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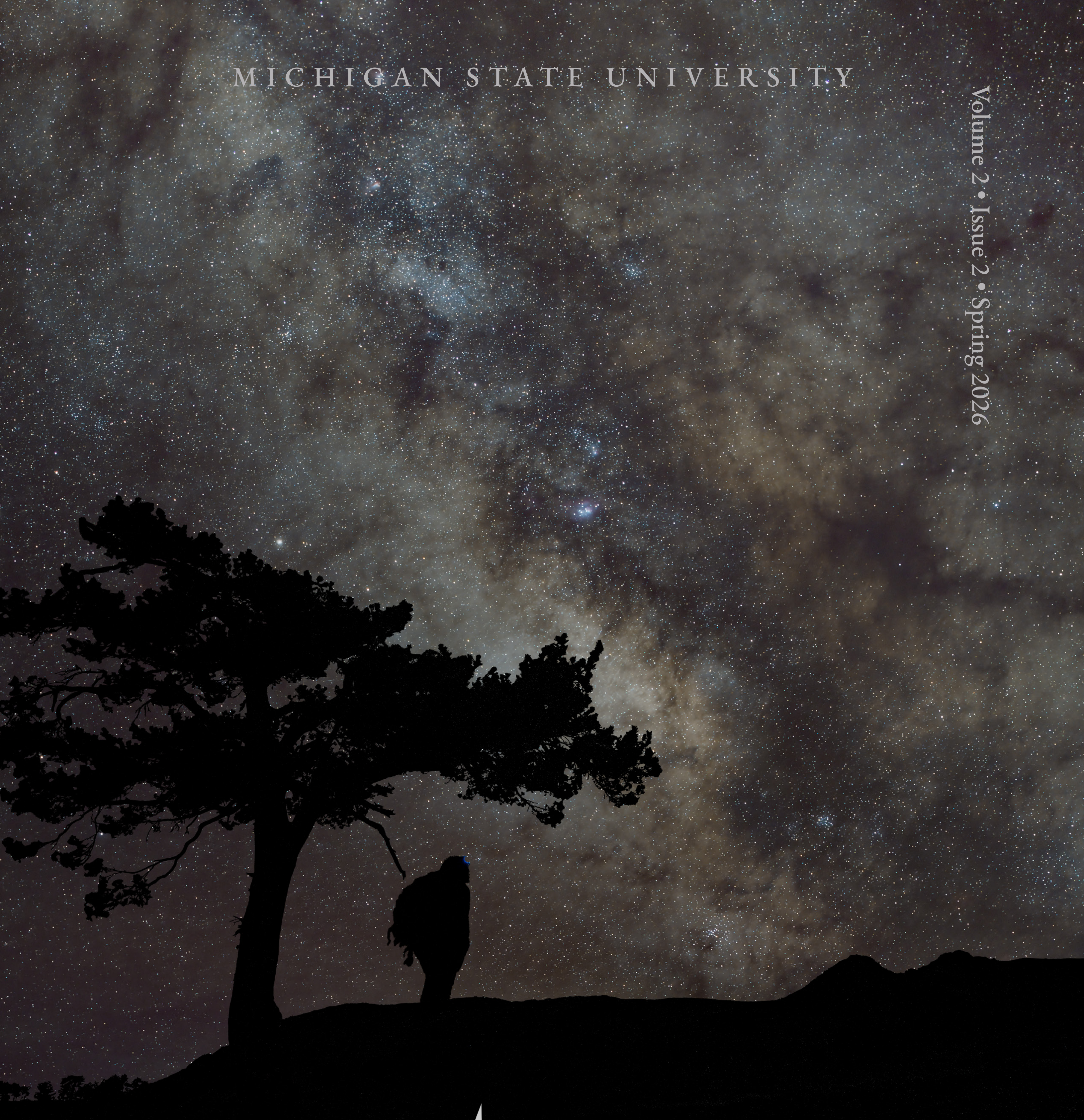

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From the Editors-in-Chief

To the readers of SPARC,

Noise abounds. The swirls and eddies of people, pixels, thoughts, things – there is a heavy onslaught of information at our unprovoked senses. What is loud feels important. What is visible feels complete. Can we discount the periphery because of our tunnel vision? Or stop trying to listen for what we cannot hear?

The surface of the field beneath our feet.
The familiar patterns of art and architecture.
The characters on a screen.
A diagnosis in a textbook.
A policy line buried in legislation.

We do, on occasion, attempt to extricate from this noise information that we deem useful. As a result, we discern. We engage. We see beyond structure and into meaning.

This is the spirit that is embodied at Michigan State University. Research begins in that moment of reconsideration. It is the decision to remain with a question long enough for it to coalesce into the semblance of an answer, to doubt what is already understood and to investigate what feels ordinary.

The work featured in this issue of SPARC reflects that impulse. Each paper makes an effort to look past the surface of what seems familiar and to engage with all questions that lie beneath it.

Be like Alice. Step through the looking glass.

Sincerely,

Jaini Gandhi

Jaini Gandhi and Nityaansh Parekh

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Zachary J. Flink

is a senior studying Turfgrass Management within the Crop and Soil Science major. For the past three years, he has worked as a student research assistant in Michigan State's World Cup Pitch Research Lab. His academic interests center on applying science to the systems and practices that produce safe, playable surfaces for golf, soccer, and other sports. He wrote this piece as an independent study evaluating the performance of four distinct field systems. He hopes this work brings greater visibility to the turfgrass industry and highlights the technical rigor required to design, maintain, and assess high-performing sports surfaces.

Evaluating the Surface Performance of Four Shallow Profile Turfgrass Scenarios

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Abstract

This case study evaluated four shallow profile turfgrass systems as distinct scenarios with respect to the Fédération Internationale de Football Association (FIFA) standards for football pitch performance. The systems consisted of sod on plastic (1.5-inch sand rootzone), over a nonwoven geotextile fabric and a modular subbase. Scenarios were defined as a rooted non-stabilized baseline (Reference), a non-stabilized turf simulating recent installation (Uprooted), a previously used rooted non-stabilized turf, and rooted turf reinforced with artificial fibers and backing (Stabilized). The objective was to determine whether systematic differences existed in volumetric water content (VWC), surface hardness, ball rebound, and rotational resistance across repeated weekly measurements. Treatment effects were detected for VWC, surface hardness, and ball rebound, whereas rotational resistance did not differ significantly. The Stabilized treatment maintained a lower VWC and greater surface hardness and ball rebound than the non-stabilized treatments. The Reference and Transplant treatments were generally similar, while the Uprooted displayed softer conditions and lower rebound. These findings indicate that shallow profile systems can differ in performance, but interpretation must account for additional systematic differences rather than attributing performance differences to a single factor. Future work should isolate reinforcement, rootzone composition, and rooting progession to determine the primary drivers of sustained playability in shallow profile turfgrass systems.

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1. Introduction

Turfgrass athletic fields are natural, regenerative surfaces expected to maintain safe and consistent performance across variable use and environmental conditions. Performance is often evaluated using field metrics that capture athlete-surface and ball-surface interactions, such as volumetric water content (VWC), surface hardness, ball rebound, and rotational resistance. VWC characterizes rootzone moisture status and is often associated with surface hardness and energy absorption (Caple et al., 2012; Dickson et al., 2018). Surface hardness represents impact response upon contact with a turfgrass system, with values influenced by both rootzone properties and turf condition (Twomey et al., 2012). Ball rebound quantifies vertical energy return during ball-surface impact and has been closely associated with surface hardness (Baker and Gibbs, 1989). Rotational resistance quantifies the torque required to rotate a studded interface as a traction metric linked to athlete stability during directional change (Rogers et al., 1998).

Under conventional methodologies, turfgrass sports fields rely on a sand-based rootzone (minimum 8 in) over a drainage profile (ASTM F3339-20). Sand-based systems are used because they support rapid drainage and are less prone to compaction than finer-textured soil mediums (Guisasola et al., 2010), providing consistent playing conditions under varying moisture content (Baker and Gibbs, 1989). While this conventional architecture is effective, it is generally associated with permanent construction and limited adaptability for rapid venue turnover.

Modern stadium operations increasingly require systems that can support multi-use schedules, including non-sporting events, short conversion windows, and repeated installation/removal cycles. In response, shallow profile systems have emerged using thinner sand layers over modular support/drainage elements rather than full-depth conventional architecture (James, 2011; Young et al., 2022). The shallow profile system utilizes sod grown on plastic (commonly referred to as sod on plastic), a propagation method in which turfgrass is seeded into a thin soil or sand medium placed over an impermeable barrier, such as a plastic. When the roots contact the physical barrier, growth continues laterally rather than downward, intertwining to form a contingent turfgrass stand that can be harvested in a shorter time frame than conventional propagation methods (Decker, 2002).

A variation of the shallow profile system is a stabilized carpet mat, in which natural turfgrass is grown into a reinforced backing and a synthetic fiber matrix that accounts for ~5% of the total turf coverage. Prior work on reinforced turfgrass systems indicates that the inclusion of synthetic materials can modify surface hardness, VWC, and traction responses (McNitt and Landschoot, 2003).

Within that context, this case study evaluated four shallow profile systems as distinct scenarios: a rooted reference, an uprooted/reinstalled disturbance, a previously used re-rooted transplant, and a stabilized carpet-mat system (Table 1). The objective was to evaluate systematic differences in performance across VWC, surface hardness, ball rebound, and rotational resistance.

2. Materials and Methods

2.1. Site Description and Experimental Design

The study was conducted at the Michigan State University (MSU) Hancock Turfgrass Research Center (HTRC) in East Lansing, Michigan. Data was collected weekly from October 20th to November 17th to evaluate the surface performance of four shallow profile turfgrass systems.

All treatments were established as sod on plastic over a 1.5-inch sand rootzone by Green Valley Turf Company (GVT) in Colorado, harvested from the plastic bilayer, and installed at the Hancock Turfgrass Research Center (HTRC) over a 6.0 mm nonwoven geotextile bilayer above an 85 mm modular sub-base system (Figure 1). The experiment was arranged as a randomized complete block design (RCBD), with three replications per treatment (12 total plots). Individual plots measured 2 ft x 3.5 ft. The treatments are defined in Table 1.

Figure 1. Shallow Profile Construction.

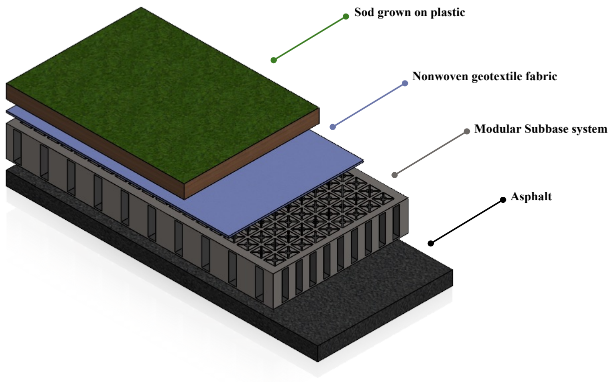

Figure 1. Original diagram prepared by Jacob M. Havican, Michigan State University, using SOLIDWORKS.

2.2. Management

To minimize nontreatment variability, all plots were managed uniformly throughout the study period, unless specified by the treatment description. Soil volumetric water content remained greater than 25% during the study period. No irrigation was administered due to rain events during the study period.

Table 1. Treatment Definitions

Treatment	Turf Species (seeded as)	Establishment Date	Age	Installation Timeline	Functional Definition
Reference	Poa pratensis	July 2023	~ 2.3 years	Installed July 2024 at the HTRC.	Baseline shallow profile system: turf remained rooted into the textile layer over the porous subbase at testing.
Uprooted	Poa pratensis	July 2023	~ 2.3 years	Initially installed July 2024, then lifted and reinstalled 24 h before each measurement date.	Disturbance treatment; representing interface discontinuity between newly installed turf and textile layer above the porous subbase at testing.
Transplant	Poa pratensis	December 2022	~ 2.9 years	Initially installed June 2024 at AT&T Stadium returned to GVT, and reinstalled September 2024 at the HTRC.	Relocated, previously used sod, turf remained rooted into the textile layer over porous subbase at testing.
Stabilized	84% *Poa pratensis*, 16% *Lolium perenne*	April 2024	~ 1.6 years	Installed September 2024 at the HTRC.	Stabilized carpet-mat sod (5% polypropylene (PP) fiber matrix, 95% natural turfgrass and a PP backing); turf remained rooted into textile layer over porous subbase at testing.

Table 1. Poa pratensis = Kentucky bluegrass, Lolium perenne = Perennial ryegrass, HTRC= Hancock Turfgrass Research Center, GVT= Green Valley Turf Company, AT&T Stadium= Stadium in Dallas, Texas.

2.3. Laboratory Characterization

2.3.1. Organic Matter

Three soil cores (1.5 in diameter x 1.5 in depth) were collected from each plot, and composited to form one analytical sample per plot. Organic matter was determined by loss on ignition (LOI). Composite samples were placed in a crucible, oven-dried at 105° C to a constant mass (48 h), cooled to room temperature, and weighed to obtain dry mass. Dried samples were then combusted at 360° C for 6 hours, cooled to room temperature, and reweighed to obtain the post-combustion mass.

Organic matter (OM %) is calculated as:

Equation 1. Organic Matter %

$$\boxed{OM\,\% = \left(\frac{W_{105}-W_{360}}{W_{105}}\right) \times 100}$$

Where W_{105} is the oven-dried mass (g), and W_{360} is the post combustion mass.

2.3.2. Particle Size Analysis

For particle size distribution (PSD), three cores (1.5 in diameter x 1.5 in depth) were taken from each plot and combined to form one composite sample per plot. Composite samples were suspended in a hexametaphosphate solution to disperse particles and separate the inorganic and organic materials, and then dried prior to sieve analysis. PSD was determined by manual sieve analysis. Samples were separated through a nested U.S. standard sieve series: No. 10 (2.00 mm), No. 18 (1.00 mm), No. 35 (500 µm), No. 60 (250 µm), No. 100 (150 µm), and No. 270 (53 µm), with the pan representing materials less than 53 µm. The sieve stack was hand-shaken for 5 minutes across samples. The mass retained on each sieve was recorded and assigned to a United States Golf Association (USGA) rootzone particle size class (USGA Green Section Staff, 2018): fine gravel (2.0-3.4 mm), very coarse sand (1-2 mm), coarse sand (0.5-1 mm), medium sand (0.25-0.5 mm), fine sand (0.15-0.25 mm), very fine sand (0.05-0.15 mm), silt (0.002-0.05 mm), and clay. Plot-level fractions evaluated for compliance with USGA rootzone recommendations (USGA Green Section Staff, 2018) and ASTM (American Society for Testing and Materials) specifications for sports field rootzone mixes.

2.4. Field Performance Measurements

Performance metrics were measured weekly at each plot across five sampling events (T0-T4): volumetric water content (VWC) %, surface hardness (gmax), ball rebound (cm), and rotational resistance (peak shear strength N · m).

