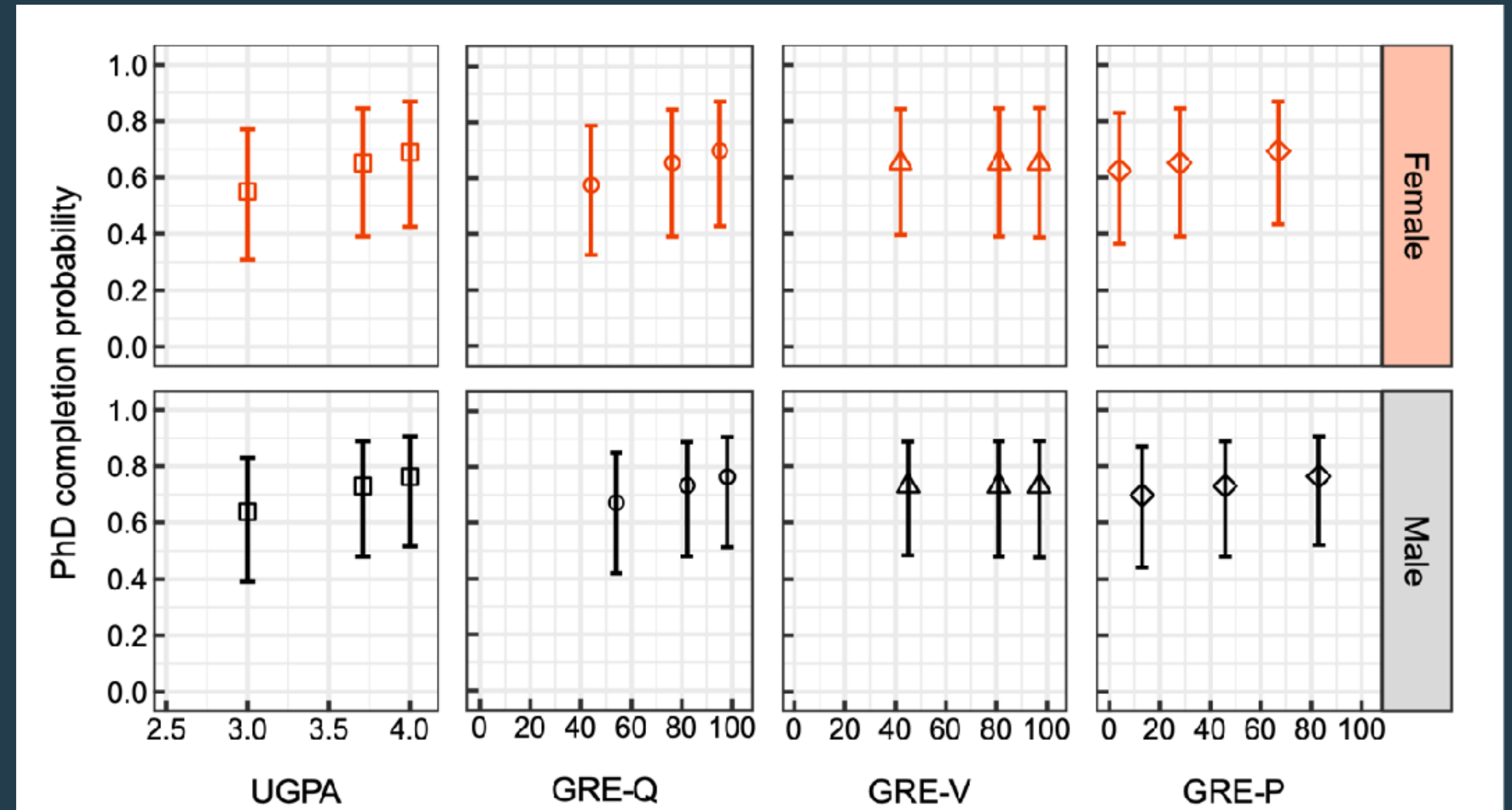
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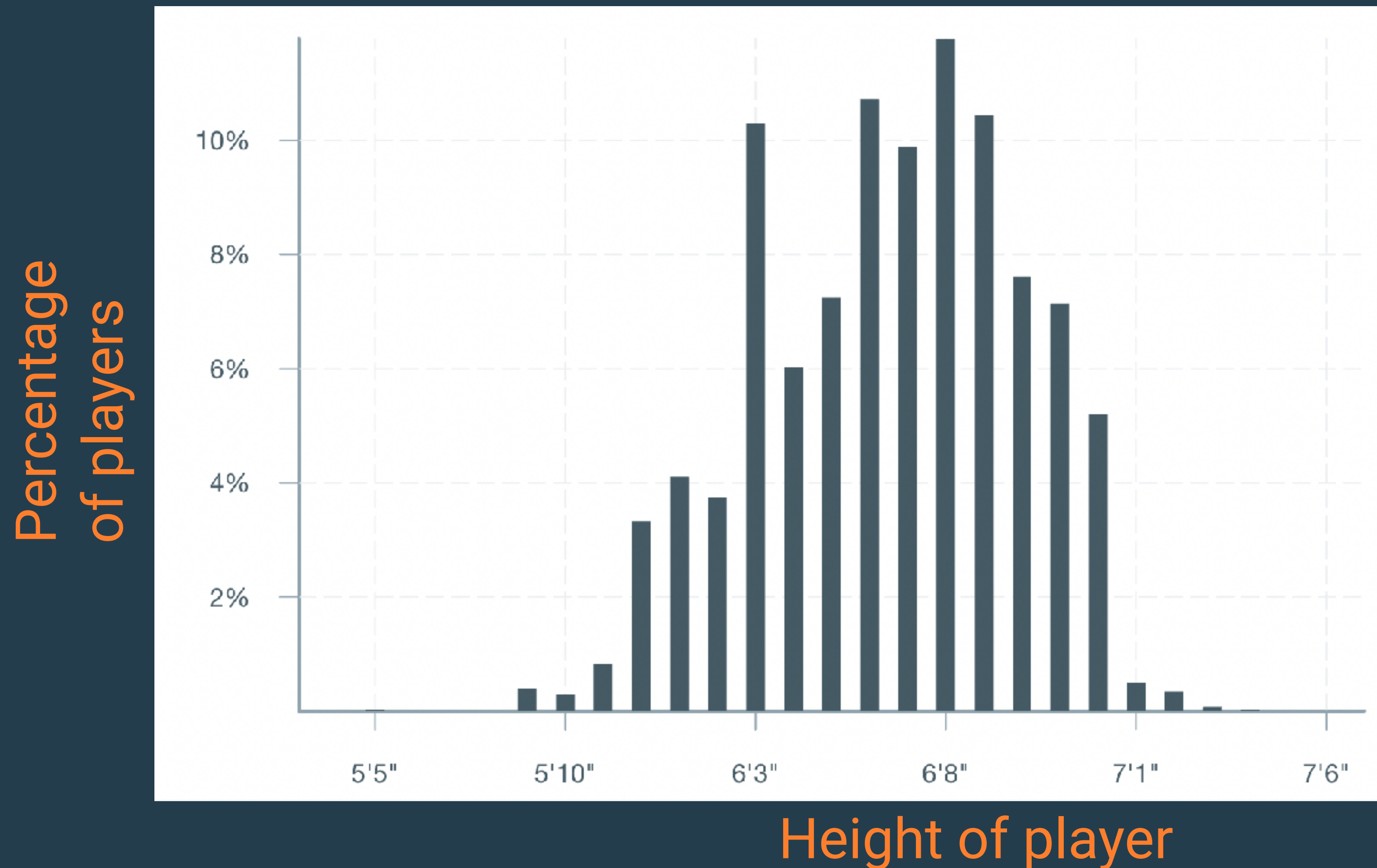
Reminder: PhD completion should not be our only marker of success

