Economies of Scales:
Evolutionary Naturalists and the Victorian Examination System

FINAL DRAFT:


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One May morning in 1870, Thomas Henry Huxley must have sighed in resignation. We can only guess at this sigh, as no record of it exists. Yet it is a plausible inference to make, for such a reaction is the least that can be expected when 3,705 animal physiology exams show up at the door, all having to be marked in three weeks time. Throughout the rest of the month of May, large packets of Department of Science and Art tests appeared at other examiners' doors. John Tyndall received 2,613 exams in magnetism and electricity, and another 2,021 in acoustics, light and heat; Thomas Archer Hirst got 3,995 exams in pure math; Edward Frankland was given 2,694 exams in inorganic chemistry. The biggest subject, in physical geography, had 5,435 exams. This was examining on an industrial scale.

This paper looks at scientific and evolutionary naturalism from an exam-centered perspective. Its focus is written exams between the early 1850s and the late 1870s: mostly science tests, especially Huxley's, although the points made about Huxley's exams can easily be extended to other scientific naturalists who also ran examinations. Huxley is given extra attention because of his reputation as a pioneering Victorian educationist, someone reforming everything from pedagogical techniques to bureaucracies.

Accounts of Huxley's work in education, and indeed histories of Victorian education in general, tend to equate education with teaching. In such accounts, exams must always be a handmaiden to teaching: necessary evils, but not nearly as important. There is also an overwhelming focus on formal schools, with educational "reform" being equated with the improvement of such institutions (or with external factors such as greater access to these institutions). But it is really only a recent assumption that education only occurs in formal schools, and that educational improvement entails the reform of such schools. There is no necessary connection.
This emphasis on teaching over exams is generally, theoretically, problematic because it ignores one important motivation for attending formal schools: to earn trustworthy credentials. And this perspective is specifically, historically, problematic because it reads the situation backwards: Victorians such as Huxley believed that exams were far more important than teaching, because the examiner's syllabus acted as a de facto curriculum for many Victorian teachers and students, with the later exam then judging whether the material on that curriculum had been properly learned.

Once Huxley's educational career is reframed as being mainly driven by examinations, situated within and informed by this Victorian orthodoxy, then a different picture emerges. For instance, the only way a student could experience Huxley's much-vaunted new teaching laboratory practices at South Kensington was to perform highly in one of his May exams, for these tests determined who was admitted to Huxley's courses. We shall see that H.G. Wells, for instance, only got to study at South Kensington because of his skill at "getting up" different subjects and taking good exams in them.

But Huxley's exams did more than just recruit students to his teaching labs. Those hoping to succeed in his exams were obliged to learn the terminology and the methods of what was coming to be known as "biology." Examinations are tools with which to ensure some level of epistemological conformity, and through exams Huxley had the authority to determine who properly knew biology and who did not. Yet what he considered the proper understanding of biology was associated with metaphysical commitments to scientific naturalism and methodological materialism (the living body seen as a machine, for instance). Candidates wishing to pass their exam had a compelling incentive to follow Huxley's lead and associate such metaphysical commitments with biology. It is highly unlikely that someone answering a question about, say, vision in the language of natural theology would have passed. Due to the sheer numbers of candidates taking his tests, Huxley's exams and syllabi must have been at least as effective as any of his speeches or articles at strengthening the cultural authority of scientific naturalism. Or more effective: unlike casual audiences for speeches or articles, examinees were compelled to closely study Huxley's lessons if they wished to further their educational careers.