VWC was measured using a Field Scout TDR 350 (Dennis Spectrum Technologies) with 1.5-inch tines, recording five subsamples per plot. Surface hardness was measured using a 2.25 kg Clegg Impact Soil Tester. The device consists of a suspended compaction hammer dropped from a fixed height. Upon impact, a connected accelerometer records the peak output corresponding to surface hardness (Clegg, 1976). The consistent procedure was followed, with three subsamples per plot. Ball Rebound was measured using an electromagnetic fixture to drop a Fédération Internationale de Football Association (FIFA) World Cup football from a fixed height. With rebound height calculated as:

Equation 2. Ball Rebound Height

$$\boxed{\textit{Ball rebound (cm)} = 1.23 \times (T - 0.025)^2 \times 100}$$

Where T is the time interval between the first and second impacts following a 2 m drop.

Two readings were taken from each plot. Ball rebound was recorded at T0, T3, and T4. Before testing, the ball was inflated to 8.6 psi to achieve a predetermined rebound height of 1.3 m when dropped on asphalt.

Rotational resistance was measured using a Dennis Shear Strength tester, recording peak shear strength (N·m) applied by a studded disk (Canaway and Bell, 1986).

2.5. Statistical Analysis

All analyses were conducted at $\alpha = 0.05$ in R Studio. Repeated field metrics (VWC, surface hardness, ball rebound, rotational resistance) were analyzed using mixed-effects models. Pairwise mean separation for repeated metrics used Sidak-adjusted comparisons (Midway et al, 2020). Rootzone particle-size fractions and organic matter were analyzed using ANOVA with Tukey's HSD for mean separation (Midway et al, 2020). Means sharing a letter were not significantly different. Code is available from the author upon request.

3. Results

3.1. System Characterization: Rootzone Particle Size and Organic Matter.

Rootzone composition differed among treatments before field performance testing. Particle size distribution showed treatment effects for the very coarse sand and medium sand. ($p < 0.05$). Fine gravel, coarse sand, fine sand, very fine sand, and silt + clay fractions did not differ among treatments ($p > 0.05$). The Stabilized treatment's rootzone contained less very coarse sand (7.2%) and more medium sand (41.1%) than the Reference, Uprooted, and Transplant treatments (11.6-11.9% very coarse sand; 33.2-36.3% medium sand) (Table 2). Fine gravel, coarse sand, fine sand, very fine sand, and the silt + clay fractions showed no significant differences among treatments. Despite differences in fraction sizes, all respective root zones met USGA recommendations and ASTM specifications.

The Stabilized Treatment displayed a significantly lower soil organic matter content (4.6%) than the Reference, Uprooted, and Transplant treatments (7.0-7.6%) (Table 3). Soil organic matter content did not differ among the Reference, Uprooted, or Transplant treatments.

3.2. Volumetric Water Content

Treatment VWC declined from T0 to T3 and slightly increased from T3 to T4 (Figure 2). Week and treatment effects were significant ($p < 0.05$). The treatment ×

Table 2. Treatment Rootzone Particle-size Distribution

Treatment	F. Gravel	VCS	CS	Med	FS	VFS	<0.002 mm
			%Retained				
Reference	0.23	11.9 a	35.4	34.2 b	9.7	5.9	2.7
Uprooted	0.20	11.8 a	35.0	33.2 b	9.8	5.7	4.3
Transplant	0.03	11.6 a	36.0	36.3 b	8.5	4.7	3.0
Stabilized	0.10	7.2 b	30.4	41.1 a	11.5	6.0	3.7
p value (<0.05)	NS	**	NS	**	NS	NS	NS
USGA rec.	≤ 3	≤ 10			≤ 20	≤ 5	≤ 8
ASTM spec.	≤ 20	≤ 20	25–50	> 25	< 10	< 5	< 8

Table 2. USGA recommends that coarse sand % + medium sand % are ≥ 60. F. Gravel=fine gravel, VCS= very coarse sand, CS= coarse sand, Med= medium sand, FS= Fine sand, VFS= very fine sand, <0.002 mm= silt + clay fractions. Means with the same letter were not statistically significant, (Tukey's HSD, α =0.05). NS, p ≥ 0.05, * p < 0.05; ** p < 0.01; *** p < 0.001. NS indicates no statistical significance.

week interaction was not significant, indicating that treatments followed a similar dry-down pattern during the measurement period. Across weeks, the Stabilized treatment maintained a lower VWC % (35.1 b) than Transplant (38.6 a) and Reference (39.0 a) (Table 5).

Table 3. Treatment Soil Organic Matter Content

Treatment	Organic matter %
Reference	7.0 a
Uprooted	7.6 a
Transplant	7.3 a
Stabilized	4.6 b
p value (<0.05)	***

Table 3. Means with the same letter were not statistically significant, (Tukey's HSD, α =0.05). NS, p ≥ 0.05, * p < 0.05; ** p < 0.01; *** p < 0.001.

3.3. Surface Hardness

Surface hardness differed among treatments and across measurement weeks, with no treatment x week interaction (Table 4). Across all sampling periods, the Stabilized treatment (70.8 a) displayed a harder surface than the Reference (55.4 b), Transplant (51.8 bc), and Uprooted (48.8 c) treatments. The Stabilized treatment was the only treatment centered within the FIFA target band (70-85 gmax), whereas the non-stabilized treatments remained below that range across sampling dates (Figure 3).

3.4. Ball Rebound

Ball rebound differed by treatment and by week, while the treatment × week interaction was not significant (Table 4). Mean separation indicated that Stabilized had the highest ball rebound (80.1 a), Transplant (69.0 b), and Reference (67.6 b) did not differ significantly. The Uprooted treatment displayed the lowest ball rebound (58.4 c).

3.5. Rotational Resistance

Rotational resistance did not differ by treatment but did differ by week; the treatment × week interaction was not significant (Table 4). Treatment means were tightly grouped (19.3-19.8 N·m) (Table 5), indicating no evidence of treatment-level separation in rotational resistance across the study period.

Figure 2. System Volumetric Water Content

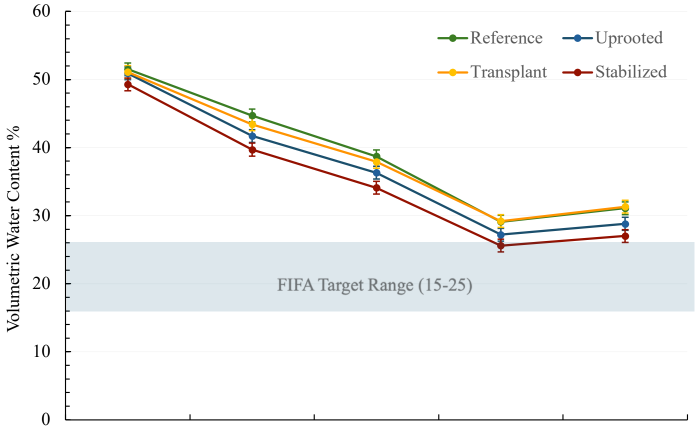

Figure 2. Estimated marginal means SE of volumetric water content %. The shaded band denotes target volumetric water content ranges specified by FIFA (15-25%).

Figure 3. Surface Hardness Across Measurement Periods

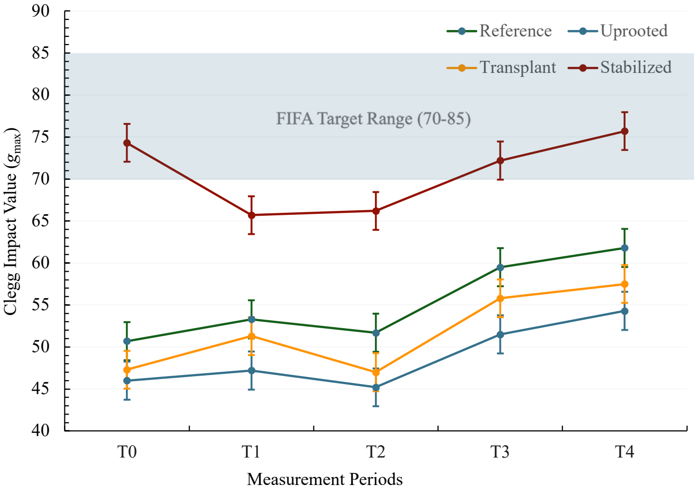

Figure 3. Estimated marginal means SE of surface hardness (gmax). The shaded band denotes target ranges specified by FIFA (70-85).

4. Discussion

The baseline characterization showed that the non-stabilized systems (Reference, Uprooted, and Transplant) were compositionally similar; in contrast, Stabilized treatment differed in species composition, organic matter, particle-size distribution, and reinforcement architecture. Accordingly, treatment differences involving the Stabilized treatment are interpreted as integrated system effects, rather than as an independent reinforcement-only response.

Figure 4. Ball Rebound by Treatment (pooled across T0, T3, and T4)

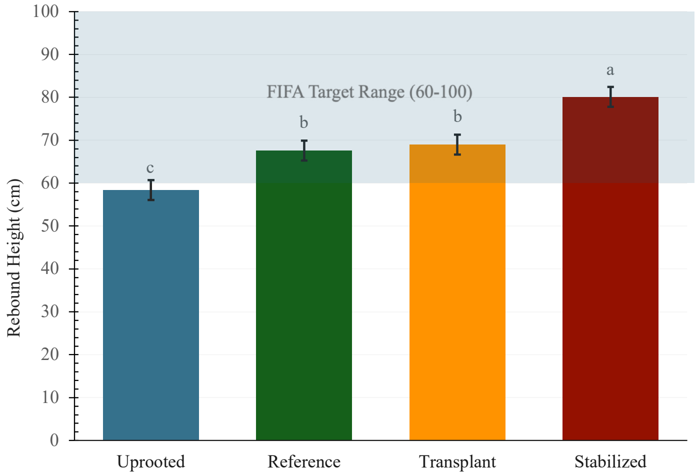

Figure 4. Estimated marginal means for ball rebound height (pooled across T0, T3, T4). Different letters indicate significant differences (Sidak-adjusted pairwise comparisons). The shaded band denotes ball target ranges specified by FIFA (60-100 cm).

Treatment effects were detected for VWC, surface hardness, and ball rebound, whereas rotational resistance did not differ among treatments. The lack of treatment separation for rotational resistance indicates that traction responses were more sensitive to week-to-week differences than vertical impact and moisture characteristics.

All treatments exceeded the FIFA target VWC range (15–25%; observed means: 35.1–39.0%). Only the Stabilized treatment met the FIFA hardness target (70–85 gmax), while the non-stabilized treatments remained below target (48.8–55.4 gmax).

Within the non-stabilized systems, Reference and Transplant performed similarly across measured playability metrics, suggesting that previously used sod can return to a comparable functional state after reinstallation and when rooting continuity is restored. In contrast, the Uprooted treatment produced a softer surface and lower ball rebound than the rooted non-stabilized treatments, consistent with the interface disruption created by repeated lifting and reinstallation.

The Stabilized treatment produced higher surface

Table 4. Mixed model ANOVA summary for repeated field performance metrics

	Volumetric Water Content (%)	Surface Hardness (g_{max})	Ball Rebound (cm)	Rotational Resistance (N.m)
Treatment	9.558*	99.436*	30.826***	0.0509 NS
Week	654.739*	14.294*	36.734***	6.200*
Treatment x Week	0.614 NS	1.112 NS	1.643 NS	0.495 NS

Table 4. Values are F-ratios from repeated-measures mixed models. Fixed effects: treatment, week, and treatment × week. Random effects: replication and subject (rep × treatment). NS, p ^{3} 0.05, * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

Table 5. Treatment Means and Mean Separation for Repeated Performance Metrics

Stabilized maintained the lowest VWC and highest surface hardness and ball rebound among treatments, while rotational resistance did not separate treatments.

	Volumetric Water Content %	Surface Hardness (g_{max})	Ball Rebound (cm)*	Rotational Resistance (N · m)
Reference	39.0 a	55.4 b	67.6 b	19.8 a
Uprooted	37.0 ab	48.8 c	58.4 c	19.5 a
Transplant	38.6 a	51.8 bc	69.0 b	19.7 a
Stabilized	35.1 b	70.8 a	80.1 a	19.3 a

Table 5. Estimated marginal means for Volumetric Water Content %, Surface Hardness values (g_{max}), Ball Rebound (cm), and Rotational Resistance (N · m) across collection dates. *Ball Rebound recorded on T0, T3, T4. Different letters indicate significant differences (Sidak-adjusted pairwise comparisons). Means sharing a letter are not statistically significant at a=0.05.

hardness, higher ball rebound than the non-stabilized treatments, and lower VWC. The literature on reinforcing inclusions has reported reduced soil water content and greater surface hardness relative to unamended systems (McNitt and Landschoot, 2003), findings that align with the lower VWC and higher gmax values observed for the Stabilized treatment. The accumulation of organic matter and thatch has been shown to reduce infiltration rates and alter water distribution in turf systems (Taylor and Blake, 1982), indicating that organic matter could plausibly contribute to the observed moisture separation. Unfortunately, the case study's design did not isolate individual factors; therefore, attributing performance outcomes to a single component would be inappropriate.

5. Conclusion

This case study demonstrated that shallow profile turfgrass systems can exhibit performance variability under the same environmental conditions and testing period. Overall, the evaluated systems did not meet FIFA moisture targets (VWC 35.1–39.0% vs. 15–25%), and only the Stabilized scenario met FIFA hardness standards (70.8 gmax). However, interpretations must be made with cognizance of differences in biological age, turfgrass species, rootzone composition, reinforcement architecture, and the aforementioned water content. The distinct characteristics of the Stabilized treatment indicate that further investigation into the effects of reinforced turfgrass is warranted using comparable treatments. The non-stabilized treatments appeared most comparable in baseline composition and performance response. The Reference and Transplant treatments showed similar performance, suggesting the practical feasibility of sod reuse given adequate rooting upon reinstallation. In contrast, the Uprooted treatment consistently showed reduced surface firmness and rebound, indicating that interface disruption can measurably degrade performance. These findings support future work to define the rooting progression after installation and its relationship to sustained performance in shallow profile turfgrass systems.

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Abby Yheaulon

is a senior Apparel and Textile Design major at Michigan State University, graduating in Fall 2026. Their work sits at the intersection of sustainability, identity, and visual storytelling, with interests spanning material experimentation, styling, editorial writing, and wearable art. They were inspired to write this piece by the tension between self-expression and consumption, especially in the "getting ready" rituals that shape how people see themselves. Through clear patterns and lived detail, they explore how insecurity becomes visible and socially communicated. They hope readers leave with more self-awareness and practical permission to choose intention over impulse.

Surface Without System: Chinoiserie and the Comfort of Seeing Without Knowing

Abby Yheaulon[1]

1. Department of Art, Art History, and Design, Michigan State University, East Lansing, MI, United States

Abstract

Chinoiserie is examined as an early instance of aesthetic appropriation in which visual surface is privileged over cultural system. Emerging in Europe during the seventeenth and eighteenth centuries, chinoiserie transformed Chinese culture into a decorative language detached from the material processes, philosophical frameworks, and relational knowledge that produced it. Rather than treating chinoiserie as a historical anomaly, the author argues that it reveals a durable logic of representation: one that generates pleasure and emotional intimacy while remaining structurally distant from meaning, labor, and relation.