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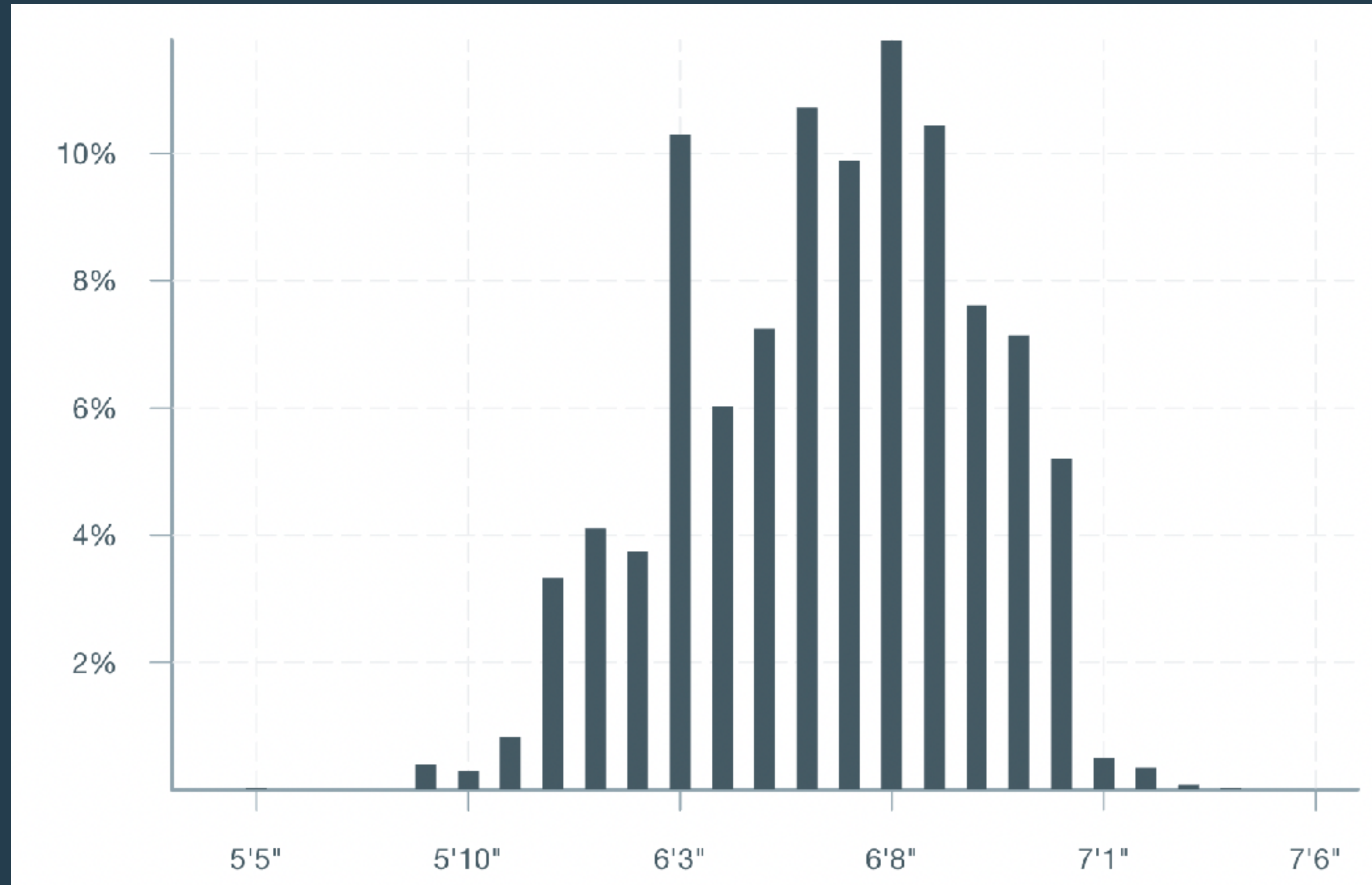
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Distribution of NBA player heights (last 10 years)

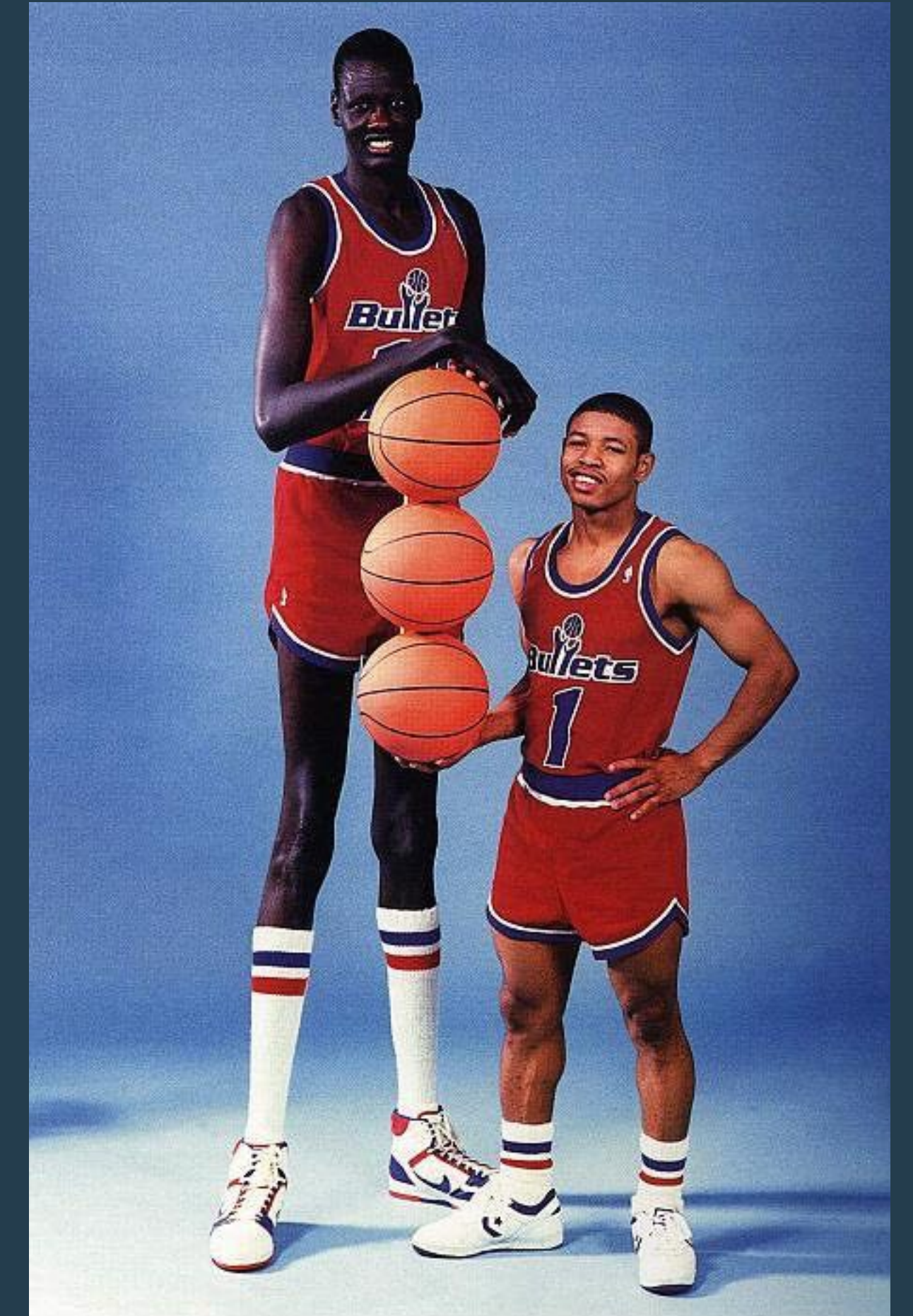


Distribution of NBA player heights (last 10 years)

Percentage
of players



Height of player



Mr. Bol (7' 7") and Mr. Bogues (5' 3")

“The GRE helps students stand out”

[4] What Are the Subject Tests?

The *GRE*® Subject Tests are achievement tests that measure your knowledge of a particular field of study.

Show what you know about a specific subject and graduate schools will take notice. The Subject Tests can help you stand out from other applicants by emphasizing your knowledge and skill level in a specific area.

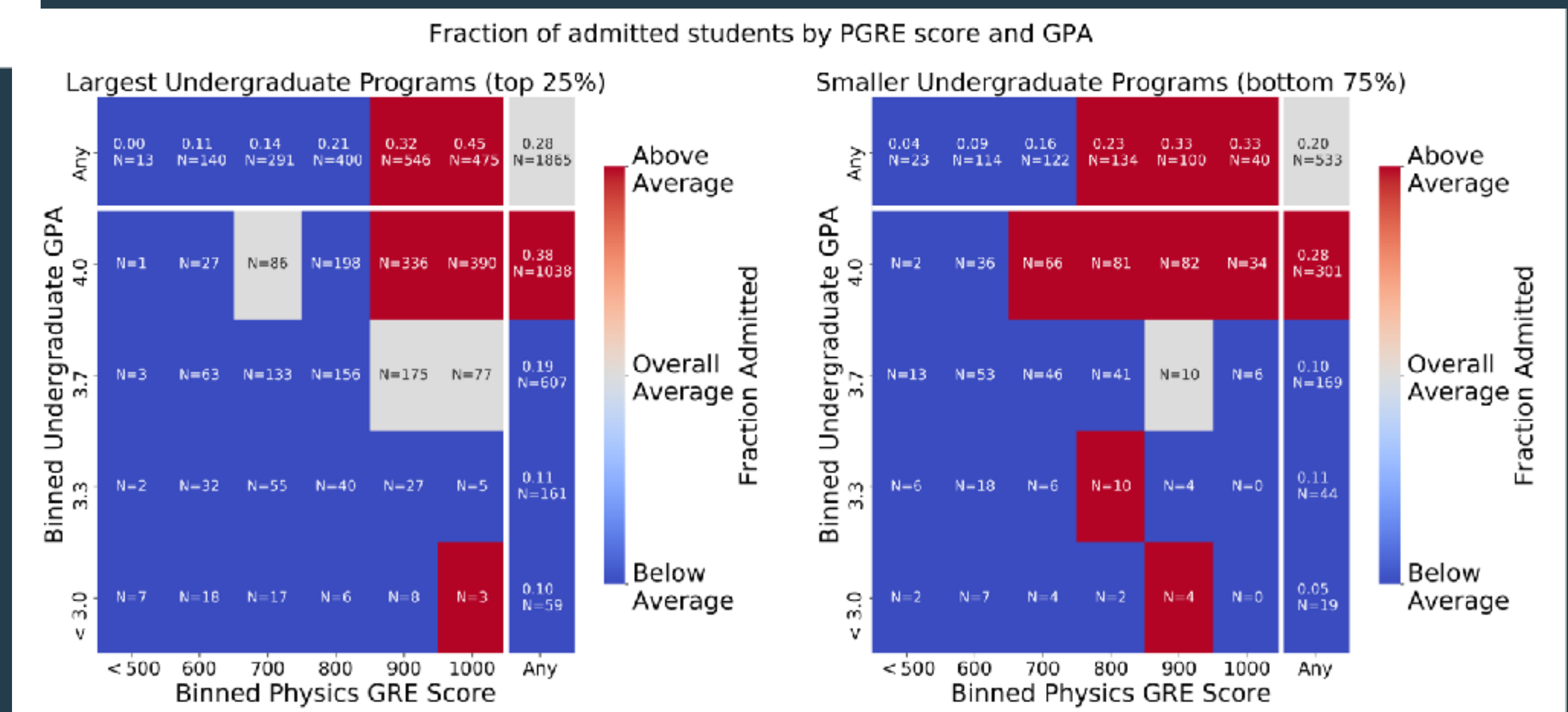
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“...scoring highly on the physics GRE does not help applicants from small or less selective schools or applicants with a low GPA ‘stand out’.” [5]