This paper first gives a brief history of written exams in England, both before and during the "mania" for these devices in the 1850s. Because this examination culture is best grasped by studying mundane routines, paperwork, and monies earned by individuals, we then look at some specific exam work done by Huxley's friend Tyndall. After laying out the workings of the Department of Science and Art (hereafter D.S.A.), the paper then reconstructs just what Huxley did with those 3,705 physiology examinations that arrived on that May morning in
1870. By focusing on seemingly dull things such as bureaucratic forms, one can supplement the Foucauldian view that exams were disciplinary tools used to maintain "surveillance" over students; for we see that examiners were themselves also subject to elaborate rules and routines.9

Indeed, what emerges is a picture of Victorian exams as parts of large, rationalized, systems of educational standards. The conceptual tools used to study metrology can be easily deployed to understand exams. For instance, it will be noted how the elaborate rules and routines that emerged in the late 1850s to govern various "Local" exams made it possible for the examiner and examinee to transcend local context and particularity. They permitted not only trust in the results, but also uniformity: the conditions under which an exam was conducted in Yorkshire were deemed equivalent to those conducted in Kent. This allowed the form of the written examination to be ignored, making it possible to focus solely on its content - the answers therein, whether penned in Yorkshire or in Kent.10 It is this ability to transcend the local that made exams powerful in Huxley's time - and in our own.

The "general mania" and the standardized routines of "Local" exams

In the 1850s England went through what the Athenaeum called a "mania for examining everybody by written answers to printed questions" - using "the examination-paper, a list of miscellaneous questions, the answering of which requires book-knowledge positively remembered, rather than habits of useful learning ready to be shown." This decade saw oral questions being replaced by written ones. This new materiality was important. Unlike the viva voce, or "living voice" format of oral questioning, written questions could be printed off identically and without limit. Meanwhile a candidate's answers served as an abstraction of his or her knowledge, able to be taken away for further investigation and comparison. In 1845 the American educator Horace Mann compared the written exam answer to a "Daguerreotype likeness, as it were, of the state and condition of the pupils' minds...instead of perishing with the fleeting breath that gave it life, it remains a permanent record."11

To be sure, before the mania of the 1850s there had been written exams at other places in England, such as the Cambridge Math Tripos. Indeed these have been so well studied, most recently by William Clark, Christopher Stray, and Andrew Warwick that it is not necessary to dwell on the Tripos here.12 Yet one point their research makes is worth rehearsing: by acting as a common rite of passage for young men who would go on to various important positions, the Tripos experience made exams into self-evidently valid measures of talent and industriousness, measures worth reproducing in other contexts.13 In other words, a
high scoring Tripos Wrangler who later became a vicar would likely support the testing of a local grammar school's pupils with external written exams. While Cambridge was the "parent of the examination-paper," according to that same Athenaeum reviewer, and likely the earliest school to use written exams in the British Isles, it was not the only English school to use them before the 1850s. They were also employed at military academies such as Woolwich and Sandhurst, and the East India Company's military academy at Addiscombe and its College at Haileybury.

In each of the above cases, however, written exams evolved within each school, fit to the needs of the larger teaching system. At London University it was the other way around: the school was built for the written exam from its 1827 inception. In 1828 it was declared that the "strictness" of its various exams, made intentionally difficult, raised the prestige of the university's credentials; in 1836 the institution was reinvented as an examining-board for King's and University College, having nothing to do with teaching. Subsequently the University of London became utterly dependent upon written exams. While the medical faculty retained some oral questioning, by March 1838 all of London's B.A. exams were written, with viva voce questioning reserved only for unusual cases. One reason was for administrative convenience. Another reason was fairness: written questions allowed honors candidates to be ranked more reliably, and published questions "exposed to scrutiny" the conduct of the examiners. Appeals to fairness were again made when in July 1857 the University of London revised its Charter to make the attainment of its B.A. conditional only on passing its exams. This reform was supposed to give poorer students a chance at a London B.A. by obviating the need to belong to one of its affiliated Colleges (and pay its dues). College membership was no longer necessary - and nor, for that matter, was class attendance. All that ultimately mattered for the London B.A. student was to pass its tests, so confident was its Senate that exams alone could determine who had been properly educated.

By 1857 many other English exam systems had appeared. Some were internal, given by a single school to assess its candidates: these included the exams of the Board of Trade for Masters and Mates of Merchantmen (1850), the Oxford Honours Schools in Math, Natural Science, History, Law and Theology (1850), and the Inns of Court (1856). Others were external, in which candidates from different schools showed up at a single place to take an examination: these included those of the College of Preceptors (1853-54), the Indian Civil Service (1855), and the Society of Arts (1856).