Drawing on the relational epistemology articulated in the poetry of Antônio Bispo dos Santos, alongside postcolonial and psychological theory, the author reframes appropriation as not only an ethical or political issue but an emotional and cognitive one. The privileging of appearance over formation is traced from decorative arts to contemporary fashion, artificial intelligence, and identity construction, where recognizability increasingly substitutes for process and becoming. By situating chinoiserie within a broader continuum of image culture, the essay argues that surface-oriented modes of seeing risk eroding our capacity to engage with the slow, unfinished systems through which culture, selfhood, and meaning are formed.

The appeal of chinoiserie is immediate and quiet. Pagodas repeat across wallpaper in careful rhythm. Birds hover in suspended gardens. Figures drift through landscapes unanchored to season or place. Everything appears balanced, ornamental, complete. The scenes promise refinement without friction and difference without demand. They offer not China, but an idea of China. One that is legible, charming, and safely distant.

This distance is not accidental. Chinoiserie, which flourished in Europe from the late seventeenth through the eighteenth century, did not emerge from sustained cultural exchange but from separation (Encyclopaedia Britannica, 2026a; Encyclopaedia Britannica, 2026b). Objects arrived before understanding. Porcelain, lacquer, silk, and tea crossed oceans without the systems of knowledge that produced them (Encyclopaedia Britannica, 2026b). In the absence of those systems, Europe filled the gap with ornament. What chinoiserie establishes is a visual logic that privileges surface over system: a way of seeing that generates pleasure and a sense of intimacy while remaining detached from process, relation, and meaning.

This logic is not historical residue. It structures contemporary visual culture.

Knowing Through Relation, Not Representation

In a poem by Antônio Bispo dos Santos, knowledge is acquired not through observation but through contact (Bispo dos Santos, 2023). One walks along cliffs and acquires steadiness. One swims against tides and acquires their force. One forms in mudflats and becomes rock. Meaning emerges through resistance, repetition, and dwelling, through proximity sustained over time.

Here, culture is not something one looks at from the outside. It is something that shapes and is shaped through participation. Knowledge is relational, ecological, and ancestral. It accumulates slowly, through shared conditions rather than extraction (Bispo dos Santos, 2023).

Chinoiserie operates in direct opposition to this epistemology. Where Bispo describes becoming through contact, chinoiserie substitutes resemblance for relation. Culture is rendered visible without being entered. Form appears without formation. The image arrives alone.

Surface and System

To understand what chinoiserie does, the distinction between surface and system must be made explicit.

Surface is visual. It is a pattern, motif, ornament, style. It is immediately legible and easily reproduced. Surface circulates quickly.

System is slow. It consists of material processes, labor, philosophy, cosmology, and ancestral transmission. Systems require time, immersion, and risk. They do not travel easily.

Chinoiserie collapses this distinction by elevating surface while severing it from system (Said, 1978). Chinese culture is transformed into an atmosphere rather than understood as a living network of relations. What remains is not simple misunderstanding, but disembedded seeing. A mode of perception that produces pleasure without obligation.

When Distance Becomes Decorative

The artists and artisans responsible for chinoiserie rarely encountered China directly (Encyclopaedia Britannica, 2026a). Instead, they encountered objects and images. Porcelain fragments, lacquered surfaces, lengths of silk. Prints circulated widely, translating partial knowledge into repeatable scenes. Pagodas floated free of geography. Figures existed without social context. Landscapes were composed for replication rather than inhabitation.

Furniture makers adapted these motifs onto unmistakably European forms. Porcelain manufactories replicated blue-and-white decoration without reproducing the material systems that made Chinese ceramics possible (Encyclopaedia Britannica, 2026a). Accuracy mattered less than coherence. Meaning yielded to pattern.

Distance was not a limitation to be overcome. It was the condition that made chinoiserie viable.

Ornament Without Obligation

What chinoiserie offers is not knowledge, but feeling. It produces calm, refinement, and the impression of cultural openness without the burden of engagement. Difference becomes pleasurable rather than demanding, something to be enjoyed aesthetically without requiring responsibility (Hooks, 1992).

Chinoiserie invites intimacy while maintaining structural distance. One can admire without understanding, desire without accountability. Culture becomes mood, an environment to pass through rather than a system to inhabit.

This is emotional intimacy without epistemic responsibility.

When Process Disappears

What vanishes under this logic is process. Chinese porcelain, silk, and lacquer are not merely aesthetic achievements. They are systems of knowledge refined across generations. They require time, discipline, and philosophical grounding (Encyclopaedia Britannica, 2026a; Encyclopaedia Britannica, 2026b). Chinoiserie reproduces appearance while obscuring how things are made, by whom, and under what conditions (Said, 1978).

Repetition replaces lineage. Ornament stands in for ritual. The object remains, but the world that produced it does not.

This separation of surface from process prefigures a broader modern condition. Value is assigned to outcome while the labor of becoming disappears from view (Fromm, 1976; Benjamin, 1969).

From Culture to Self: Appearance as Identity

This logic does not remain confined to objects. It extends inward, shaping how identity itself is understood. Increasingly, being something is treated as a matter of appearance rather than formation. The look of intelligence substitutes for study. The performance of confidence replaces its construction. Aspiration is mistaken for arrival.

Erich Fromm described this shift as a movement from being to having. A mode of selfhood in which identity is accumulated through signs and declarations rather than formed through lived experience (Fromm, 1976). In this framework, recognizability matters more than integration. Presentation replaces infrastructure.

Donald Winnicott warned that when identity becomes primarily performative, it risks collapsing into what he called a false self. Socially legible and often admired, yet disconnected from the slower, riskier processes through which a self is actually formed (Winnicott, 1971). The self appears complete while remaining structurally unfinished.

This is surface logic applied to being.

Fast Fashion, AI, and the Acceleration of Arrival

In contemporary fashion, this logic returns not as décor but as print. “Asian-inspired” motifs circulate widely. Dragons stretched across synthetic satin. Cranes frozen mid-flight. Calligraphic gestures loosened into pattern. They are instantly recognizable and largely unmoored from language, ritual, or place. What remains is recognition without inheritance, style without lineage (Appadurai, 1990).

Produced far from their cultural origins and consumed at the pace of trend, these garments offer familiarity without relation. Culture becomes atmosphere, worn briefly, folded away, replaced. The image travels easily. The system does not follow (Appadurai, 1990).

The same acceleration appears in artificial intelligence. Emphasis is placed on finished output rather than the research, uncertainty, and relational thinking that once made such outcomes possible. Arrival is simulated without the journey. Process disappears behind polish. Once again, surface is mistaken for system.

A Note from the Studio

This logic is increasingly visible within art and fashion education itself. In studio culture, work is often evaluated by how convincingly it performs completion. Cohesion, finish, and immediate legibility take precedence over inquiry. Research recedes. Process is aestheticized or omitted. The question shifts from how did you get here to does it look resolved?

This preference for appearance over formation not only shapes objects. It shapes makers (Fromm, 1976; Winnicott, 1971).

What Remains at Stake

Bispo’s poem does not offer resolution. It offers orientation (Bispo dos Santos, 2023). Knowledge, it insists, is acquired through dwelling rather than browsing, through staying rather than sampling. Meaning accumulates where relation is sustained.

Chinoiserie demonstrates how easily images can travel farther than understanding. Its afterlife points to a deeper risk. As surface continues to replace system, we risk losing not only cultural knowledge, but our tolerance for the slow, unfinished nature of becoming itself.

The question is not whether beauty is permissible.

It is whether we are willing to remain with the processes that make beauty mean something.

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is a third year Arts and Humanities major, and she has a double minor in Education and Society, and Writing. Her research interests include disability studies and rhetoric. This piece was written as a part of a humanities course in the Residential College in the Arts and Humanities (RCAH), and the assignment asked students to historicize a certain type of representation through three different media examples across time. She wrote this piece to explore the representation of those with intellectual and developmental disabilities in film, and how these portrayals create a certain discourse involving sexuality and gender.

Representations of Intellectual and Cognitive Disabilities, Gender, and Sexuality in Film

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Abstract

The representation of intellectual and cognitive disability in film and television has increased quite a bit over the years, and with that increase, certain tropes have started to develop and become more normalized over time. This paper will look at specific tropes involving cognitive disability and sexuality through the representation of disabled characters and people in the 1939 film *Of Mice and Men*, the 1999 TV show *Freaks and Geeks*, and the 2024 reality show *Love on the Spectrum*. From the 1930s through present times, the trope of naivety for cognitively disabled people in romantic contexts has persisted. Furthermore, the trope of femininity for cognitively disabled men has created a dissonance between femininity and disability when projected onto women with cognitive disabilities. Overall, these tropes work to perpetuate a distance between intellectual disability and sexuality through the added factor of gender expression.

Background

Before diving into the particular tropes involved in these films and shows, it's important to understand the context behind each piece of media. To start, *Of Mice and Men* was originally published as a novel in 1937, and the story follows George and Lenny, two farm workers during the Great Depression. A couple of Lenny's main character traits are that he has an undiagnosed cognitive disability, that he's a very large and strong man, and that he enjoys nurturing small animals and petting smooth things, which is contradictory to his intimidating stature. They meet the owner's son, Curley, and his wife (who is unnamed throughout the book), and George warns Lenny to stay away from Curley's Wife because she's promiscuous and perceived to be a danger to Lenny. The scene analyzed in this text is Curley's wife's death scene, in which she offers for Lenny to touch her hair because he likes touching soft things, the moment escalates, and then he accidentally snaps her neck because he's unaware of his own strength.

Freaks and Geeks is a teenage drama that takes place in the 1990s, and it follows the story of a high schooler named Lindsay Weir as she struggles to fit in and find her place in school. The first episode features a character named Eli who has a cognitive disability, and Lindsay stands up for him when he's been rejected by two girls after asking them to the homecoming dance. Lindsay's way of standing up for Eli involves asking him to the homecoming dance in order to silence his bullies. The scene in which Lindsay asks Eli to the homecoming dance is the part of the show that this paper will dive into.

Lastly, *Love on the Spectrum* is a reality dating show that features people on the autism spectrum, and narrates their experiences with dating and relationships. The episode discussed in this paper highlights a woman named Dani and her experience with getting ready for a date. Dani wants to explore her own sexuality, but is unsure of her partner's beliefs and value systems regarding sex, and this conflict is shown through her getting ready process as the scene starts with her reading sexually explicit titles out loud from a book about sex and dating.

Each of these films or shows features a character with a cognitive disability and involves some expression of romance or sexuality. There are two problematic tropes that are developed and maintained through the representation of these characters including that of the "naive disabled person" in romance, and the "feminized disabled man". These two tropes perpetuate harmful narratives that put distance between disability and expressions of sexuality.

Trope of Naviety

The idea of naivety for disabled people in romantic contexts is implied through Curley's Wife's death scene in *Of Mice and Men*, through the way in which she is killed and the script choices leading up to that moment. For example, early on in the scene, Lenny is explaining that he likes the feeling of soft objects, and Curley's Wife chuckles and states "You're goofy. But you're kind of a nice fella. Just like a big baby," (Milestone, 1939). This shows that Curley's Wife sees Lenny as more of a child than an adult, which infantilizes Lenny's character, and implies that Curley's Wife has a stronger idea of the social context of the scene due to Lenny's childish additions to the conversation. Furthermore, the general context of the scene situates Curley's Wife as knowledgeable and promiscuous, and Lenny as naive and unaware of her intentions. Curley's Wife offers for Lenny to pet her soft hair, and while her intentions are somewhat ambiguous, Lenny seems to be unaware of that ambiguity, and doesn't see the gesture as potentially romantic. Curley's Wife's knowledge of the possible romantic undertones of the gesture and Lenny's lack of knowledge are then situated as dangerous for both of them as the scene with Lenny accidentally killing her. So not only is Lenny portrayed as childlike and naive within the context of romance, those traits turn out to be dangerous for him because his innocence contributes to the accidental murder of Curley's Wife.

On a similar note, the trope of the "naive disabled man" in romance is also perpetuated through the representation of disability in *Freaks and Geeks*. During the scene where Lindsay asks Eli to the homecoming dance, the prioritization of Lindsay's character instead of Eli positions Lindsay as a savior and Eli as naive or childlike. The start of the scene shows Eli getting rejected by two girls after asking them to the dance, but Lindsay witnesses the scene and when she starts walking over to him, the camera starts following her and the scene essentially shifts to Lindsay's point of view (Feig, 1999). This switch in point of view says a lot about which character's storyline is more important, and it shows that the viewer is supposed to sympathize with Lindsay's position as a savior and thus Eli's position as the person being saved. As the scene progresses, a couple of bullies knock Eli's books out of his hands and make fun of him after he was rejected by the two girls. Lindsay then stands up to the bullies and asks Eli to the dance as a method of defending him. After Eli excitedly says yes to Lindsay's offer, she half smiles at him, and then she breaks eye contact with him and her face flickers into a nervous expression that one could even describe as a grimace (Feig 1999). This further promotes the idea of naivety on Eli's part because it's clear in Lindsay's expression that she isn't enthusiastic about going to the dance with him, but he remains oblivious to her feelings. So not only are his actions naive at the start of the scene when he asks the girls to the dance and gets rejected, he's also naive to Lindsay's intentions of saviorism. While this naivety isn't necessarily portrayed as dangerous, the trait is still portrayed as unsafe when combined with disability due to the bullying that Eli is subjected to and his apparent need for Linsday to intervene. The trope of naivety implies that Eli is at his safest when Lindsay takes over the direction of the scene and asks him to the dance, thus deeming Eli incapable of having agency over his own romantic expressions.

Finally, the reality show *Love on the Spectrum* also perpetuates ideas of naivety and disability through the infantilization of disabled people in romantic and sexual contexts. To elaborate on this idea, the visuals shown paired with Dani's voiceover during the scene of Dani getting ready for a date create a separation between disability and sexuality through the infantilizing of Dani as a person. At the start of the scene, a voiceover of Dani reading chapter titles from a book about sex starts playing, and the audience sees several different visuals including a shot of Dani's bedroom, and the many stuffed animals placed on her bed. While the camera is fixed on the stuffed animals the audio includes two chapter titles read in Dani voice including "Striptease Fantasies" and "Tips and Tricks and Licks" (Holden, 2024). The childlike image of stuffed animals on her bed is juxtaposed with the sexually explicit titles that she's reading out loud, and this dissonance contributes to a feeling of discomfort for the viewer when disability and sexuality are put together in the scene. A bed without stuffed animals might invoke an understanding of maturity for Dani, but the image of the stuffed animals infantilizes her, and it makes the expression of her sexuality through the voiceover seem wrong or uncomfortable to the viewer. The image combined with the voiceover implies childlike or even infantile traits for Dani, and both of these traits should not be paired with sexuality which thus presents an idea of wrongness for her expression of sexuality. Although, this scene doesn't necessarily represent the combination of disability and sexuality as inherently dangerous, it does represent this combination as awkward or uncomfortable, and the viewer is likely meant to sympathize with those feelings of uncomfortability.