[4] <https://www.ets.org/gre/subject/about>
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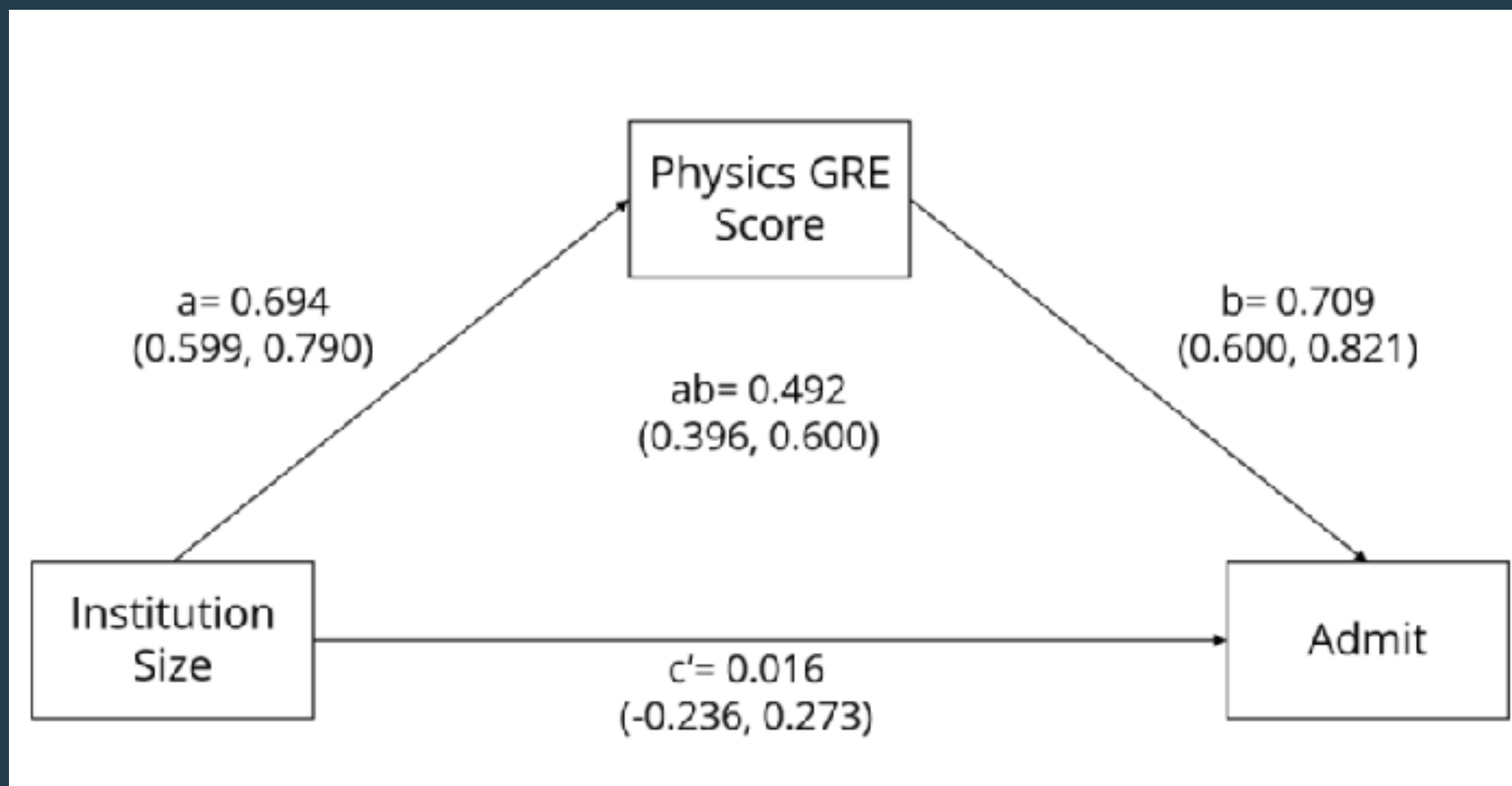
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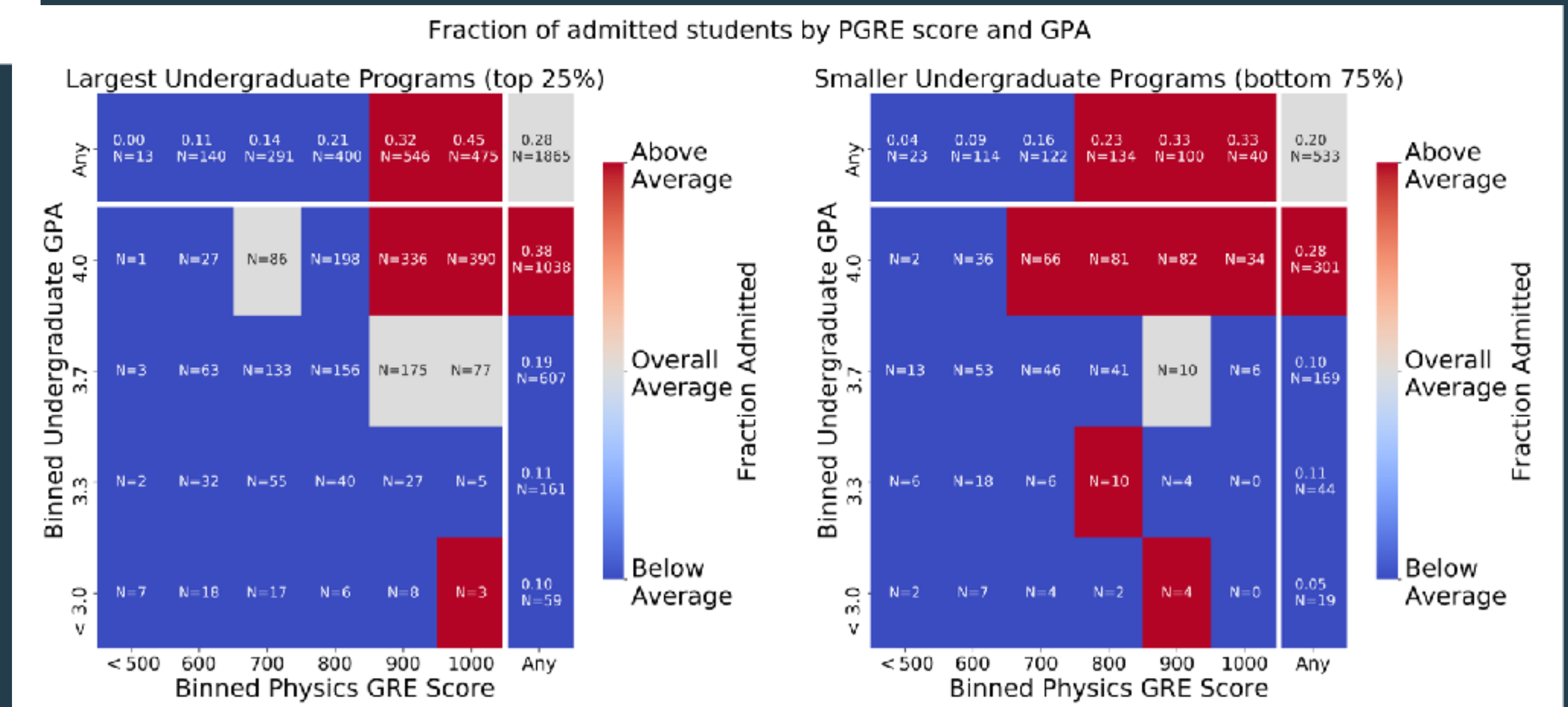
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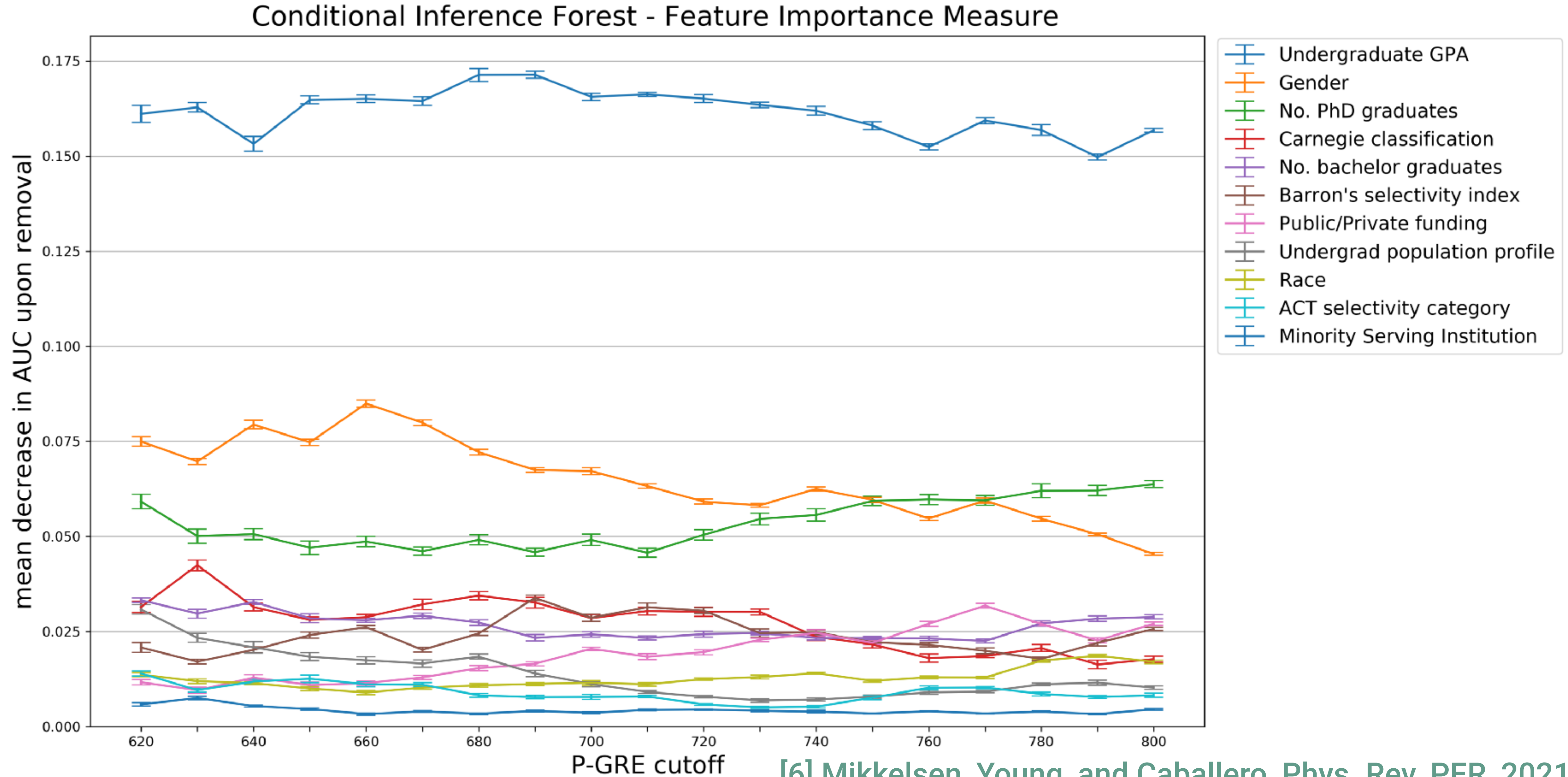