While Scotland tended to have a more homogeneous education system, England's was more sectarian and decentralized, preventing any standard curriculum. As a result external exams came to set English schools' curricula by default. Candidates at external exams were taught to syllabi published by
examiners, then tested to see if they had learned that material. The effect was to crystallize the belief that teaching and examining must be kept separate; since examining set the standards to which teachers and students aspired, it was more important than teaching. Like most Victorians, Huxley took this division for granted. His involvement as an examiner at the University of London only strengthened his self-image of being an examiner first, then a teacher.

Arguably the most important English external exams were the Oxford Local Exams. They started in that watershed year of 1857, which in addition to the new Charter of the University of London saw military and administrative reforms spurred by the Crimean War and Indian Rebellion. The significance of the Oxford Locals was to set out an organizational model that other exam-systems followed, including those of the D.S.A. The Oxford Locals were intended to strengthen private middle-class grammar schools (roughly equivalent to secondary schools) by setting explicit standards and then testing to them. In early 1857, Oxford scholars devised a syllabus of exam topics in subjects ranging from classics and languages to math and chemistry, and sent that syllabus to participating grammar schools around Exeter. Those schools taught the subjects it listed. Then on the morning of Tuesday June 16th, 107 fourteen- and sixteen-year old boys showed up at an Exeter hotel, paid a fee, received an identifying number, and inside standardized booklets wrote answers to questions based on the syllabus. The exams ran for three days. Then the answer booklets were sent back to Oxford and were marked by July 1st. The results were tabulated and published, and the highest scoring candidates won prizes. All who passed received non-degree certificates with Oxford's imprimatur.19

One educational reformer later suggested that the exam method of the Oxford Locals might be "one of the great discoveries of our day" because it combined "economy of labour; absolute uniformity of standard, and all the security of the utmost publicity".20 In modern-day terminology, "economy of labour" and "uniformity of standard" were rationalizing steps. Complicated tests intimately related to local settings - evanescent oral questions of each candidate, or different questions posed at a particular school, for instance - were distilled into simpler tasks and standardized procedures that transcended those local contexts. It was simpler for specialists to draw up questions in their field and delegate the actual running of the exam to a local committee, to organize the boys into age cohorts that answered identical questions, and for the papers to be marked all at once by those same specialists. It was standardized when a schedule of exams was drawn up, a set of specific rules was used to run the exams, and the identical questions printed off on uniform physical documents.21 The third part of the discovery - "security of the utmost publicity" - referred to the eventual publication not only of the results but also of the questions, allowing anyone to see what had been asked at
the exam. The public was thereby assured that the Oxford Locals were trustworthy and impartial indicators of a candidate's knowledge.

The rationalization of the exam process - coupled with a dawning awareness that examiners didn't have to be physically present at the exam itself - made it easy to add new test centers for the Oxford Locals. The assumption that examiners had to be physically present at an exam was likely a vestige of oral testing, and it had restricted just how many candidates could write a single exam. Removing this constraint made economies of scales possible: far more candidates could be tested with a single exam. Hence one year later, in June 1858, the Oxford Locals had ten times as many boys as before (1,223) simultaneously sitting at eleven locations throughout England. More candidates made the Oxford Locals more important. In response, Cambridge started its own Local exams six months later, and London allowed its Matriculation (entrance) exams to be taken at five provincial colleges - provided that extremely detailed rules were followed by candidates and by its own subexaminers to maintain the Matriculation exam's fairness and image of fairness. One year later, in 1859, the exams of the D.S.A. were organized in the same way, with local organizing committees and satellite exam centers.