To summarize the trope of the "naive disabled person" in romance as represented through these 3 sources, it's important to note that the tropes had different implications for different periods of time. The original film for *Of Mice and Men* came out in 1939, and while this representation of disability as innocent was rather progressive for its time, it did create the notion that expressions of romance and sexuality should not be pursued by people with disabilities because there would be dangerous outcomes for everyone involved. This representation created its own Foucauldian "regime of truth" which persisted throughout time and can be seen through the representation of disability in *Freaks and Geeks* and *Love on the Spectrum* (Hall, 1997). *Freaks and Geeks* aired in 1999, and the representation of Eli as naive and innocent is reminiscent of the representation of Lenny in *Of Mice and Men*. The idea of disability and romance as dangerous is still prevalent through the representation of Eli, however the stakes are lowered from death and murder to bullying and ridicule. The stakes are then lowered to uncomfortability and awkwardness through the representation of Dani as childlike and naive in *Love on the Spectrum*.

While the combination of disability and romance is portrayed as less and less dangerous as time goes on, that idea of danger which originated from the *Of Mice and Men* 1930's still has an impact on media to this day. In Michel Foucault's *History of Sexuality* (1976), he explores the ways in which sexuality is constructed by society and that the repression of sexuality is an exercise of discursive power. This theory applies to the evolution of discourse surrounding disability and sexuality, because it outlines how this theme of repression is socially constructed and it becomes more widely accepted through consistent media representation and perpetuation. The representation of disabled people as naive or childlike in romantic contexts creates a specific narrative that determines disability as separate or distant from expressions of sexuality. This discourse of disability and sexuality is also circulated through the trope of the "feminized disabled man" which manifests itself in all three examples.

Feminization of Disabled Men Trope

Moving away from the ideas of naivety and danger, the trope of the "feminized disabled man" in romance pops up in *Of Mice and Men* through the conversation and death scene with Lenny and Curley's Wife . Lenny's character is essentially demasculinized based on the representation of his life goals and interests in the scene where he interacts with Curley's Wife and then accidentally kills her. At the beginning of the scene, Lenny and Curley's Wife both start describing some of their aspirations for the future, and Lenny explains that his ideal life involves raising rabbits on a farm with George. This aspiration for existing outside of the workforce nurturing other beings was likely seen as a feminine trait at the time, and Lenny's identity as a disabled person paired with this distinctly feminine life goal demasculinizes his character. He goes on to say "I just like to pet nice things. Smooth things," (Milestone, 1939), which shows that his goals include becoming a caregiver to animals and being able to pet them because he enjoys their smooth texture. Curley's Wife then agrees with him and states that she also likes smooth textures, which feminizes this trait on Lenny's part, and creates an association between femininity and disability for the viewer. Furthermore, because Lenny has been represented as both childlike and feminine, the viewer is meant to feel a sort of dissonance between both disability and sexuality, and femininity and sexuality. Again, this representation was likely very progressive for the time in which the movie was released, but it still created the trope of the "feminized disabled man" and this harmful stereotype about disability and femininity, and the relationship those identities have with expressions of sexuality. This trope was reproduced in many years to come, and it continued to contribute to the implied dissonance between disability and sexuality.

The representation of Eli in *Freaks and Geeks* does similar work to *Of Mice and Men*, as the typical gender roles of the time are flipped through the ways in which Lindsay and Eli are portrayed in their scene together. Towards the end of the scene, Lindsay asks Eli if he wants to go to the homecoming dance with her, and he responds with "Yes! Yes, I do. Yeah, please..." (Feig, 1999), and this makes it clear that Lindsay is standing up for Eli by publicly asking him to the dance, and that he's very grateful for her efforts. This episode was written in the 1990s, and the general norm for the time was that men courted women and that boys were supposed to ask girls out to high school dances. Although it's probable that some women were defying this standard by 1999, this show still exists in a time when the dominant narrative was that men courted women. This scene reverses typical gender roles for who is supposed to ask who to a high school dance because Lindsay asks Eli out, and he's supposed to be grateful and excited because of her courting efforts. However, this gender role reversal likely wouldn't have happened without the added factor of Eli's disability, because Lindsay wouldn't feel the need to stand up for him and defy typical gender roles if he weren't being bullied due to his identity as a disabled person. Similar to the intentional shift in point of view from Eli to Lindsay, this scene also displays a shift in gender expectations due to the added identity of disability, which contributes to the looming narrative of disability and sexuality as two separate concepts that shouldn't line up. The implication of Lindsay asking him to the dance was that the only way for this expression of romance to be safe was for Lindsay to step in and save Eli, and for her to assume a masculine role in their interactions. However, even in that situation, Lindsay's facial expressions throughout the scene make it clear that she doesn't have genuine interest in Eli, which reinforces the idea of wrongness for disabled people in romantic contexts.

To change gears a bit, in *Love on the Spectrum*, the trope of the "feminized disabled man" doesn't present itself in its usual form, but it does have an effect on the scene in which Dani is getting ready for her date. As previously mentioned, the visuals at the start of the scene display Dani's bedroom, while a voiceover of her listing sexually explicit titles plays in the background. After this part of the scene, the next clip actually shows Dani sitting on her bed, reading more of the titles out loud. While she's reading these explicit titles, such as "Skin Teasing" and "Erotica and pornography" (Holden, 2024), the viewer can observe very feminine aspects of her bedroom such as her purple bedsheets, a pink floral poster above her bed, and a candle on her nightstand. The feminine backdrop juxtaposed with the words that Dani is saying implies a contrast between expressions of femininity and expressions of sexuality, and the viewer is likely to pick up on that contrast. This leads to the perpetuation of the idea that expressions of sexuality are incongruent with femininity and disability, which is an idea that is likely influenced by the trope of the "feminized disabled man". Just like Lenny's representation in *Of Mice and Men*, in *Love on the Spectrum*, romance and sexuality are represented as wrong when paired with a feminine, disabled person. Similarly, the feminized representation of Eli in *Freaks and Geeks* implies that he isn't able to participate in the typical romantic gender roles of the time, which continues the representation of disability as separate from expressions of sexuality. Just as the audience is meant to feel uncomfortable with Lenny and Eli in romantic contexts due to their "feminine" traits, the audience for *Love on the Spectrum* is meant to feel uncomfortable with Dani's expressions of sexuality due to her identity as a disabled person and her feminine nature.

Essentially, the trope of the "feminized disabled man" was perpetuated through the representation of Lenny's nurturing goals in *Of Mice and Men*, and the swap of gender roles by Lindsay and Eli in *Freaks and Geeks*. Moreover, as disabled women start to gain representation in film and TV, the idea of feminizing disabled men plays into the ways in which femininity is represented for women with disabilities. In *Love on the Spectrum*, Dani's femininity is positioned in contrast with her explicit expressions of sexuality which is reminiscent of the contrast between femininity and expressions of romance for Lenny and Eli in the earlier forms of media. The trope of the "feminized disabled man" has existed in film for almost a hundred years, and although its form changed in order to fit into modern representations of disabled women, its implications were still the same. On the issue of representation, Alan Nadel writes that when "Repeated at sundry sites, in sundry forms, a group of narratives become cogent," (Nadel, 1997). The intersection of femininity and disability are positioned in contrast with expressions of romance and sexuality in all three pieces of media, and that message remains cogent throughout time due to the consistent repetition of the "feminized disabled man" trope.

Conclusion

In summary, the representation of cognitive disabilities in romantic contexts can be very harmful in film, and this can be seen through the creation and perpetuation of the "naive disabled person" and "feminized disabled man" tropes in regards to romance. The trope of the "naive disabled person" developed over time as the implications of it evolved from danger to discomfort surrounding the idea of disabled people in romantic expressions. Furthermore, the trope of the "feminized disabled man" remained persistent in romantic film plotlines for disabled characters, and when cognitively disabled women started to gain more representation in TV, this trope began to impact their portrayal and the ways in which their femininity relates to a viewer's often negative perception of disability and sexuality.

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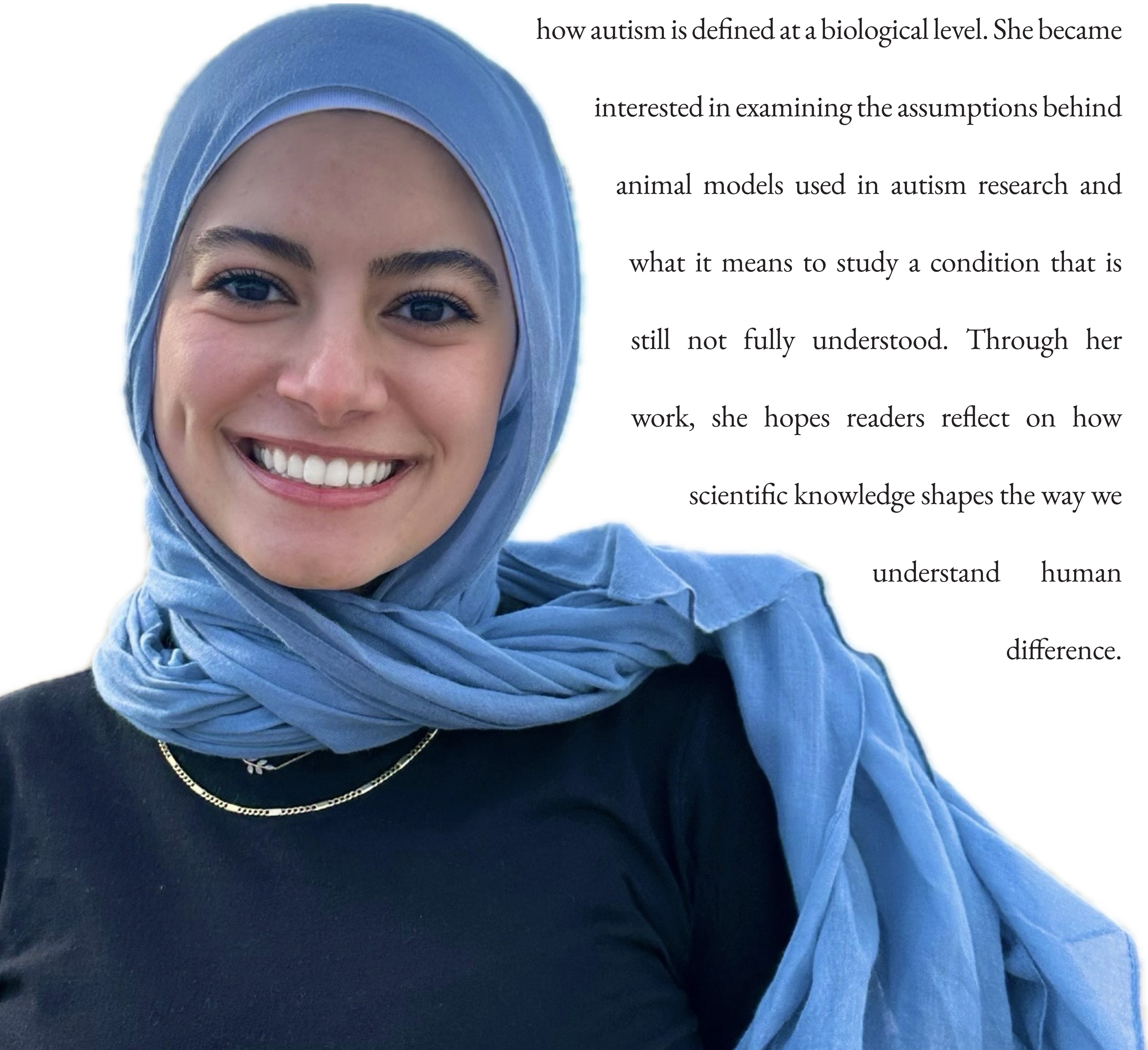

Autism Between Synapses and Society: A Cross-Level Review

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Abstract

Autism is investigated across multiple levels, including genetics, synaptic function, neural circuits, behavior, and social theory. Yet these perspectives often operate independently, leading to different and sometimes competing interpretations of what autism represents. This literature review examines how autism is defined and modeled across biological and social frameworks, with a focus on sensory development and heterogeneity. Molecular and animal research highlights altered synaptic plasticity, inhibitory signaling, and sensory processing, while genetic studies demonstrate that autism reflects multiple developmental pathways rather than a single biological mechanism. At the same time, social and theoretical scholarship argues that diagnostic categories are historically shaped and dynamically interpreted. Population-level surveillance data further show that patterns of autism identification change over time, suggesting that prevalence reflects evolving awareness and clinical practice in addition to biology. Taken together, these perspectives indicate that autism cannot be reduced to a singular essence. Instead, it emerges differently depending on the level of analysis and the interpretive frameworks applied. This review argues for a cross-level, humility-based approach that situates biological findings within broader social and developmental contexts. Rather than resolving autism into one definitive explanation, this review highlights the importance of examining how definitions are constructed across scientific and social domains.

Introduction

A central question in autism research is: What is autism? When reviewing the current literature on autism, one may notice a division when comparing social, biological, and clinical literature. This raises a related question that matters just as much: what does autism mean to autistic people, and how does that compare to scientific and clinical literature?

In biological and clinical literature, Autism is typically defined as a heterogeneous neurodevelopmental condition characterized by differences in social communication and restricted or repetitive patterns of behavior (Gadad et al., 2013; Uchino & Waga, 2013). At the same time, research also emphasizes that autism shows remarkable genetic and phenotypic heterogeneity with multiple developmental pathways rather than a single underlying mechanism (Litman et al., 2025). Social and theoretical literature further argues that autism is more than just a biological condition. This scholarship suggests that autism is a category shaped by historical, cultural, and diagnostic factors (Verhoeff, 2012).

Autism is studied across many levels (genes, cells, circuits, behavior, and experience), but these perspectives rarely communicate with each other. In practice, researchers often rely on biological and animal models to represent autism, and then use findings from these models to make broader conclusions about autistic individuals. The problem is not that these models are inaccurate, but that it is not always clear what exactly they are measuring. Are they measuring autism, or are they measuring more general processes like sensory sensitivity, stress, and adaptation? Since autism is still not fully understood, the conclusions drawn from models should be interpreted carefully and with humility.

Population-level data further illustrate how definitions and identification practices shape our understanding of autism. According to the CDC Autism and Developmental Disabilities Monitoring (ADDM) Network, autism prevalence among 8-year-old children in the United States increased from approximately 1 in 150 in 2000 to 1 in 36 in 2020 (CDC ADDM Network, 2022). Over this same period, demographic patterns shifted. Earlier reports showed higher identification rates among White children and children from higher socioeconomic backgrounds, whereas more recent data show increased identification among historically underrepresented groups, including Black and Hispanic children. In 2022, autism prevalence among 8-year-old children was 36.6 per 1,000 among Black children, 33.0 among Hispanic children, and 27.7 among White children (CDC 2025).

The proportion of autistic children with co-occurring intellectual disability has also changed over time. These shifts suggest that autism prevalence reflects not only biology, but also evolving diagnostic practices, awareness, access to services, and clinical interpretation. If the identification markers for autism have changed over time, then the meaning of the category itself cannot be assumed to be static.