“Physics GRE scores explain some of the differences in admission probability based on the applicant’s undergraduate institution.” [5]



[4] <https://www.ets.org/gre/subject/about>
[5] Young & Caballero, Phys. Rev. PER, 2021

GRE cutoffs favor high GPAs, large schools, and men ^[6]



[6] Mikkelsen, Young, and Caballero, Phys. Rev. PER, 2021

Michigan State as a Case for Change

68 Faculty and Teaching Staff
~200 Graduate Students

Physics and Astronomy



NSCL/FRIB



Michigan State as a Case for Change

68 Faculty and Teaching Staff
~200 Graduate Students

~300 PhD Applicants/yr
~60 Admitted PhD Students/yr
~30 New PhD Students/yr

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MSU Physics and Astronomy is a large, high research activity program.

Physics and Astronomy



NSCL/FRIB



Admissions Process (Pre 2018)

- Applicants submitted transcripts, GRE scores, statements, letters
- Spreadsheets organized applicant materials and a large (10+) committee reviewed applicants
- Soft cut-offs for GRE were used

Michigan banned Affirmative Action programs by ballot initiative in 2006.

The University of Michigan, Michigan State University, Wayne State University, and any other public college or university, community college, or school district **shall not discriminate against, or grant preferential treatment to**, any individual or group on the basis of race, sex, color, ethnicity, or national origin in the operation of public employment, public education, or public contracting.

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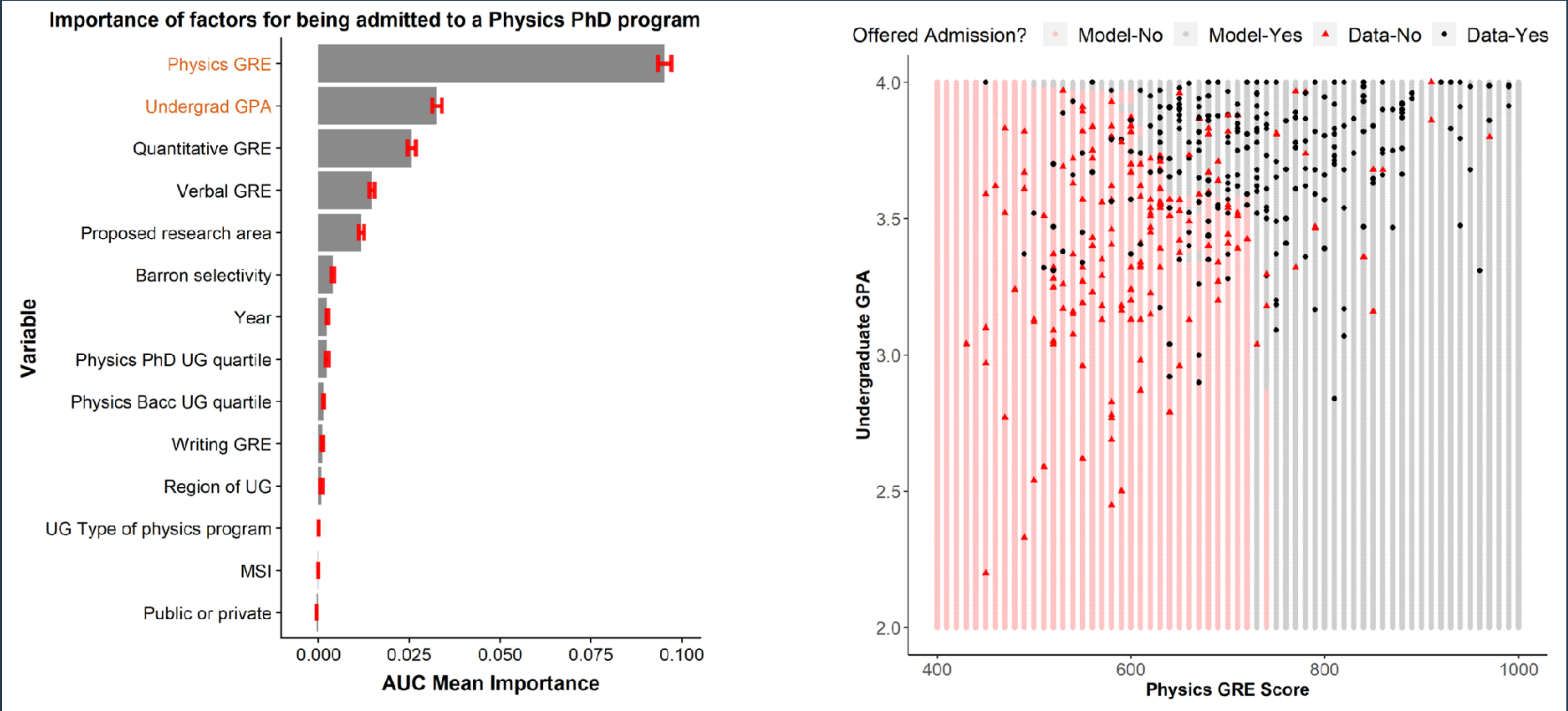
Admitted Student Population

	Women	Racial/Ethnic Minorities
Fall 2016 and before	Not Recorded	
Fall 2017	5%	13%

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Can predict ~80% of admitted students with PGRE and UGPA [7]