Overseas exam centers throughout the British Isles, then overseas, were easily added thereafter. By 1864 colonial students were being tested in Trinidad (by Cambridge) and in Mauritius (by London), in exams ranging from Classics to Chemistry. While this is to leave out many complications over the next thirty years, the procedures of Cambridge and London became more refined, and their results trusted enough, that it became unproblematic to compare examinees throughout the British empire, regardless of ethnicity or gender. The point is obliquely made in one 1895 poem celebrating the Cambridge Local Examinations Syndicate.

Though Roman legions ruled the world,  
Though Britain's thunderbolts are hurled  
At Monarchs in Ashanti Plains;  
The Locals Syndicate preside  
O'er realms more gloriously wide,  
Broad as the sky are their domains  
Black babes or yellow, brown or white,  
Cram manuals from morn to night  
No hue from culture now refrains;  
The infant startles from his cot,  
His bottle and his bed forgot,  
To moan aloud the name of K[eynes].
The very standardization of various exams ultimately made it possible for each candidate to be removed from local custom, the "daguerreotype likenesses" of their minds compared with others. Like other systems of standards, the testing procedures had become routine and invisible, a testament to their success. We shall study some of these procedures in more detail with Huxley and his 1870 D.S.A. physiology exam, but first turn to the opportunities that exams offered London men of science in the 1850s.

"At these horrid examination papers" - men of science as examiners

Many scientific naturalists began their careers during the mania of the 1850s, and so exams became a way for them both to shape science and to supplement meager incomes. Large sums of money were available. William Brock has estimated that about half of the £51,884 spent by the D.S.A. between 1853 and 1870 on examining went to men of science, particularly members of the X club such as Huxley, Tyndall, Frankland and Hirst.25

Such large figures are easier to grasp by focusing on individual examiners. Consider the early career of John Tyndall. When he gained his position at the Royal Institution in May 1853 on a salary of £200 a year, promised raises didn't always materialize, so he cast about for ways to supplement his income. In July 1855, as part of a modernization drive, the Royal Military Academy at Woolwich (which trained the Royal Artillery and Royal Engineers) instituted an entrance exam. Tyndall was offered its official examinership in science. He accepted it but grumbled about having to prepare questions not only in physics and chemistry, but also in metallurgy, geology, botany, zoology and entomology. Tyndall's questions were worth only half as much as those in Classics, which didn't seem right for the training of "scientific" soldiers like engineers. It is unclear how much the position paid at first, but when in April 1857 he was offered just £25 to set exams for the next school year, Tyndall resigned.26

However only nine months later, in January 1858, further reforms in military education following the Crimea and Indian Rebellion got Tyndall a new position. He became examiner for the new Council of Military Education. His expanded duties included setting 10 exams for students and candidates at Sandhurst as well as Woolwich. More importantly it paid £150 a year, and Tyndall told Hirst that the position might lead to something important.27 Yet problems again arose: the military once more clawed back his salary by £50, and his questions in experimental science were still worth only one-third of those in Latin and one-half of those in Greek.28

Tyndall became disheartened, sometimes travelling to the wrong exam location by accident, and periodically complaining about "these horrid examination
papers". On both December 20, 1859 and January 22, 1861 he sent Huxley in his stead to watch over the Woolwich exam-takers, in the 1859 case because Tyndall was packing for a continental holiday. In the 1861 case, Tyndall didn’t mark those exams either - citing "unavoidable work", he gave them to Edward Frankland instead. But Frankland procrastinated. The exam was taken on a Tuesday and was due back on a Friday. When Tyndall received an official query as to why they were late, he paid a visit to Frankland's house on Sunday. There, he found that his panic-stricken friend had enlisted his wife Sophie to help him finish his marking; they didn't finish until midnight. Tyndall ultimately resigned his examinership over this incident, although he rationalized it to his mentor Michael Faraday by saying he hadn't been given enough time in which to judiciously assess each candidate. Tyndall didn't mention that he had delegated the marking.