Recent work shows both the promise and the complexity of cross-level autism research. Russo and colleagues propose a sensory-first cascading model, arguing that early sensory differences can shape later developmental and social outcomes (Russo et al., 2025). At the same time, Litman and colleagues demonstrate that autism includes multiple phenotypic groupings that map onto different underlying genetic programs, suggesting that there may not be one single biological pathway that explains autism (Litman et al., 2025). These frameworks support the idea that autism cannot be reduced to a single concept or mechanism.

This literature review examines how autism is represented across scientific, clinical, and lived-experience perspectives, with a focus on sensory and developmental models. By synthesizing what is measured in biological research with how autism is described in social theory and experiential frameworks, this review argues for a more careful approach to interpretation, particularly when translating animal models into claims about autistic lives. Qualitative research offers contextual insight into perception, regulation, and social interaction that may not be fully captured in laboratory measures. Including these perspectives does not replace biological research, but it helps situate findings within the broader meanings attached to autism.

Sensory and Developmental Frameworks of Autism

The social perspective in this review centers on theoretical and historical frameworks and social theory that emphasize meaning, context, environment, and function rather than deficit. Scholars in social science and medical humanities have questioned whether autism can or should be treated as a singular biological entity or fixed clinical object (Verhoeff, 2012; Pettit, 2026). Instead, they argue that autism is shaped by historical, cultural, and diagnostic practices (Pettit, 2026). The way autism is defined influences which behaviors are noticed, measured, and labeled as autistic.

Experiential and interpretive literature has emphasized that autism is not only a collection of observable behaviors but also a lived way of perceiving and regulating within particular environments. When social meaning is excluded from scientific models, there is a risk of misinterpreting behaviors that may serve adaptive or regulatory purposes (Verhoeff, 2012). The meaning of autism depends on who is defining behavior and at what level it is being analyzed. Many behaviors categorized as "symptoms" may function as strategies for regulation within specific contexts rather than simple deficits.

Verhoeff critiques the long-standing assumption that autism is a "natural kind" with a single underlying essence (Verhoeff, 2012). He argues that the significant phenotypic heterogeneity of autism challenges the idea that there is one unifying biological core. Autism presents across a wide range of cognitive profiles, levels of support needs, and behavioral expressions. Diagnostic categories have shifted historically and culturally, which further complicates attempts to locate autism exclusively within a biological framework (Verhoeff, 2012). Efforts to identify a single core deficit overlook the variability found across biomarkers, symptoms, and cognitive traits.

Hacking's concept of "interactive kinds," discussed by Pettit under the framework of historical ontology, further develops this critique (Pettit, 2026). Human science categories are not fixed natural kinds; they are shaped by historical and social processes. Diagnostic labels influence how individuals understand themselves, and individuals, in turn, influence how categories evolve. Autism can be understood through this interactive model, where scientific research, clinical definitions, and lived experiences co-construct the category over time (Pettit, 2026). This perspective challenges strict biological essentialism without rejecting biological research altogether.

Crespi and Badcock propose a different kind of model. They conceptualize autism and psychosis as diametrical disorders of the social brain (Crespi and Badcock, 2008). In their framework, autism involves reduced social-cognitive inference, while psychosis involves exaggerated or hyper-mentalistic tendencies. They draw partly on genomic imprinting theory and discuss biological growth patterns associated with each condition (Crespi and Badcock, 2008). While their model remains biological, it complicates deficit-based interpretations by positioning autism within a broader spectrum of social brain variation rather than framing it as a simple impairment.

Russo and colleagues introduce a cascading sensory model of autism that shifts attention to early sensory processing (Russo et al., 2025). They argue that early sensory differences may influence the later development of social communication abilities. In this framework, early variations in sensory processing influence developmental trajectories, leading to differences in social interaction and behavior (Russo et al., 2025). This model is significant because sensory features were historically underemphasized in autism research, despite being included in DSM-5 criteria, which define autism in terms of differences in social communication and restricted or repetitive patterns of behavior, including atypical sensory responses such as hypersensitivity or reduced sensitivity to environmental stimuli. The inclusion of sensory features reflects growing recognition that sensory processing differences are a core component of the autistic phenotype rather than a secondary feature (Russo et al., 2025). Russo's work suggests that understanding early sensory differences may clarify how later social characteristics emerge.

Litman and colleagues provide further evidence for heterogeneity at the genetic level (Litman et al., 2025). Using mixture modeling, they identify distinct phenotypic classes of autism that correspond to different genetic programs. Their findings suggest that autism does not arise from a single pathway but reflects multiple developmental trajectories with different molecular timing and genetic variation (Litman et al., 2025). This supports a pluralistic view of autism and challenges single-mechanism explanations.

Taken together, these frameworks reveal tension between essentialist models and plural, developmental, and interactive accounts. Autism emerges not only as a neurodevelopmental condition but as a category shaped by biological processes, historical definitions, and lived interpretation. The diversity found in both social theory and genetic evidence makes it difficult to sustain the idea of autism as a singular, unified entity.

Biological Models

Biological scientists have also attempted to answer the question of what autism is by studying it at the molecular, cellular, circuit, and behavioral levels. Many of these models rely on animal systems, especially rodent models, to investigate neural mechanisms that may underlie sensory reactivity and regulation. However, this raises an important question: are these models measuring “autism,” or are they measuring more general processes such as stress, adaptation, or altered development? The interpretation depends on the assumptions made about what autism represents biologically.

One major line of research focuses on Fragile X syndrome (FXS) models. FMR1 knockout mice are frequently used because Fragile X syndrome is one of the most common single-gene conditions associated with autism. These mice lack functional FMRP, which is an RNA binding protein that regulates the translation of synaptic proteins, due to silencing or mutation of the FMR1 gene. Importantly, they model a specific genetic pathway, not autism as a whole.

Because FMRP functions as a regulator of mRNA translation at synapses, its loss is expected to alter synaptic plasticity. Accordingly, Huber et al. (2002) examined synaptic plasticity in FMR1 knockout mice. FMRP had previously been shown to bind subsets of mRNAs and regulate translation. This study investigated how the absence of FMRP affects neuronal function in mammals. They found that mGluR-dependent long-term depression (LTD), which is protein synthesis dependent, was selectively enhanced in FMR1 knockout mice. In contrast, NMDA receptor–dependent LTD remained normal. Rather than showing a simple deficit, the study demonstrated exaggerated mGluR-dependent plasticity. The authors proposed that FMRP plays a critical role in regulating activity-dependent synaptic plasticity and suggested that mGluR antagonists could have therapeutic relevance. This work supports a synaptic dysregulation or plasticity imbalance model rather than a straightforward loss-of-function model.

Patel et al. (2014) further explored synaptic development in FMR1 knockout mice, focusing on cortical connectivity and pruning. Prior hypotheses suggested that hyperconnectivity in FXS and related autistic conditions may result from excessive synapse formation or impaired pruning. Patel and colleagues used simultaneous electrophysiological recordings between neighboring layer 5A pyramidal neurons during postnatal development. Wild-type mice showed normal developmental pruning between postnatal days 15 and 30, reflected in reduced connectivity. FMR1 knockout mice did not show this decrease, indicating persistent connectivity. Connection strength and kinetics were largely unchanged; the primary difference was the presence of connections. The study also observed increased silent NMDA synapses, suggesting delayed pruning rather than overproduction. This shifts the interpretation away from “too many” synapses toward altered developmental regulation of connectivity.

Together, Huber and Patel illustrate that FMRP loss does not produce simple deficits but instead alters synaptic regulation and developmental timing. These findings complicate deficit-based interpretations and instead suggest imbalanced or mistimed plasticity.

A related but distinct mechanism involves inhibitory circuit dysfunction. Kourdougli et al. (2023) investigated parvalbumin (PV) interneurons in FMR1 knockout mice. PV interneurons are key inhibitory cells that regulate cortical excitation and sensory balance. Prior studies suggested reduced PV activity in adult FMR1 knockout mice. Kourdougli examined when this hypoactivity emerges and whether increasing PV activity at different developmental stages could restore circuit and behavioral function. They found that PV interneurons were hypoactive early in development and that this was associated with reduced PV cell density and sensory hyperreactivity. Early activation restored some gene expression patterns but did not fully restore circuit function, whereas activation after the critical period improved behavioral outcomes. This study highlights the importance of developmental timing and suggests that inhibitory dysfunction contributes to sensory hypersensitivity.

O'Shea et al. (2025) extend circuit-level findings to thalamocortical regulation. Studying lateral geniculate nucleus (LGN) neurons in FMR1 knockout mice, they observed reduced burst firing and a shift toward tonic firing modes. They also found reduced calcium currents at hyperpolarized potentials. Because the thalamus plays a central role in sensory gating and filtering, these findings suggest impaired sensory gating mechanisms. Together with PV interneuron findings, this supports models emphasizing excitation–inhibition imbalance and altered sensory processing rather than isolated social deficits.

Behavioral models attempt to translate these cellular and circuit findings into measurable outcomes. Zeidler et al. (2018) examined the effects of baclofen, a $GABA_B$ agonist, on social behavior in FMR1 knockout mice. Previous work suggested that baclofen could correct certain FXS phenotypes. However, in this study, baclofen treatment worsened performance on behavioral tests such as the automated tube test, used to assess social dominance, and the three-chamber sociability assay, which is commonly used to measure social interaction deficits relevant to autism-like behavior in rodent models. This demonstrates the complexity of translating inhibitory circuit theories into behavioral interventions and suggests that excitation/inhibition balance cannot be reduced to a simple pharmacological correction.

Uchino and Waga (2013) reviewed SHANK3 as an autism-associated gene. SHANK3 encodes a scaffolding protein located at excitatory synapses and is critical for synapse formation and maintenance. Mutations in SHANK3, including those seen in 22q13.3 deletion syndrome, have been associated with autism diagnoses. SHANK3 mutant mice exhibit impaired social interaction and repetitive behaviors. This work reinforces a synaptic model of autism, linking molecular synaptic architecture to behavioral outcomes.

Environmental models further complicate the biological picture. Gadad et al. (2013) investigated prenatal exposure to valproic acid (VPA) as a model of autism. Pregnant rodents exposed to VPA produced offspring that showed reduced social interaction, increased repetitive behaviors, elevated anxiety-like responses, and altered sensory processing relative to controls. The review highlights potential cerebellar involvement and demonstrates how environmental exposure can produce autism-like behavioral phenotypes.

Mihalj et al. (2025) also used a prenatal VPA model in rats. They found delayed motor reflexes, reduced ultrasonic vocalizations, altered cortical neuronal branching, and increased expression of GABAergic markers such as Gad65, Vgat, and Gabrb1. Specifically, they observed reduced cortical branching overall and increased arborization in GABAergic neurons. These findings suggest early developmental disruption and altered inhibitory signaling. However, the assumption that all prenatally exposed animals uniformly model autism raises interpretive questions, particularly given known heterogeneity in genetic and developmental pathways.

Across molecular, circuit, and behavioral levels, biological models do not converge on a single mechanism. Instead, they reveal altered synaptic plasticity, disrupted pruning, inhibitory circuit dysfunction, sensory gating abnormalities, and environmental vulnerability. These findings support mechanistic insights but also highlight heterogeneity. Biological research, much like social theory, does not point to a singular unified essence of autism but instead reveals multiple interacting developmental pathways.

Discussion

Across these models, different scientific sources are telling different stories about autism. Molecular studies tell a story of altered synaptic plasticity and developmental timing. Circuit-level research tells a story of excitation–inhibition imbalance and sensory gating differences. Genetic studies tell a story of heterogeneity and multiple developmental pathways. Social theory tells a story about categories that are historically constructed and dynamically shaped. It is important to note that these are not contradictory stories, but they are not identical either.

Autism appears differently depending on the level at which it is observed. At the synapse, it may appear as altered mGluR-dependent plasticity. At the circuit level, it may appear as PV interneuron hypoactivity or thalamic gating changes. At the behavioral level, it may appear as repetition or social withdrawal. At the lived level, it may appear as sensory overwhelm, focus, regulation, or adaptation.

This shift in meaning reflects what Fitzgerald (2017) describes in their ethnographic analysis of contemporary neuroscience. In Tracing Autism: Uncertainty, Ambiguity, and the Affective Labor of Neuroscience, Fitzgerald examines how neuroscientists work within uncertainty as they interpret brain signals, models, and measurements. Rather than uncovering fixed truths, researchers must make careful judgments about what counts as meaningful data, while recognizing that these representations are partial and provisional (Fitzgerald, 2017). Similarly, autistic individuals navigate ambiguity in how their behaviors are interpreted and classified. In both cases, meaning is not simply discovered but constructed through interpretation.

Autism, then, is not reducible to any one level. It is relational. It exists between neurons, environments, and interpretations. Biological mechanisms are real, but their meaning is shaped by the frameworks used to interpret them.

The central question becomes not “what is autism?” but “how is autism being defined in this context, and what assumptions are guiding that definition?”

Recognizing this does not invalidate biological research. Instead, it suggests the need for humility. No single model, whether genetic, synaptic, behavioral, or social, captures the full phenomenon.

Implications

If different scientific approaches are telling different stories, then future research must be more intentional about how those stories are constructed.

For scientists, this may mean designing animal models and behavioral assays that account not only for pathology but also for function. Repetitive behaviors, for example, may represent regulatory processes rather than mere dysfunction. Experimental designs could ask what a behavior accomplishes for the organism rather than only whether it deviates from a norm.

For clinicians, this suggests framing support around sensory environments and adaptive strategies rather than focusing exclusively on correcting behaviors. Understanding regulation as a goal may change intervention approaches.

For research collaborations, bridging qualitative and quantitative methods may help align biological findings with lived meaning. Genetic heterogeneity and developmental timing studies already demonstrate pluralism at the molecular level. Incorporating lived accounts may prevent reductionist interpretations of those findings.

Conclusion

The goal of this review is not to define autism once and for all, but to illuminate how definitions are made.

Across molecular, circuit, genetic, and social frameworks, autism does not appear as a singular unified entity. It emerges as a pattern of differences shaped by biology, development, environment, and interpretation.

By examining how neurons, researchers, and autistic individuals each construct meaning around autism, we move toward a science that acknowledges both mechanism and experience.

A humility-based approach does not weaken autism research. It strengthens it by recognizing that complexity is not a flaw in the data but a feature of the phenomenon itself.