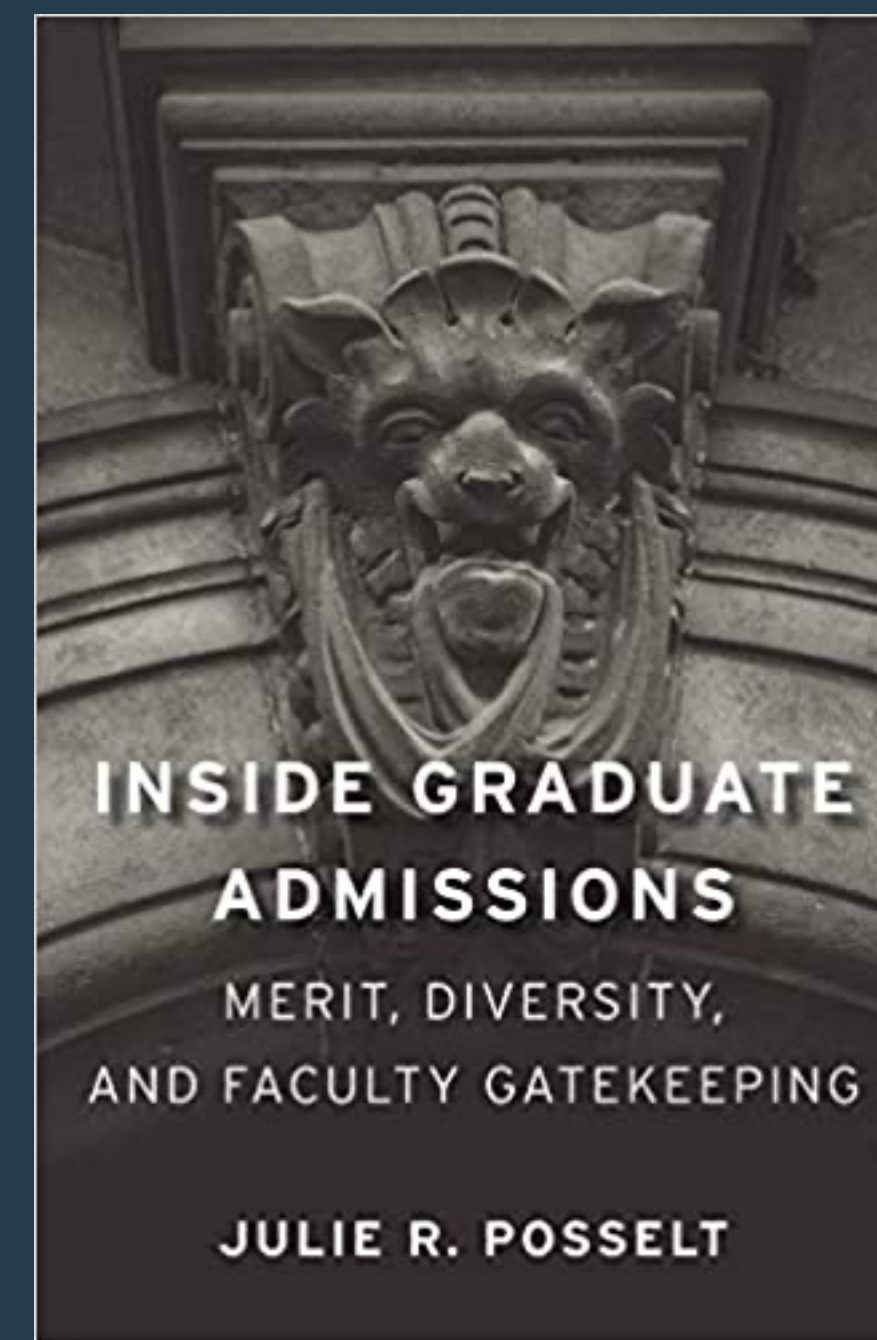
Changes to Process

[8] Posselt, Inside Graduate Admissions, Harvard University Press, 2016

[9] IGEN; pullias.usc.edu/igen/

Changes to Process

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 - Julie Posselt (USC) delivers Colloquium
 - With Casey Miller (RIT), JP runs workshop on Graduate Admissions Rubrics [8,9]
 - Graduate Program Committee develops initial rubric

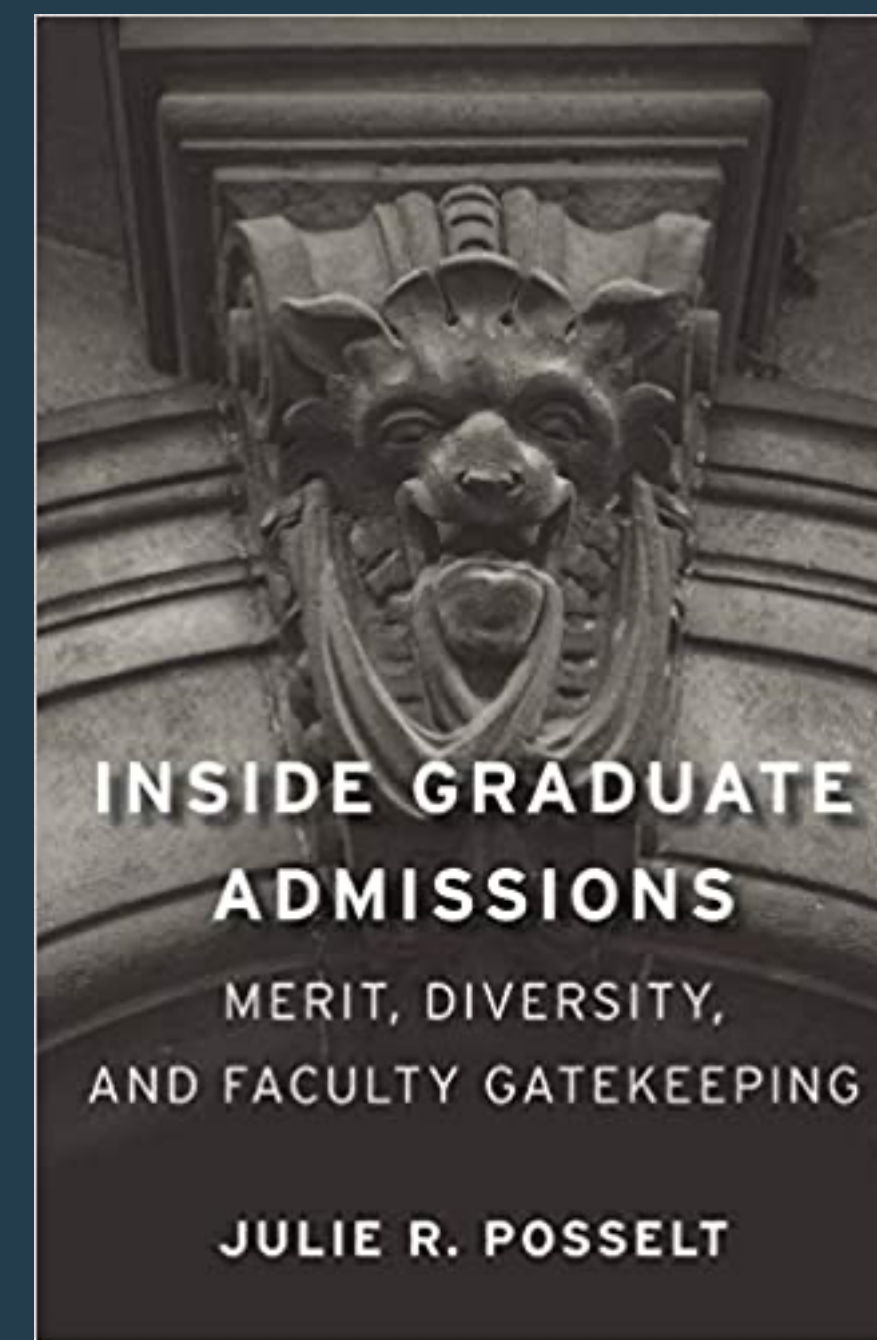


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 - Graduate Program Committee develops initial rubric
- Spring 2018
 - First class of students admitted using rubric



[8] Posselt, Inside Graduate Admissions, Harvard University Press, 2016

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item	subitem	High	Medium	Low
Academic Preparation (25%)	Physics Coursework	GPA $\geq$ 3.7 (A-) in all core subjects: CM1&2, EM1&2, QM1&2, SM1, if not taken 2nd semester courses yet are they planning on taking them?	GPA $\geq$ 3.3 (B+) in all core: CM1&2, EM1&2, QM1&2, SM1; OR GPA $\geq$ 3.7 (A-) in CM1, EM1, QM1, SM1 if no 2nd semester courses taken	GPA $\geq$ 3.7 (A-) in EM1 and CM1; GPA $\geq$ 3.0 (B) average in other advanced courses; any grades $<$ 2.7 (B-) without explanation
	Math Coursework	Real and Complex Analysis, Group Theory with GPA $\geq$ 3.5 (A) grades	DiffEq, Linear, and a Math Methods course, all with $\geq$ 3.5 (A) grades; or more than this with GPA $\geq$ 3.0 (B or A) grades	Bare bones math prep (e.g., up to DiffEq), or low grades regularly on math
	Other Coursework	Consistently 3.5 (A) grades	Consistently 3.0 (B) grades with nothing below a 2.5 (B-/C+)	One or more 2.5s (B-/C+)
	Academic honors and/or recognitions	multiple honors, e.g., Dept/University Honors; Phi Beta Kappa, etc	one academic award/recognition	No academic honors in college documented in the application
Research (25%)	variety/duration	two years in research	one year in research; only REUs	nothing more than coursework laboratories
	quality of work	multiple indications of excellence	clearly made significant contributions to the project	limited intellectual or technical contribution to projects; "button pusher"
	technical skills	a variety of experiment, theory, and/or computational skills	has developed only one class of skill (exp or theory or comp)	nothing more than coursework laboratories
	dispositions	clear commitment to and enthusiasm for research; AND understands what the process entails	clear commitment to and enthusiasm for research; OR understands what the process entails	not clear if they know what they are getting into with a PhD; seems lukewarm about research
Non-Cognitive Competencies (25%)	Achievement Orientation	Consistently strives to improve or meet a high standard of excellence in all areas	Has demonstrated a high standard of excellence in selected areas	No evidence of striving for excellence provided in application or student record
	Conscientiousness	Takes responsibility for personal performance, both the good and the bad; AND demonstrates efficiency and organization	Takes responsibility for personal performance, both the good and the bad; OR demonstrates efficiency and organization	No evidence of taking responsibility for performance AND minimal evidence of efficient, organized work
	Initiative	Consistently seeks out or acts on opportunities AND takes leadership	Consistently seeks out or acts on opportunities OR takes leadership	Has not sought out or taken advantage of opportunities AND does not have a record of leadership
	Perserverence	Application clearly describes successful coping with failures/ obstacles	Basic or perfunctory description of overcoming challenges	Application does not describe experience with failure/obstacles