It took T.H. Huxley longer to become jaded about exams, partly because his early years were filled with exam successes. Indeed he favored exams and a scholarship ladder to support poor but talented students because of his own history. In September 1841, at age 16, he wrote to the University of London to ask about its Matriculation exam. A year later Huxley took 9 hours to take a medal exam for the Society of Apothecaries. He'd studied 16 hours a day over the previous 3 months for it. He won its silver medal, which, when combined with a testimonial from John Henry Newman, gained Huxley and his brother free tuition at Charing Cross medical school. There, Huxley earned more prizes. By August 1845 Huxley took London's first Bachelor of Medicine exam, being given the gold medal for anatomy and physiology by examiner William Sharpey. Although he couldn't complete his degree because his scholarship ended, such victories got Huxley talent-spotted as an assistant-surgeon with a scientific bent, getting him posted to *HMS Rattlesnake* rather than to a more typical naval mission. This placement helped to make his career.

If we jump ahead to July 1854, Huxley's first academic appointment at the School of Mines paid £200 a year. At the time his friend Joseph Hooker earned £100 merely for setting two days' worth of botany exams for East India Company medical candidates. "I call that a decent wage," said Hooker coolly. Hooker would later suggest conspiratorially to Huxley that the cultural position of science would be helped when they had "sufficient command over the public, as examiners in London, and as confidential advisors and professors elsewhere". While Huxley must have agreed with Hooker, more concretely the prospect of earning more money must have been just as attractive.

In the summer of 1856 Huxley got a tip from his friend William Benjamin Carpenter: because he'd just been elected Registrar of the University of London, Carpenter would have to give up his examinership in physiology and comparative anatomy. While proclaiming his impartiality, Carpenter encouraged Huxley to
stand for his old position, and to canvass Senate members for the upcoming
election. Thus prepared Huxley ran against four other candidates, and won the
position on July 9. As Sharpey's "grandson," Huxley earned £125 a year to ask
anatomy and physiology questions of medical students, sometimes in the very
same M.B. exam that he himself had shone in 11 years before. When London's new
B.Sc. program began in 1859, four new exams were also added. To ease his
examining load Huxley was joined by George Busk (later another X-club
member). Both men were paid £150 a year - a £25 raise for Huxley.35

The Department of Science and Art: Promoting "free trade in education"

In 1859 Huxley also became an examiner for the Department of Science and
Art, along with Tyndall. Frankland joined the D.S.A. in 1868 or 1869, and Hirst in
1870.36 Covering 23 subjects from machine construction to drawing, from "steam"
to zoology, D.S.A. exams followed the procedures of the Oxford Locals - a board
of examiners set printed questions to be answered at satellite exam centers. But the
D.S.A. added something new: in its mission to produce new science teachers, it
gave money to teachers based on their students’ exam results. Good grades were
literally monetized.

To discuss this shift we must briefly venture into the larger world of English
education. Following the Great Exhibition of 1851, the chemist-turned-civil
servant Lyon Playfair pointed out that Continental participants who won prizes
tended to be those who showed principles of science and art; he suggested that
British industry might improve by following this example. Playfair’s observation
intrigued Prince Albert, who pushed for ways to make British industry more
"scientific." In March 1853 Henry Cole's Department of Practical Art, which
originally had been set up to encourage industrial design, had a "Science" section
added to it, headed by Playfair; the combined group became the Department of
Science and Art. The D.S.A. bought land in South Kensington to establish
museums and other institutions. When in 1856 the D.S.A. was made part of the
new Education Department, its mandate was made clear: increase the number of
English art and science teachers, particularly those of the "Industrial Classes".37

But how? The D.S.A. couldn't set up Normal Schools to train teachers -
spending on education had exploded with James Kay Shuttleworth's new system of
training pupil-teachers, and Chancellor Gladstone, eager to cut the government
budget, was constantly pressing the D.S.A. to reduce expenditures.38 Nor could a
standardized curriculum be imposed - the peculiarly decentralized, class-ridden,
and sectarian nature of English education forbade it. It is worth recalling that in the
1850s there was there was no English education "system" to speak of, if by this
word one denotes a graduated set of levels of formal schooling, usually sorted by
age group. Instead there were smaller branches - a poor student might attend a "British and Foreign school" for a few years; a middle class student might head to a grammar school; an upper class student might go to a public school; a working man might learn at a mechanics' institution.