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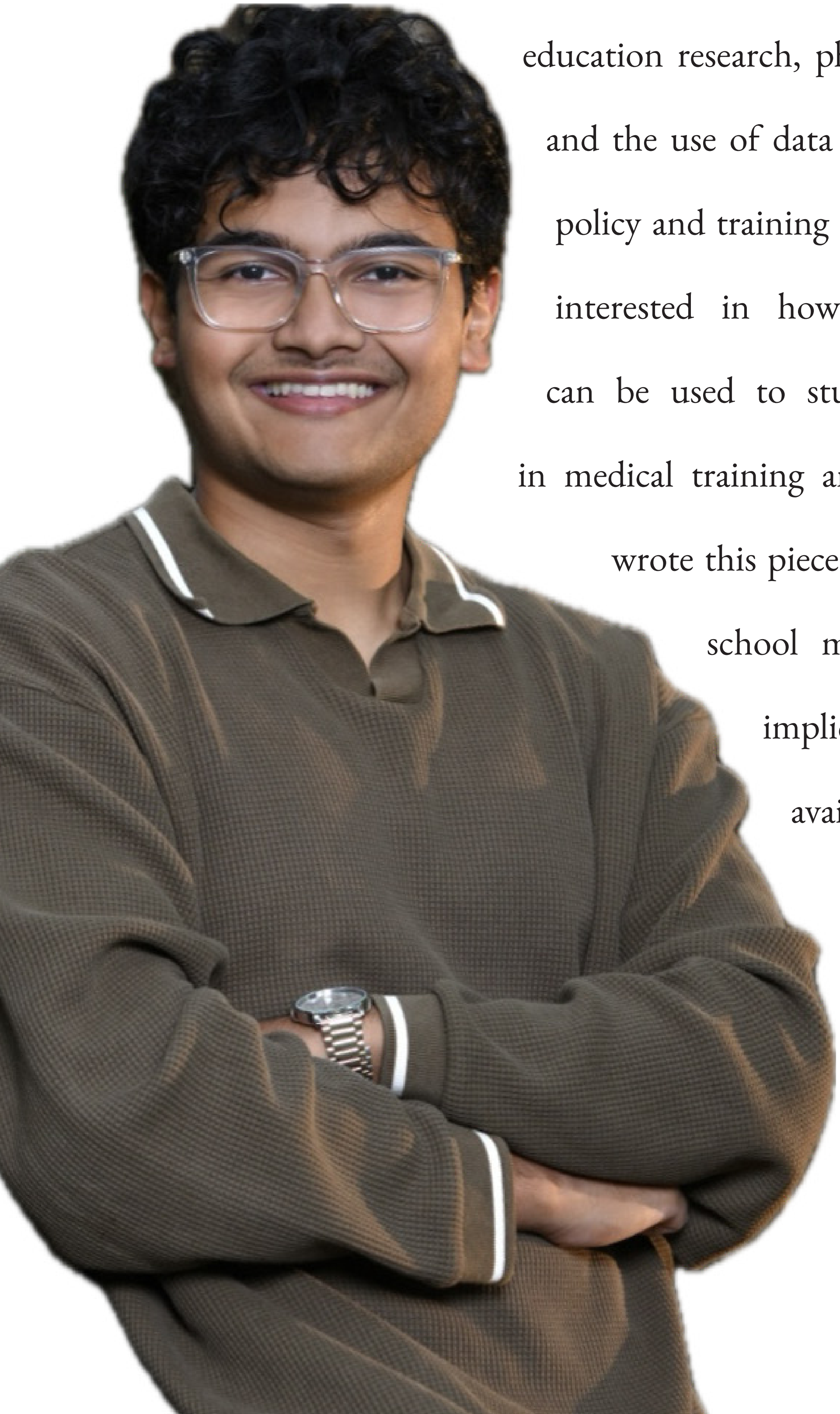

Rising Matriculation Age and the Cost of Delay: Admissions Incentives, Public Investment, and Physician-Years

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Abstract

The average age of U.S. medical school matriculants has steadily increased as gap years have shifted from optional exploration to competitive necessity. Nearly three quarters of recent matriculants are age 23 or older, reflecting delayed entry into medical training. Because medical education is heavily subsidized through federal research funding, graduate medical education payments, and publicly backed student lending, delayed entry into practice carries system-level consequences. This manuscript introduces physician-years as a measure of return on public investment, defined as cumulative years of clinical service delivered after training. Applying observed and projected graduation ages to retirement benchmarks demonstrates a measurable decline in expected physician-years across recent cohorts, with even modest age increases translating into tens of thousands of forfeited physician-years nationally. Simultaneously, admissions incentives that reward prolonged credential accumulation function as socioeconomic filters and misalign with institutional missions centered on diversity, primary care, and service to underserved communities. Realigning admissions incentives to decouple time from competitive advantage offers an upstream strategy to improve workforce supply, equity, and the return on public investment in medical education.

The Rising Matriculation Age

Last year, I was admitted to an early assurance program that guaranteed my seat in medical school. For the first time since starting college, I was no longer competing in the pre-medical arms race of résumé stacking and accumulating hours. Now, as many of my peers at Michigan State approach graduation, what was once the traditional moment to apply to medical school has shifted. Instead of deciding whether to take a gap year, more and more are deciding how many they need just to remain competitive.

Taking a gap year no longer feels like a choice for personal growth or exploration. It is increasingly treated as a requirement, somethinag applicants do because they must, not because they want to. What is often presented as enrichment is beginning to function as an expectation. The average age of medical school matriculants continues to rise, and gap years, once described as optional periods of development, are becoming normalized across the admissions landscape.

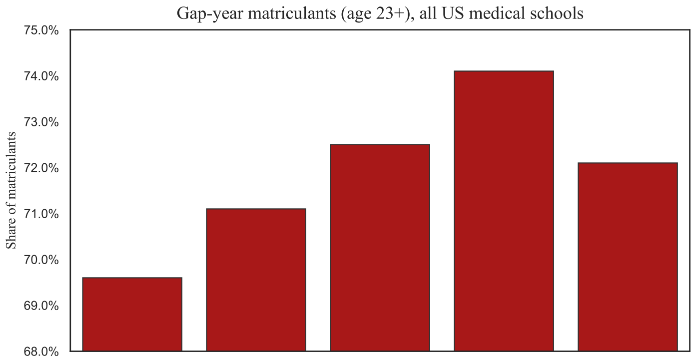

Figure 1. U.S. medical school matriculants aged ≥23 years, 2021–2025 (AAMC, 2023b, 2024b, 2025b) (See Appendix B for more details).

Nearly three quarters of recent medical school matriculants are now 23 or older. Because most students graduate college at 21 or 22, matriculating at 23 or older

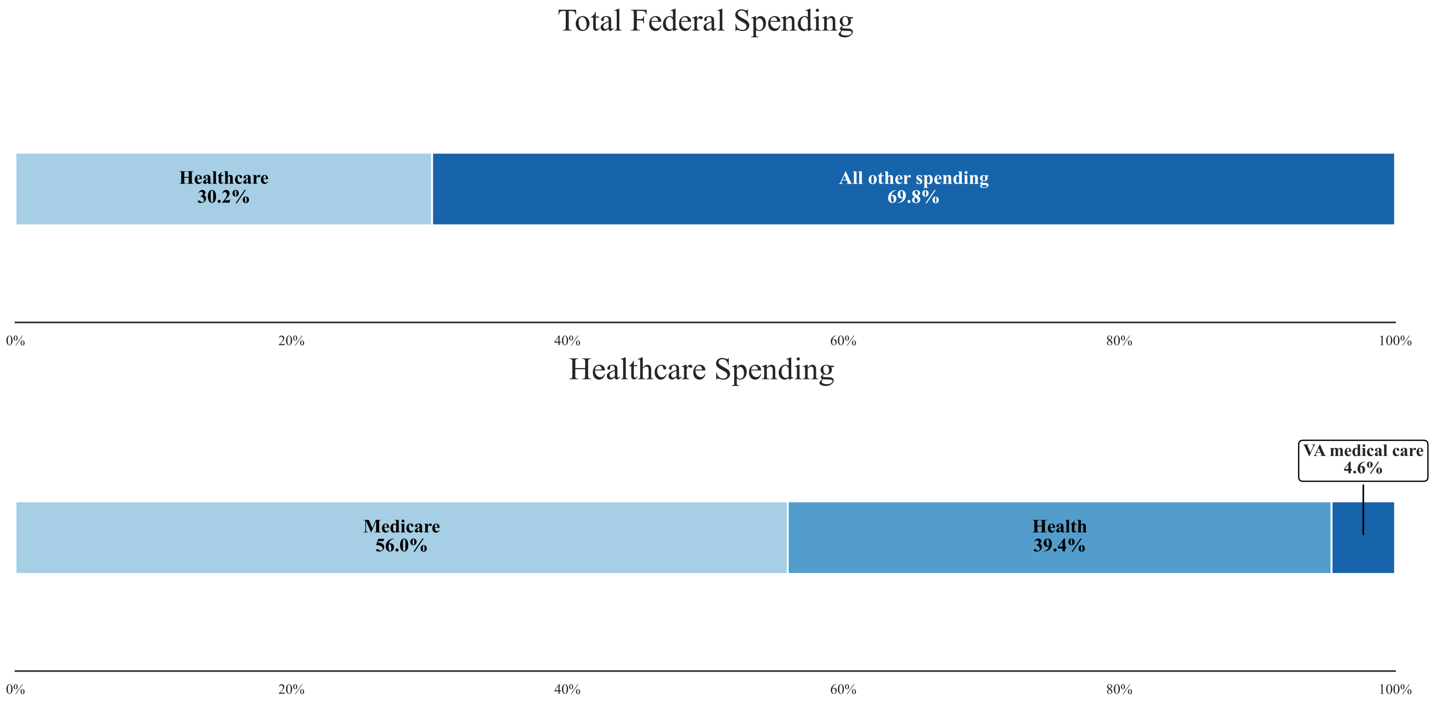

Figure 2. Federal spending by major category and breakdown of healthcare expenditures, fiscal year to date (USDT, 2025).

typically reflects at least one year between undergraduate graduation and medical school entry. In 2021, that figure stood at 69.6 percent. By 2024, it had climbed above 74 percent (Figure 1). The direct transition from undergraduate study into medical school is increasingly the exception rather than the rule. This is not a new phenomenon. As early as 2017, 62.6 percent of entering MD students reported taking at least one gap year (AAMC, 2024a). What was once a majority has steadily moved toward near universality.

Delayed entry into training does not simply alter personal timelines. It shifts when physicians begin practicing and how long they ultimately serve. That timing matters because medical training in the United States is not a private enterprise. It is publicly subsidized at multiple stages.

The Public Investment

So far this fiscal year, roughly one in three federal dollars has gone to healthcare, making it the single largest area of public investment (Figure 2). Medical education operates within that publicly financed system. Federal dollars support medical schools directly and subsidize residency training through graduate medical education funding. Federal support reaches medical training through multiple channels (NIH, 2025; USDE, 2025a; USDHHS, 2025; Heisler et al., 2025). Both undergraduate medical education and graduate medical education depend substantially on public dollars.

Federal and State Funding For Medical Schools

Despite the rising cost of tuition, student tuition and fees account for only about 5 percent of recorded medical school revenue. In contrast, public sources of revenue such as federal grants and contracts comprise roughly 14 percent, with another 8 percent from government and parent support (AAMC, 2024c). Much of this public funding flows through biomedical research. The National Institutes of Health invests roughly $48 billion annually in medical research, most of it awarded as grants to universities and medical schools (NIH, 2025). While not allocated specifically for classroom instruction, these grants finance faculty positions, laboratories, and research infrastructure that underpin medical school overhead (NIH, 2024, Section 7.9.1).

States also contribute directly to undergraduate medical education. Ohio's Clinical Teaching Support appropriations allocate over $33 million annually across public medical colleges to subsidize faculty time and clinical training during the clinical years (Bradford, 2025).

Federal and State Funding for Residency Training

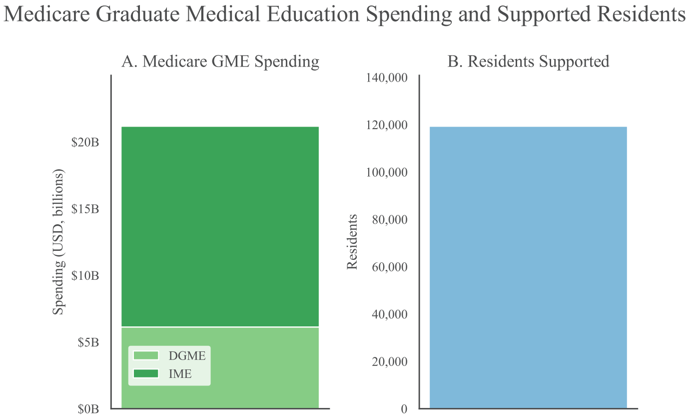

Figure 3. Medicare Graduate Medical Education (GME) spending and resident positions supported, FY2023. (A) Medicare GME spending totals $21.2 billion in FY2023, including Direct GME (DGME) and Indirect Medical Education (IME) payments. (B) Medicare GME supports 119,328 resident physicians in full-time equivalent (FTE) positions. Values reflect FY2023 totals (Heisler et al., 2025).

Public subsidization is even more explicit at the residency stage. Medicare is the largest single source of federal graduate medical education (GME) support with payments in 2023 totaling approximately $21.2 billion, between Direct GME (DGME) and Indirect Medical Education (IME) payments (Figure 3). DGME payments compensate teaching hospitals for resident salaries and supervisory costs, while IME payments are given to account for higher indirect patient care costs (CMMS, 2025; Heisler et al., 2025). These payments operate under statutory formulas and caps, linking public dollars directly to the training pipeline in a structured, policy defined way (CMMS, 2025).

Beyond Medicare, state Medicaid also contributes to GME funding. Medicaid GME payments vary widely across states, but national estimates place spending in the range of several billion dollars annually (Heisler et al., 2025). In Michigan, the publicly reported Medicaid GME pool distributes tens of millions of dollars annually to major teaching hospitals, illustrating how state policy directly finances residency training capacity (MDHHS, 2024).

Public Financing of Medical Students

At the student level, the public finances medical education directly. Graduate and professional students may borrow up to $20,500 per year at a fixed interest rate of 7.94 percent and can borrow up to the full cost of attendance at 8.94 percent through federal loan programs (USDE, 2025a, 2025b). Unlike private lenders, federal programs guarantee access to capital, standardize terms, fix rates for the life of the loan, and absorb default risk, placing the federal government in the position of financier and insurer of medical training.

Public dollars also directly purchase future service. Military Health Professions Scholarship Programs cover full tuition and required fees while providing a monthly stipend during training (U.S. Air Force, 2025). Federal workforce programs administered through the Health Resources and Services Administration similarly fund scholarships and loan repayment in exchange for service in underserved areas (HRSA, 2025).

Across institutions, hospitals, and individual students, medical training is deeply embedded in public finance. Federal and state dollars subsidize research infrastructure, fund residency positions, guarantee student lending, and in some cases directly purchase future service. The pathway to becoming a physician is not one that is paid for solely by those who chose to walk it. Each and every step is paved and sustained by taxpayer capital. The public at large is investing in the years of future clinical service of every physician. The longer it takes a physician to start practicing, the smaller the return on that public investment becomes.

The ROI: Physician-Years

When the public finances the training of a physician, it is not merely funding a degree. It is investing in "physician-years," the cumulative years of clinical service each trained doctor will provide over the course of their career. A physician-year is one year of direct patient care delivered by a fully trained attending physician. Therefore, the total physician-years available from an individual physician can be expressed as:

Physician-Years = Retirement Age – Attending Age

A physician becomes an attending upon completion of residency. Primary care physicians typically complete training three years after medical school graduation and retire from direct patient care at a median age of roughly 65 (Patterson et al., 2016). When those boundaries are applied to observed and projected medical school graduation ages, between 2019 and the projected 2028 cohort, mean physician-years decline from a high of 34.36 to 33.96 years (Figure 4).