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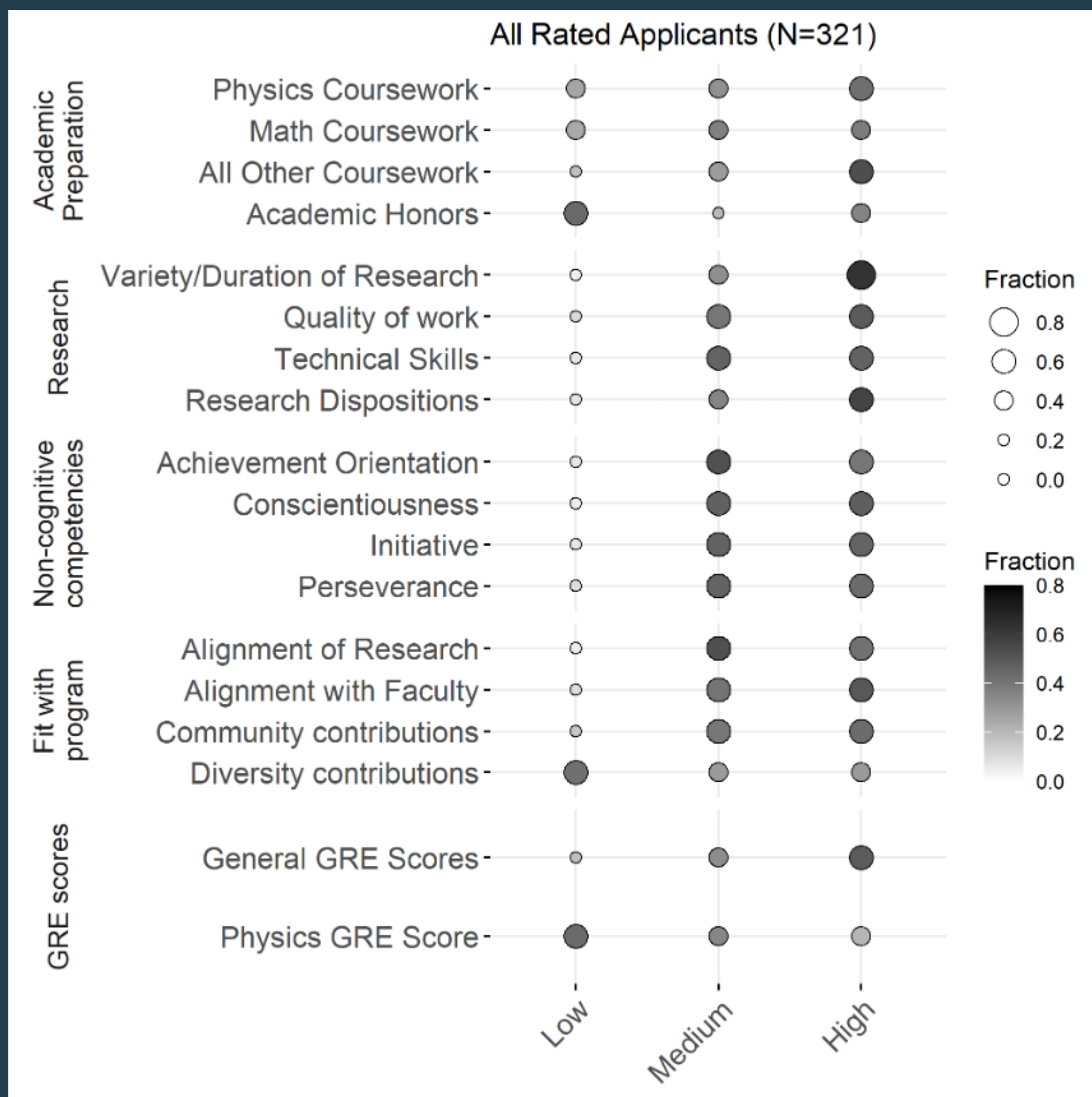
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	faculty	someone wants to hire as RA now and/or there is a clear fit with current faculty expertise	someone could supervise, but interests do not directly support a faculty member's work	faculty aligned with applicant's interests are not seeking students
	community	has clearly contributed positively to prior department/school culture, and would do the same for our program	some evidence of participating in service activities	applicant only discusses him/herself; no evidence of engagement in department or university activities
	diversity	applicant has been an active advocate for diversity in physics	belongs to an underrepresented identity group; first generation in college or low SES; and/or contributes to another type of diversity the department seeks	contributions to diversity are unclear from the application
GRE Scores (10%)	General GRE	Verbal(V) and Quantative(Q) scores $\geq 75\%$ (or 157 for V and 160 for Q) AND Analytical Writing (AW) ≥ 4.0	V & Q scores $\geq 75\%$ (or 157 for V and 160 for Q) BUT AW <4.0	V or Q score $<75\%$ and AW <4.0
	Physics GRE	$\geq 75\%$	50-74%	$<49\%$