Following the mid-Victorian passion for "free trade in education", rather than train new science teachers at a central location and thus increase their supply, the D.S.A. decided to stimulate demand for becoming a science teacher. Paying for exam successes clearly rewarded anyone who became a good science teacher. Funding-by-exam-success was an ideal policy for a civil servant because passing an exam was a clear signal that a student had properly acquired scientific knowledge: standards could be set, without having to overburden education inspectors. The exam results were abstractions of knowledge gained - and these abstractions could be quantified and tabulated to defend D.S.A. turf against encroaching political paymasters like Gladstone. By tying payments and the production of new science teachers directly to exam successes, the D.S.A. would be seen as exquisitely responsive to the improvement of science education. (Of course, to accept this notion one would have to equate educational improvement with the increased passing of exams - a point to be discussed below).

The ingenious government mandarin Cole had already experimented with "payment on results" to increase the number of art teachers. By January 1857, Playfair was moving in the same direction. Eager to cut funding for Irish public science lectures (he thought them of dubious value), but requiring justification, he had attendees take exams afterward. Playfair was stunned to learn that the Irish exam answers were "surprisingly good", presumably because the tests had "forced the pupils to read & study". The exam results showed Playfair that how science was taught was not as important as he had assumed. So why not leave teaching to the diverse methods of "private enterprise"? In a letter to Tyndall he declared that it was enough to stimulate science teaching by rewarding by exam results: his Department cared not if science was taught in a school or a "garret, by books, oral demonstration, or Experiment". Playfair's assumptions were precisely the same as those informing the University of London's Revised Charter: passed exams by themselves were sufficiently demonstrative of good teaching.

In June 1858 Playfair left the D.S.A., and Cole became its sole Head. Playfair's administrative duties were given to a 24-year-old Royal Engineer and decorated Crimea veteran, Lieutenant John Donnelly. Like the successful Wranglers and Double Firsts who equated education with exam successes, Donnelly was presumably also well disposed to exams, having entered Woolwich in 1849 as the top candidate. By June 1859 he and Cole had turned Playfair's notions about funding by exam results into a formal process. The new D.S.A. exams combined payment for exam results with the procedures of the Oxford
Locals. Specialist examiners such as Huxley were hired to draw up and then publish syllabi of examinable topics. The first student exams were held in June 1860, and were taken by roughly 500 candidates. Like the Oxford Local exams, the D.S.A.'s own exam system grew rapidly thereafter as new exam centers were added. In 1860, for Huxley's first animal physiology exam, there were about 100-200 candidates. In 1863 there were 349; by 1868, 1,182; and by 1870, to repeat, 3,705.

Protocols of Examination

Just what did Huxley do with those 3,705 physiology exams of May 1870? His actions can be reconstructed with D.S.A. reports, directories and memos, as well as with Huxley's 1872 Devonshire Commission testimony, which is also discussed in Bernard Lightman's chapter in this volume. Such a method necessitates some caution - it sometimes means we must infer particular events from general rules. But this step is necessary to understand how such exams became both uniform (and thus rapidly expandable), yet impartial (and thus trustworthy) measures of science education.

The Animal Physiology exam was one of the most popular of the 23 different D.S.A. topics. Broken up into three subexams, or "papers" in the British parlance, a candidate could only take one a year, and in succession from elementary, through advanced, to honors. Candidates were both male and female and ranged from 11 to 45 years of age. To help candidates prepare, Huxley had issued a biannual syllabus with a list of testable topics since 1860: the more advanced the exam paper, the more specific and searching its anatomical and physiological questions. The syllabus also recommended various books for study, including Huxley's own *Lessons of Elementary Physiology*. Tyndall and Frankland also put their own textbooks on their syllabi, and even recommended each other's. While it would be uncharitable to suggest that financial interest was the only motive, such recommendations to large and captive audiences cannot have harmed the sales of these books: Huxley's *Lessons*, for instance, went through four editions and 29 printings between 1866 and 1895.