Direct Loss: System-Level Service Contraction

That 0.40-year reduction may appear marginal, but nationally, it represents thousands of full professional lifetimes of care that will never be delivered. With total U.S. medical school enrollment at 100,723 students (AAMC, 2025c), a 0.40-year reduction translates to more than 40,000 physician-years of future service forfeited across currently enrolled medical students.

If the average graduation age were to increase by a full year the loss would be equivalent to eliminating roughly 2,900 full primary care careers from the workforce, assuming an average 34-year practice span.

Indirect Loss: Burnout and Workforce Attrition

The calculation above assumes continuous practice until retirement. In reality, not all physicians remain in full-

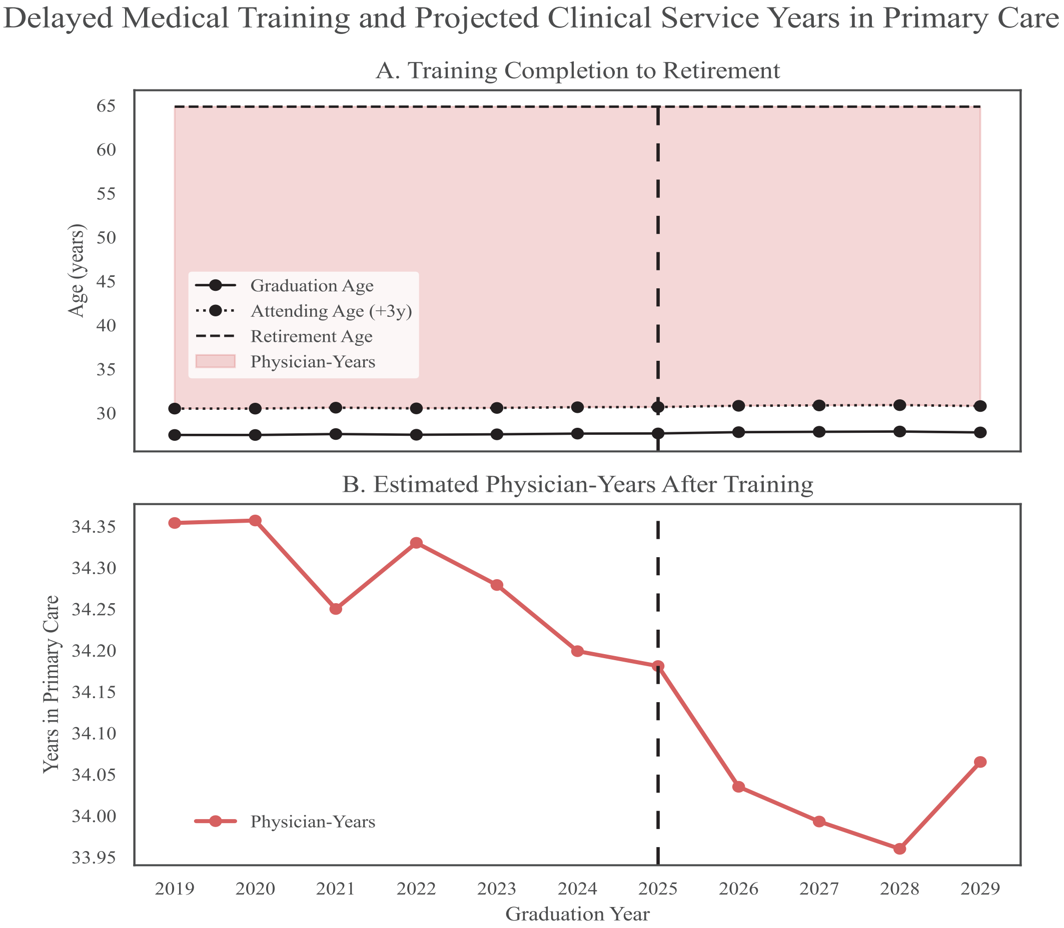

Figure 4. Training completion age, retirement age, and projected physician-years in primary care, 2019–2029 (AAMC, 2023a, 2025a, 2025b; Petterson et al., 2016) (See Appendix B for calculation details).

time clinical care for the entirety of their careers. Burnout remains prevalent. In a Veterans Health Administration workforce study, primary care physicians exhibited some of the highest burnout rates, rising from 46.2 percent in 2018 to 57.6 percent in 2022, with partial improvement in related measures by 2023 (Mohr et al., 2025). Excessive workload, administrative burden, and insufficient recovery time are commonly cited contributors (AMA, 2025).

Importantly, the physicians of today reporting high burnout completed training before gap years became as normalized as they are now. The modern admissions system increasingly selects for prolonged premedical timelines characterized by competitive credential accumulation, extended unpaid clinical work, and delayed financial stability. Sustained high-pressure performance prior to entry into practice may compound stress before physicians begin practicing independently.

If physicians enter the workforce later and already fatigued, two effects compound:

1. Fewer physician-years due to delayed entry.
2. Greater risk of reduced clinical hours, transition to non-clinical roles, or earlier exit from practice.

The system therefore faces not only direct loss from delayed entry, but potential attritional loss from diminished career longevity.

Medical School (Ad)missions: Having Your Cake and Eating It Too

Across the country, medical schools articulate a clear mission: to train physicians who reflect and serve their communities. Mission statements routinely invoke diversity, health equity, rural care, and service to underserved populations. Of the 176 U.S. MD-granting schools, 99 explicitly reference diversity and 47 specifically mention service to underserved or rural communities in their mission statements (AAMC, 2023c).

At face value, the commitment is clear. Yet something does not line up.

The modern admissions landscape increasingly normalizes one, two, sometimes three gap years between college and medical school. Applicants are incentivized to accumulate low paid clinical work, unpaid research, and volunteer experiences that enhance competitiveness while delaying financial stability.

Who can afford that delay?

Not students who must begin earning immediately. Not those supporting families. Not those without the option of living at home rent free. The capacity to tolerate prolonged low income becomes a socioeconomic filter. By rewarding extended credential accumulation, the system advantages applicants with financial insulation and disadvantages those without it.

Primary Care and the Self Selection Problem

The same misalignment appears in the primary care workforce. The AAMC projects a shortage of 20,200 to 40,400 primary care physicians by 2036, with rural and underserved communities most affected (AAMC, 2024d). Yet primary care remains among the least competitive residency matches, with fewer applicants per position and persistent unfilled slots (NRMP, 2024, 2025).

That reality is hard to reconcile with the fact that 65 of 176 U.S. MD-granting schools explicitly reference primary care, community, or rural practice in their mission statements (AAMC, 2023c).

Schools state that they value community physicians. The admissions arms-race rewards something else.

An environment that incentivizes prolonged metric optimization may also favor applicants oriented toward competitive specialty pathways. If admissions were primarily selecting for sustained commitment to primary care, those positions would not remain persistently less competitive and prone to unfilled slots (NRMP, 2025).

Extended gap years favor applicants who strive to chase publications, prestigious research roles, and increasingly optimized metrics. By rewarding the maximization of competitiveness, admissions may disproportionately elevate applicants positioned for specialty competitiveness while filtering out those more likely to enter primary care or return to underserved communities. The pattern becomes self reinforcing:

- Missions emphasize community need.
- Admissions reward extended optimization.
- Financially insulated applicants disproportionately matriculate.
- Competitive specialty pursuit remains attractive.
- Primary care shortages persist despite mission statements.

The system attempts to maximize prestige and social accountability simultaneously, pursuing diversity alongside elite metrics, rural representation alongside research productivity, and community physicians alongside top board scores.

It is trying to have it both ways.

Premeds: The Front End Bottleneck

In the 2025–2026 cycle, more than 54,000 applicants competed for U.S. medical school seats, and only about 43 percent ultimately matriculated (Figure 5; AAMC, 2025c). The majority of applicants, including reapplicants, don't get in.

In any given cycle, admissions operates as a zero sum tournament. For one applicant to secure a seat, others must not. As acceptance rates decline and applicant numbers rise (Figure 5; AAMC, 2025c), gap years shift from optional exploration to strategic necessity. They no longer function primarily as time for reflection, growth, or maturity. They function as competitive optimization windows.

Clinical hours, research publications, service roles, leadership titles, second applications. In an arms race, no credential confers durable advantage, because competitors accumulate the same signals in response. The timeline stretches not because students are unsure, but because the system rewards more. When the same accolades are assembled in the same sequence for the same signaling purpose, the experience becomes standardized rather than developmental.

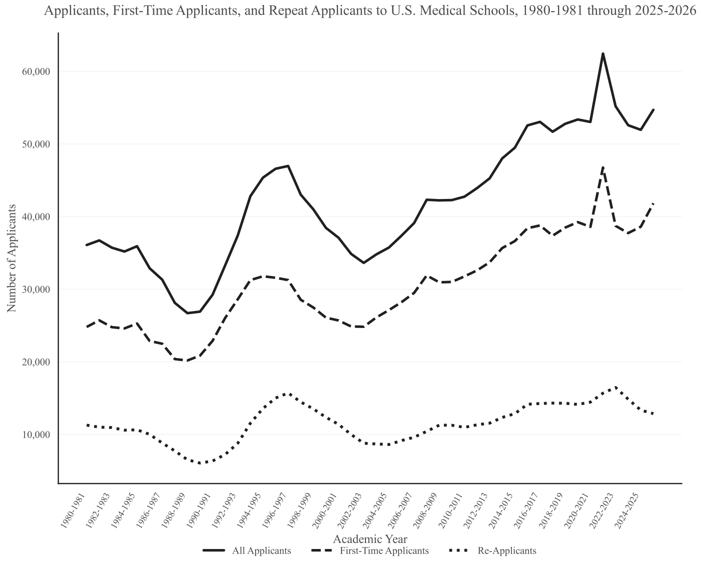

Figure 5. Applicants, First-Time Applicants, and Repeat Applicants to U.S. Medical Schools, 1980–1981 through 2025–2026. Recreated from AAMC FACTS Table 1 data (AAMC, 2025d).

The result is predictable: mutually assured escalation, résumé inflation, financial exposure, deferred earnings, psychological strain, and multi-year uncertainty, all the while applicants grow older and more credentialed without becoming more mature.

Attrition and Human Capital

A system in which fewer than half of applicants matriculate in a given year necessarily produces attrition over time. Not everyone has the means to reapply indefinitely. Some leave medicine entirely, either voluntarily or because they cannot afford to continue.

Certainly those individuals are not unmotivated or unqualified. Just to make it to the application stage, they completed prerequisite science coursework, sat for the MCAT, and sustained years of service and research engagement. They are high-achieving, science-trained, service-oriented students who invested years of their lives into a single professional trajectory.

When applicants pivot after multiple cycles, the result is structural inefficiency. Aggregated across applicants, the lost time accumulates not as forgone physician-years but as unrealized academic-years: years spent in admissions limbo that could have been redirected earlier to contributions across science, engineering, public health, industry, or research. Delayed filtering delays the reallocation of academic talent: an internal brain drain. The public subsidizes medical education because it values physician labor, yet this upstream pathway absorbs thousands of academic-years from individuals drawn from the upper tail of academic and scientific achievement, years that never translate into clinical practice and delay potential contributions elsewhere.

The Solution: Decoupling Time From Advantage

Medical schools state that they value diversity, service, and primary care. Yet the admissions arms race disproportionately rewards applicants who can afford prolonged, low income optimization. If the goal is both social accountability and workforce efficiency, the structure must change.

Two reforms follow:

1. “Normalize” the Gap Year

Gap years do not need to disappear, but they must stop conferring competitive advantage. Schools can accomplish this by publishing explicit diminishing returns for common escalation signals: capping the evaluative weight of post-graduation research beyond a defined duration, standardizing how clinical hours above a competency threshold are considered, and clearly stating that excessive credential accumulation does not increase admissions probability.

The purpose is not to eliminate development, but to decouple time from advantage. When additional years no longer systematically improve admissions odds, escalation slows and delayed entry will naturally reach an equilibrium.

2. Conditional Acceptance With Built In Development

Schools can reduce uncertainty by offering conditional acceptance during college, followed by a structured development year prior to matriculation. Programs at Northeast Ohio Medical University illustrate this model, allowing students to reserve a future seat and either matriculate immediately or defer to a later cohort (Moses et al., 2023).

This development year can remain intentionally flexible, allowing students to work, save money, or pursue service or clinical engagement without admissions penalty. Schools select mission-aligned students earlier through provisional admission rather than relying exclusively on post-graduation credential accumulation.

Realigning Incentives in the Premedical Pipeline

This manuscript began with rising matriculation age and declining physician-years. It traced the public financing of medical education and quantified the system-level loss from delayed entry.

At the center lies a simple asymmetry:

- The public invests early.
- The system delays output.
- Applicants absorb the risk.

Because medical education is publicly subsidized, efficiency is not merely a private concern. Delayed entry reduces cumulative service. At the same time, competitive escalation filters by financial insulation, not community need or mission alignment. These are not separate problems but two expressions of the same structure: time becomes a purchasable advantage, and workforce supply is reduced in the process. The admissions system cannot simultaneously maximize prestige, prolong uncertainty, and claim to address physician shortages.

The purpose is not to eliminate gap years or discourage exploration. Time away from direct training can be restorative, exploratory, or necessary. But it should be chosen, not compelled. A gap year should feel like freedom, not obligation.

Physician shortages and workforce imbalances have been well documented. Delayed entry cannot be treated as neutral. The pipeline does not begin at residency. It begins with the premedical pathway. Reform will require broader coordination, but it starts with individual medical schools, because they control admissions incentives and therefore the structure of delay itself.

Right now, that front end is where the inefficiency begins.

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Appendix A: Calculations

Calculation of Federal Healthcare Spending Share

Federal healthcare spending was estimated from FY2026 year-to-date (YTD) obligated shares reported in the USAspending Budget Function Explorer (USDT 2025).

Healthcare was defined as the sum of the Medicare and Health budget functions plus the hospital and medical care sub-function within Veterans Benefits and Services. Veterans medical spending was isolated because the Veterans Benefits and Services function includes both healthcare and non-medical income support.

Extracted FY2026 shares:

- Medicare: 16.9%
- Health: 11.9%
- Veterans Benefits and Services: 4.6%
- Hospital and medical care sub-function: 30.3%
    - Veterans healthcare share = 4.6% × 30.3% = 1.39%

Total federal healthcare share = 16.9% + 11.9% + 1.39% = 30.2% of FY2026 YTD federal outlays

Replication: retrieve FY2026 shares for Medicare, Health, and Veterans Benefits from the USAspending Budget Function Explorer, obtain the VA hospital and medical care sub-function share, multiply to isolate VA healthcare, then sum the three components.

Source: (USDT 2025)

Calculation of Michigan Medicaid Graduate Medical Education (GME) Pool Total

Michigan Medicaid Graduate Medical Education funding was estimated using the publicly available 2024 GME Pool distribution document published by the Michigan Department of Health and Human Services (MDHHS, 2024).