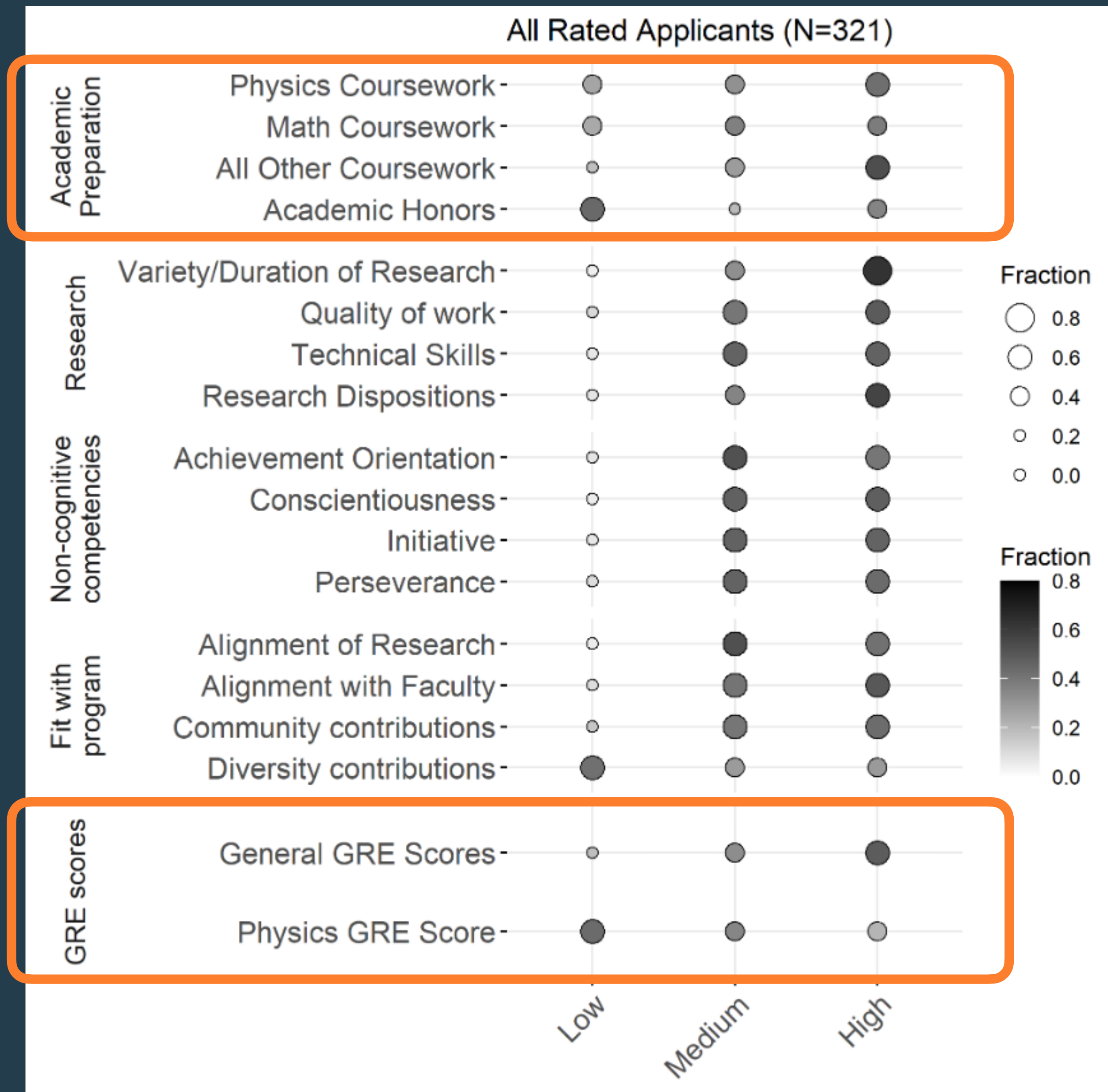
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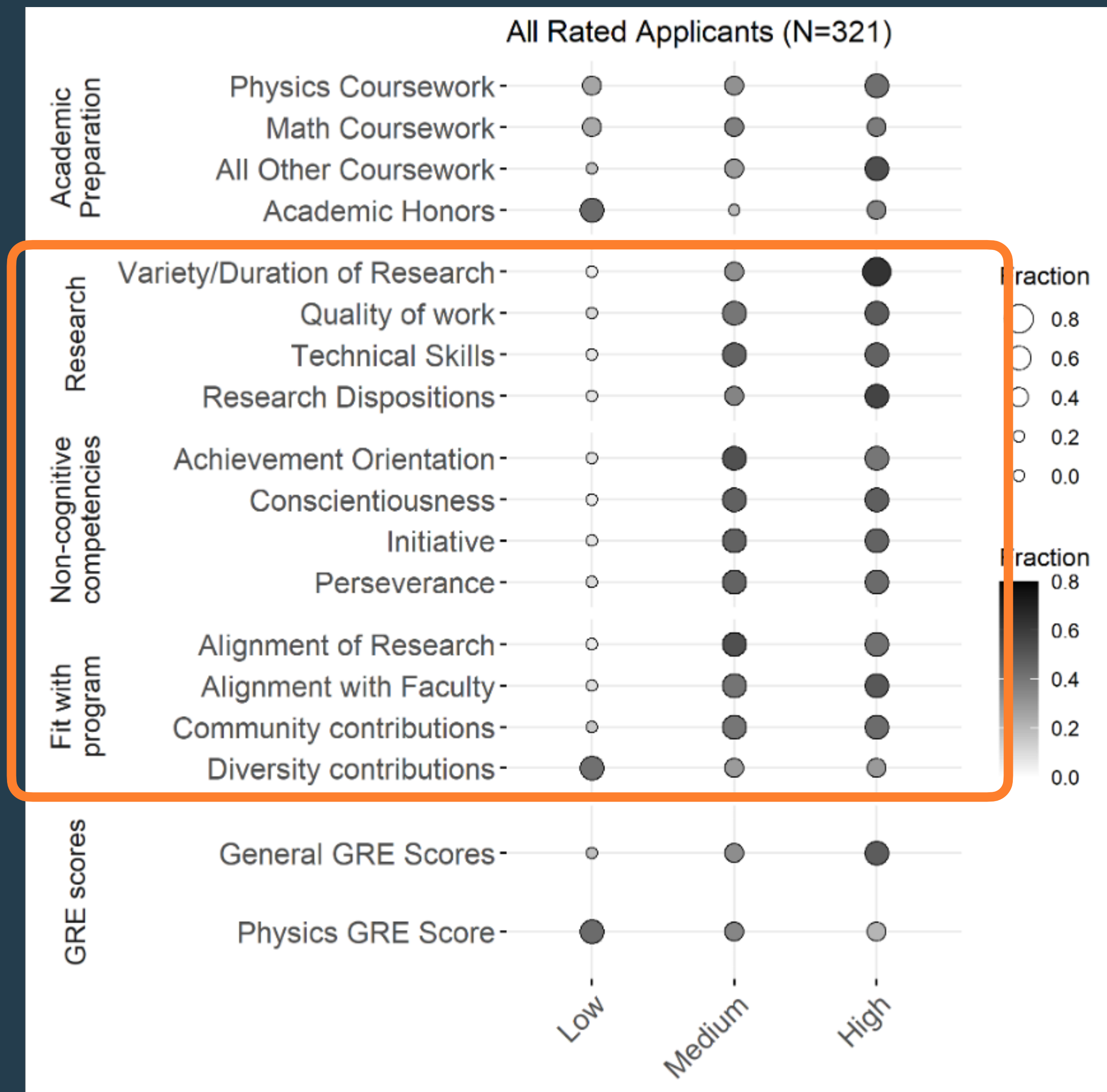
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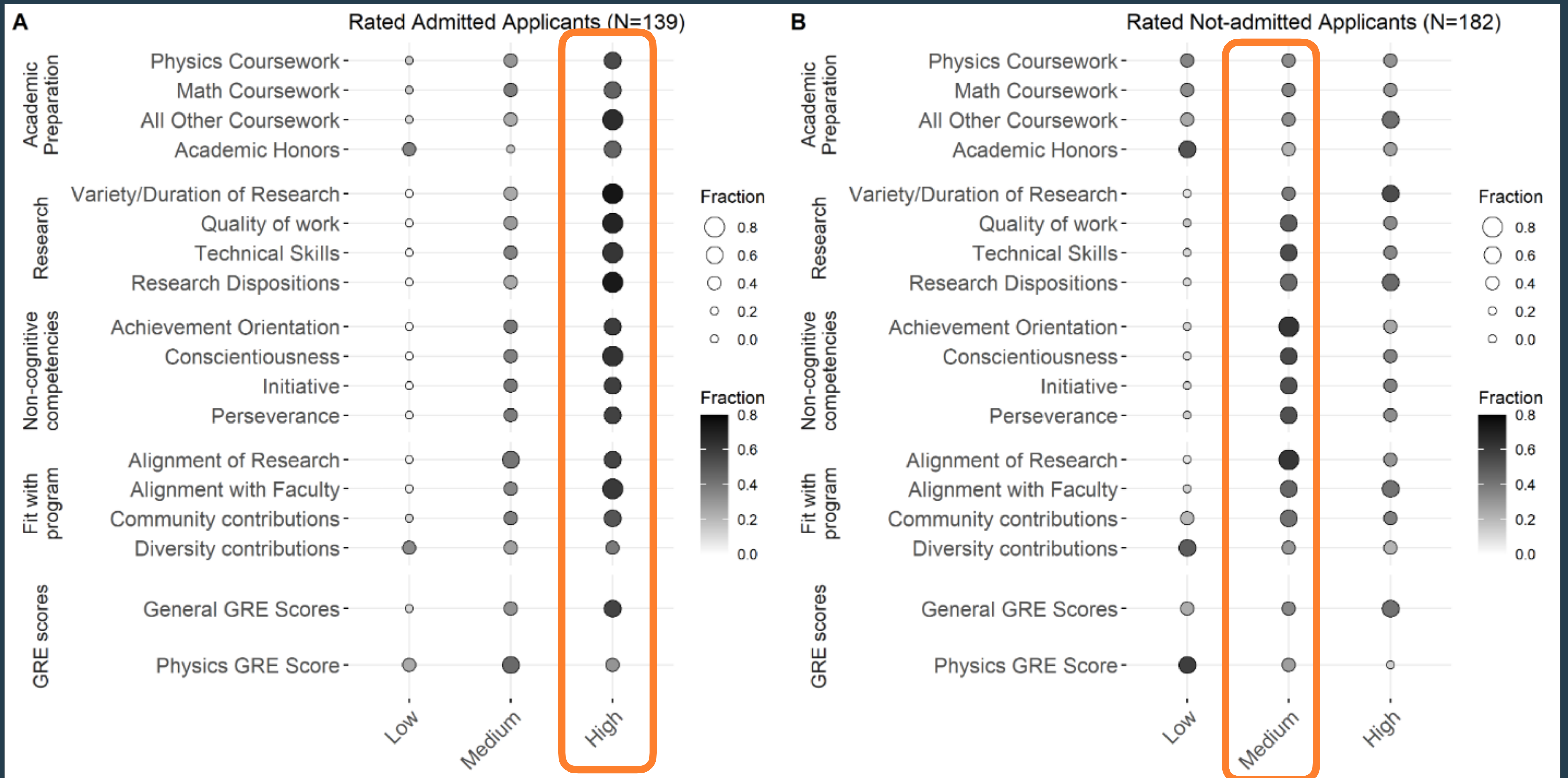
Some criteria have ratings across rubric levels