As a D.S.A. examiner in both animal physiology and zoology (a far less popular exam), Huxley received a 100 guinea retaining fee in addition to the other monies he earned. A few months before the May exam date, Huxley wrote out the questions for the three papers. Each question was worth a certain number of marks, and only 100 marks' worth of questions could be answered in total. The intention was to create a uniform percentage scale, allowing quantitative comparisons of individual exams. Although the physiology syllabus changed fairly slowly over the preceding decade - its entire point was to prevent surprises, after
all - Huxley nonetheless had to ensure he wasn't repeating "hobby questions". For he was being closely watched by teachers, exam coaches, and students eager to divine what was to be in his upcoming exam. Since each student's exams would bring an average of 13s 7d to his or her school, a great deal of money was at stake.\textsuperscript{51}

The money involved made security important too. The leaking of exam proofs had already caused problems at the University of London. Thus all D.S.A. questions and proofs travelled between Huxley and the printers in special envelopes. Only certain printing houses could be used, and these firms had a single locked room in which all composition, printing, and proof-checking was conducted. Finally, the proofs were watermarked so that if one was leaked it could be traced back to a specific printer. By 1870, while there were some minor cases of cheating, no major cases of exam fraud had yet occurred.\textsuperscript{52}

As Huxley and the printers finished their preparations, arrangements were made for candidates to take the exams. The May 1870 physiology exam was to be taken at 570 centers throughout the British Isles, with 65 in London alone. To set up a new class and assure the D.S.A. that the exam proceedings would be trustworthy, a committee of local residents submitted a form attesting to their own respectability. Sometimes they were then visited by a Department Inspector - if he judged that no committee member held a position with enough "public responsibility", D.S.A. acceptance was withheld until they added someone with such a job.\textsuperscript{53} Meanwhile, exam candidates had until March 31st to pre-register with their local committee. Anyone could take the exam, although only students of certificated teachers would earn D.S.A. payments. New candidates arriving at the test centre on the May exam day were given a unique identification number, partly for privacy and impartial treatment by the examiners, and partly so that the D.S.A. could track each candidate over several years' worth of exams. At 6:55 p.m. in each centre, the relevant sealed exam package was opened in the presence of at least three committee members.\textsuperscript{54} At 7:00 all candidates throughout the British Isles began answering Huxley's questions. Over the next three hours one of 73 specially appointed Royal Engineers might make a surprise inspection to ensure "uniformity of action"; after all, the D.S.A. had two and a half pages of rules governing how exams were to be run.\textsuperscript{55} When the exam ended, the committee filled out yet another form certifying that the rules had been followed, placed the exam papers in yet another security package, and mailed it back to South Kensington.

The speed of the Victorian Post Office meant that the 3,705 animal physiology exams were received by Huxley the following morning. Now he had three weeks to mark them. Thankfully he had the help of one assistant examiner for every thousand papers. Donnelly seems to have arrived at this figure by taking 70 papers marked in a 6 hour day - the tolerable daily limit - and multiplying it by 15
business days. Huxley had hired his assistants well in advance of the exam, insisting that each one be "able and distinguished" in physiology, able to make quick yet accurate judgments on the candidates' answers. Each assistant received £1 for every 20 elementary papers he marked, and £1 10s for every 20 advanced papers. The total amount works out to about £50 per assistant: not a large sum, but a little more patronage that Huxley could dole out, giving him another tool with which to shape his field. Thus Michael Foster - who been one of Huxley's laboratory demonstrators at South Kensington and then his choice as the new praeclector of physiology at Cambridge in May 1870 - eventually became physiology co-examiner; Foster selected various assistant examiners from among his physiology students.