The document reports facility level payments across three columns:

- GMEH Payments
- Podiatrist Payments
- GMEH Dental and GMEP Payments

To calculate total statewide GME pool distributions, the reported totals from each column were summed.

GMEH Payments: $142,734,919
Podiatrist Payments: $617,968
GMEH Dental and GMEP Payments: $19,535,420

Total Michigan Medicaid GME Pool Payments:

$142,734,919 + $617,968 + $19,535,420 = $162,888,307

Rounded total reported in text: approximately $163 million.

<u>Replication:</u> retrieve the “2024 Graduate Medical Education Pool” distribution document from the Michigan Department of Health and Human Services website, extract the statewide totals listed for GMEH, Podiatrist, and GMEH Dental/GMEP payment categories, and sum the three values.

<u>Source:</u> (MDHHS, 2024)

Calculation of mean of reported annual medians age of Retirement of Primary Care Physicians

Retirement age was estimated from Petterson et al. annual median retirement ages by taking the simple arithmetic mean of the yearly medians reported for 2010 to 2013 in the `median_retire_age_direct` column.

Extracted annual medians (direct patient care):

- 2010: 64.7
- 2011: 64.9
- 2012: 65.1
- 2013: 64.7

Mean retirement age:

(64.7 + 64.9 + 65.1 + 64.7) / 4 = 64.85 years

<u>Replication:</u> retrieve the annual median retirement ages for primary care physicians from Petterson et al. for 2010 to 2013, sum the four median values, and divide by 4 to obtain the mean retirement age used in the analysis.

<u>Source:</u> (Petterson et al 2016)

The 40,000 Physician-Years National Extrapolation Calculation

<u>Source of 0.40-year reduction:</u>

From Figure 4, mean physician-years decline from 34.36 years (2019 cohort) to 33.96 years (projected 2028 cohort).

Decline in physician-years per student:

34.36 – 33.96 = 0.40 years

<u>National extrapolation:</u>

Total forfeited physician-years =

(Decline in physician-years per student) × (Total enrolled students)

= 0.40 × 100,723

= 40,289.2 physician-years

≈ 40,000 physician-years (rounded to nearest thousand)

Replication:

1. Retrieve mean physician-years for 2019 and projected 2028 from Figure 4.
2. Subtract 33.96 from 34.36 to obtain the per-student decline of 0.40 years.
3. Multiply 0.40 by total U.S. MD enrollment (100,723, AAMC 2025c).
4. Round to the nearest thousand for narrative reporting.

Sources: (Figure 4; AAMC, 2025c).

The "2,900 Full Careers" Calculation

Derivation of mean modeled career length:

From Table 2 (Panel B of Figure 4), physician-years by cohort (2019–2029) are:

34.35, 34.36, 34.25, 34.33, 34.28, 34.20, 34.18, 34.04, 33.99, 33.96, 34.07

Mean physician-years across 2019–2029:

(34.35 + 34.36 + 34.25 + 34.33 + 34.28 + 34.20 + 34.18 + 34.04 + 33.99 + 33.96 + 34.07) ÷ 11

= 376.01 ÷ 11

= 34.18 years

Rounded for interpretability and conservative reporting:
34.18 ≈ 34 years

This value represents the modeled average duration of direct patient care after training and before retirement.

Physician-years lost from a 1.00-year reduction applied nationally:

Physician-years lost =
1.00 × 100,723
= 100,723 physician-years

Convert physician-years into equivalent full careers:
Equivalent full careers =
100,723 ÷ 34
= 2,962.44
≈ 2,900 full careers

Rounded to nearest hundred for narrative clarity.

Replication:
1. Retrieve physician-years for 2019–2029 from Table X2.
2. Compute the arithmetic mean of those 11 values.
3. Round the mean to 34 years for modeling clarity.
4. Multiply total enrollment (100,723, AAMC 2025c) by a 1.00-year change.
5. Divide by 34 to convert total physician-years into equivalent full careers.

Sources: (Table 2; AAMC, 2025c).

Calculation of Mission Statement References to Diversity, Underserved or Rural Service, and Primary Care or Community Practice

Mission statements for U.S. MD-granting medical schools were obtained from the AAMC MSAR mission statement compilation (AAMC, 2023c). Each listed school was treated as a single observation.

Three binary indicators were defined:

Diversity reference: mission text contains any of the terms "diversity," "diverse," "inclusion," "equity," or "disparities."

Underserved or rural service reference: mission text mentions "underserved" or "rural."

Primary care or community practice reference: mission text contains "primary care" or "community."

Each mission statement was reviewed once and coded for the presence of either of the three categories. Schools were counted once per category regardless of multiple mentions within the same mission.

Counts were summed across all schools in the compilation.

Extracted counts:

- Total MD-granting schools: 176
- Schools referencing diversity: 99
- Schools referencing underserved or rural service: 47
- Schools referencing primary care or community: 65

Share referencing diversity = 99 / 176 = 56.3%

Share referencing underserved or rural service = 47 / 176 = 26.7%

Share referencing primary care or community = 65 / 176 = 36.9%

Replication: obtain the AAMC MSAR mission statement compilation, review each school's mission text, assign binary indicators based on the specified keywords, and sum counts across schools.

Source: (AAMC, 2023c)

Acceptance rate derivation using AAMC FACTS Table 1 (2025–2026)

Acceptance rate definition:

Acceptance rate = Matriculants / Applicants
FACTS Table 1 values (2025–2026):
Applicants AA = 54,699
Matriculants MM = 23,440
Acceptance rate =23,440 / 54,699= 0.4286 = 42.86%≈43%

Replication: Retrieve Applicants and Matriculants for 2025–2026 from AAMC FACTS Table 1, divide matriculants by applicants, multiply by 100 to express as a percent, and round to the nearest whole percent to match the manuscript text.

Source: (AAMC, 2025c)

Appendix B: Charts and Figures

All data and figures and code stored in Google Drive:

https://drive.google.com/drive/folders/1wq43WaIfZSEZX2Tu5c9BfyCZtqaQLuth?usp=sharing

Figure 1-

Percentages were calculated by summing AAMC age-group shares for 23–25, 26–28, and >28 years in each matriculation year. Bars denote annual proportions; values are labeled. Y-axis shown from 68 to 75%.

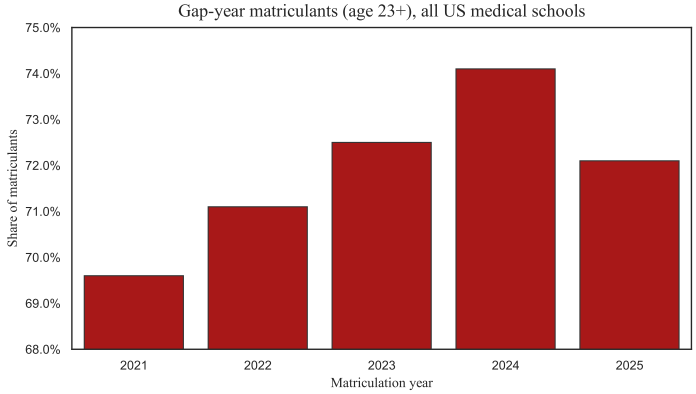


Figure 4 - Training completion age, retirement age, and projected physician-years in primary care, 2019–2029

Physician-years were defined as the expected duration of direct patient care after completion of training and before retirement. For each graduation year:

Physician-years = retirement age – attending age

Attending age was defined as graduation age plus a typical 3-year primary care residency.

Observed graduation age (2019–2025)

Mean graduation age for each year was estimated from AAMC Graduation Questionnaire age-bin distributions (AAMC, 2023a, 2024b, 2025a). Reported bin percentages were converted to an approximate mean using midpoint assumptions:

- Under 24 → 23
- 24–26 → 25
- 27–29 → 28
- 30–32 → 31
- Over 32 → 34

Mean graduation age = Σ(percent_bin × midpoint_bin) / 100

Projected graduation age (2026–2029)

Future graduation ages were projected by shifting AAMC matriculant age distributions (AAMC 2025b) forward by four years (typical medical school duration). Mean matriculant age was estimated from AAMC matriculation age bins using midpoint assumptions:

- Under 20 → 19
- 20–22 → 21
- 23–25 → 24
- 26–28 → 27
- Over 28 → 30

Mean matriculant age = Σ(percent_bin × midpoint_bin) / 100

Projected graduation age = mean matriculant age + 4

Projected graduation years therefore correspond to matriculation years + 4 (e.g., 2022 matriculants → 2026 graduates).

Attending age

Attending age = mean graduation age + 3 years

Three years reflects the standard duration of U.S. primary care residencies (family medicine, internal medicine, pediatrics).

Retirement age anchor

Retirement age was defined as the median age of retirement from direct patient care among U.S. primary care physicians reported by Petterson et al. (2016). The mean of yearly medians (2010–2013) was used as a constant retirement benchmark:

Retirement age ≈ 65.0 years

This value was applied uniformly across graduation cohorts.

Physician-years calculation

For each graduation year:

Physician-years = retirement age – (graduation age + 3)

Example (2025 cohort):
Mean graduation age ≈ 28.1
Attending age ≈ 31.1
Physician-years ≈ 65.0 – 31.1 = 33.9 years

Projection boundary.

The vertical dashed line at 2025 marks the transition from observed graduation ages (AAMC GQ) to projected values derived from matriculant age distributions shifted forward by four years.

Replication.

1. Retrieve AAMC Graduation Questionnaire age-at-graduation bin percentages for 2019–2025.
2. Convert bins to mean graduation age using stated midpoints.
3. Retrieve AAMC matriculant age distributions for 2021–2025 from the 2023 and 2025 Matriculating Student Questionnaire.
4. Convert bins to mean matriculant age using stated midpoints.

5. Add four years to obtain projected graduation ages (2026–2029).
6. Add three years to obtain attending age.
7. Subtract from retirement age (≈ 65) to obtain physician-years.
8. Plot graduation age, attending age, retirement age, and physician-years.

Sources: (AAMC, 2023a, 2025a, 2025b; Petterson et al., 2016)

Appendix C: Additional Figures

Figure 1B: U.S. medical school matriculants aged ≥23 years, 2021–2025. (Non-truncated)

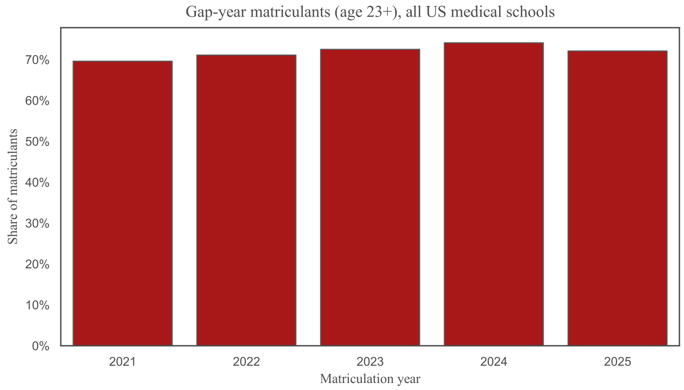
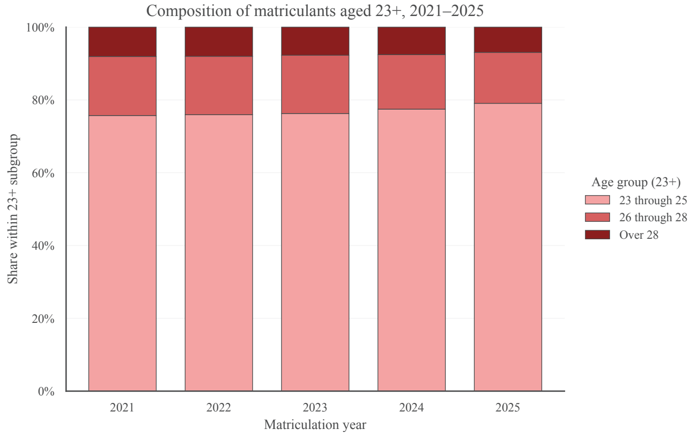


Figure 1C: U.S. medical school matriculants aged ≥23 years, 2021–2025. (Non-truncated,broken down by age group)



Appendix D: Data Tables

Table 1: Derived totals for matriculants aged ≥23 years based on AAMC MSQ age-group distributions, 2021–2025. Corresponds to Figure 1 in the Main Text.

Year	Total 23+ (%)
2021	69.6
2022	71.1
2023	72.5
2024	74.1
2025	72.1

Note: Values calculated by summing AAMC Matriculating Student Questionnaire age categories 23–25, 26–28, and over 28 years (AAMC 2023b, 2024b, 2025b).

Table 2: Modeled Physician-Years and Physician-Months by Graduation Cohort, 2019–2029. Corresponds to Panel B of Figure 4 in the Main Text.

Year	Graduation Age	Attending Age	Physician-Years
2019	27.50	30.50	34.35
2020	27.49	30.49	34.36
2021	27.60	30.60	34.25
2022	27.52	30.52	34.33
2023	27.57	30.57	34.28
2024	27.65	30.65	34.20
2025	27.67	30.67	34.18
2026	27.82	30.82	34.04
2027	27.86	30.86	33.99
2028	27.89	30.89	33.96
2029	27.78	30.78	34.07

Note: See Appendix B: Figure 4 for more information on how each of these values were calculated.

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Through the Lens: A Photographer’s Perspective

The cover image captures a lone figure beneath a tree, gazing up at the Milky Way. The photograph was taken in the mountains of Denizli, Turkey, at an elevation of roughly 1200 meters — far from the interference of city lights. In that stillness, the night sky reveals what is otherwise hidden.

Today, much of the natural world remains present, yet unseen. Artificial light and constant distraction have dimmed our connection to what lies just above us. The Milky Way, our home in space, once a familiar presence to every human civilization, has become something that many people will never witness without intentionally seeking it out in the most remote places.

And yet, it is always there. Our galaxy spans roughly 946 quadrillion kilometers across and contains hundreds of billions of stars. The faint band visible in the image is the dense core of the system — home to a supermassive black hole around which everything, including our solar system, orbits. Even more astonishing, the light reaching the camera has traveled for thousands of years, meaning we are not only looking across space, but back in time.

As Carl Sagan once wrote,

> *“The cosmos is within us. We are made of star-stuff. We are a way for the universe to know itself.”*

Climbing to this mountain placed me within that connection, where distance from artificial light revealed the tapestry of our galaxy. In that moment, the sky no longer felt distant, but something I was part of.

Sincerely,

Fatih Gorkem Imamoglu

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We are honored to feature the work of student researchers whose curiosity, creativity, and academic rigor reflect the spirit of discovery. We thank faculty mentors, professors, and instructors across the university who continue to advocate for undergraduate research and education and whose philosophy towards mentorship in the arts and sciences remains unperturbed.

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Support from units within the university ensure the journal's continuation on campus.

We are grateful for all the opportunities that MSU continues to create for undergraduate researchers.

The blue of SPARC is deeply rooted in the green of Michigan State.

From the Editorial Board,
Student Papers in Academic Research Collaborative

Be like Alice. Step through the looking glass.

Cover picture by Fatih Gorkem Imamoglu.