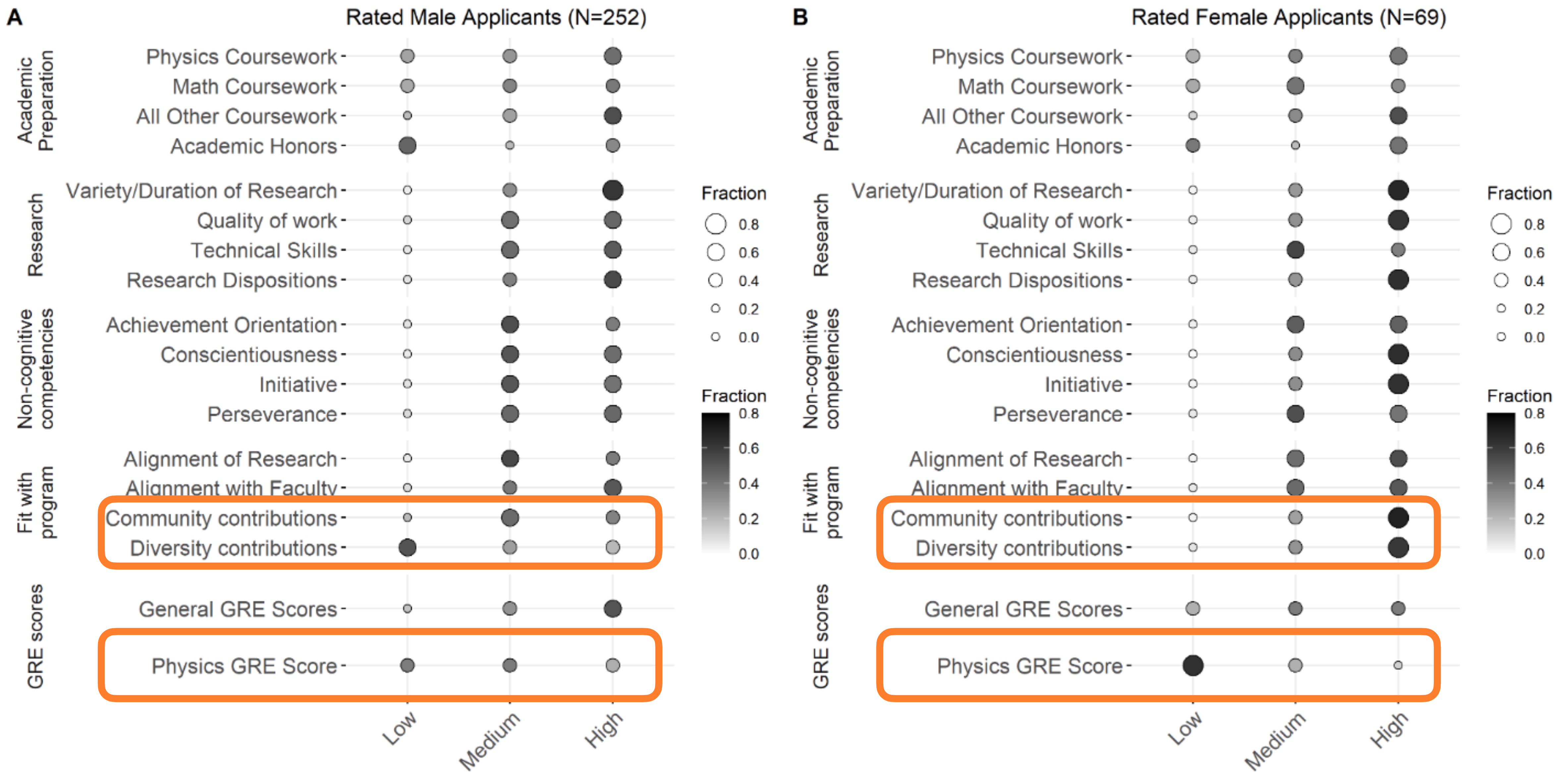
Some criteria have concentrated medium and high ratings



Admitted applicants score “high”; rejected applicants score “medium”



Only differences in ratings between male & female identified applicants
Physics GRE scores and service/diversity contributions.



Admissions Rubric (2018 onward)

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- Academic Preparation (25%)
 - coursework; grades; honors

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 - coursework; grades; honors
- Research (25%)
 - experience; quality of work; skills

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Reminder

Fall 2017	5%	13%
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Applicants

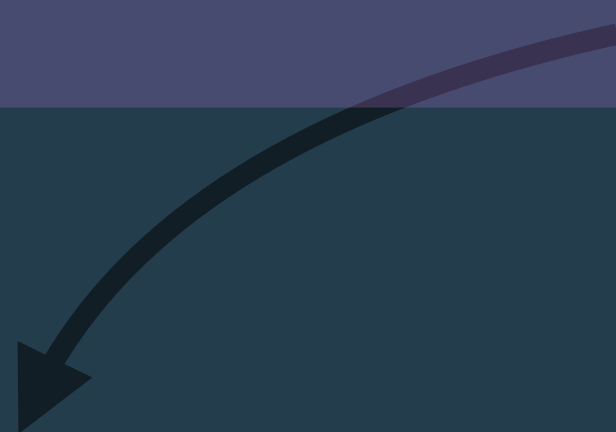
Recruiting

Focus for
Today

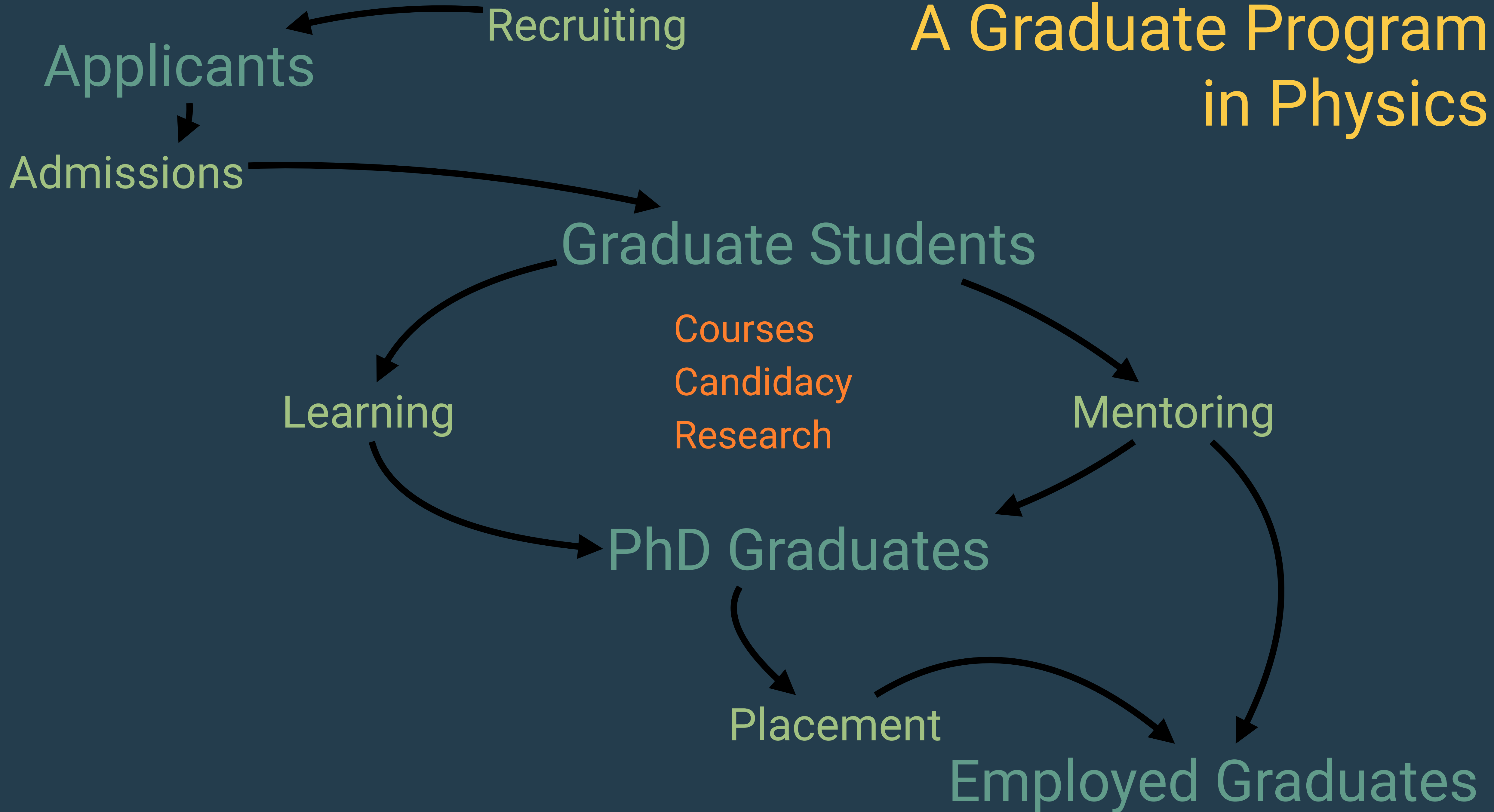
Admissions

Graduate Students

Holistic
Rubric-Based
Admissions



A Graduate Program in Physics



There's lots of work to do

- First year experience is being retooled; focus on transition to graduate school
- Pathways to PhD candidacy requires reflecting on goals and offering alternatives
- We must address systemic sexism[10] and racism throughout our program
- MSU joined the APS Inclusion, Diversity, and Equity Alliance (APS-IDEA)

[10] Aycock et al, PRPER 15, 010121 (2019)

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 - Reduced number of required courses
- Candidacy requirements deemphasize exams
 - Can earn good grades in courses or subject exams (per course choice)
- Shifting graduate instructional culture
 - Subject exam committees design and grade exams collaboratively
 - Grad course help desk for all first year courses
 - Grad course instructors use evidenced-supported group work activities

Take-Aways

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- Admissions rubrics codify what we value, and can help increase diversity [8,9]
- There's still lots of work to do (re: equity and inclusivity)

Thank you!

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