To secure marking uniformity, Huxley and his three assistants met as soon as he received the completed exams. They established their style of marking and defined various levels of answer quality. While Huxley's specific marking style is not known, he did think that the typical answer in the advanced physiology paper was equivalent to that of the average medical student. For his part, Donnelly made suggestions to all D.S.A. examiners: first class papers should score over 69 percent in the elementary paper and 74 percent in the advanced: this mark was attainable by "a well-taught, clever, first year student, or an average second year student". Donnelly's system would give a first class mark to about one-third of the elementary candidates and one-quarter of the advanced. Meanwhile, second class papers should score over 29 percent in the elementary exam and 39 percent in the advanced: a mark open to "a fair, even a large, proportion of moderately stupid" candidates taught well for 30 to 40 lessons. Huxley could mark the honors papers however he liked.

At the end of this first meeting each assistant carried away his batch of 1,000 papers, which would have left 705 papers for Huxley to mark himself (paying at least £35 5s, and taking up just over 10 days in his active schedule). He had to mark the 28 honors papers himself (paying £4 4s). And to ensure that all papers were being marked uniformly, Huxley also had to look over at least 20 percent of his assistants' exams (735 papers paying £1 for every 20 papers checked, earning £36 15s). After grading for about a week, all physiology examiners met again to further calibrate their marking: each assistant brought 50-60 representative and problem papers to the meeting, comparing them, asking Huxley questions, and revising their marking. Sometimes they would meet a third time. Impartiality was important to them: since the candidates were knowable only by numbers, the examiners never knew their identities and didn't want to.

With the papers marked in three weeks, and the D.S.A. having one week in which to prepare the lists and statistical tables, all exam results were published one month later. Thus alerted, qualified teachers could apply to the D.S.A. for any
money they earned by sending in yet another form.\textsuperscript{63} In 1870 a first class elementary or advanced physiology paper paid £2; a second class, £1; a first class honors paper, £4. That year saw the average teacher earning £35 for all of their students' exams; the most paid out was £227 10s. \textsuperscript{64} Although students themselves could not earn Department money, they might win awards: medals, books or instruments, or scholarships both large and small. For Huxley's part, combining all of the payments above plus a few others, such as meeting fees and drawing up questions, he earned about £195 from his D.S.A. examining in 1870.

The monies disbursed, the teaching and acquisition of scientific knowledge thus encouraged, the cycle would move again towards its May 1871 climax. Over the next decade the number of candidates continued to grow: 6,191 candidates took Huxley's physiology exam in 1883.\textsuperscript{65} "[T]o look over a thousand sets of answers to the same paper by people you don't care about, is next door to penal servitude", said one commentator of the D.S.A. exams in that same year,\textsuperscript{66} and it's hard not to shudder in agreement.

\textbf{Huxley's Catechisms?}

In the early years of the D.S.A.'s exams Huxley was enthusiastic about them, telling Hooker in 1864 that they were "the most important engine yet invented for forcing Science into ordinary education". In July 1868 he testified before the first Samuelson Commission that the D.S.A's system was "one of the greatest steps ever made in this country towards spreading a knowledge of science among the people" because it spread science from "below upwards" rather than "from above downward."\textsuperscript{67} But Huxley eventually followed Tyndall into disillusionment. His 1874 Rectorial Address at Aberdeen University looked back to his own days as an examinee: there, he confessed his shame at "how very little real knowledge underlay the torrent of stuff which I was able to pour out on paper". By 1877 Huxley described competitive exams as the "educational abomination of desolation of the present day".\textsuperscript{68}

Huxley's disenchantment was not unique - by the mid-1870s, public opinion had shifted against exams, transforming them from near-magical devices of social reform into distasteful and overused tools. Even Playfair, who in 1857 had done so much to create payment by results, was by 1873 attacking the hegemony of exams.\textsuperscript{69} This new resentment was partly caused by the massive expansion of the system of payment by results. In 1862 the D.S.A.'s system was taken by the Department's Liberal political masters and deployed in the far larger realm of English primary education. Intended to reform and cut costs, the infamous "Revised Code" rewarded teachers at government-funded schools when their children did well in tests in the so-called three R's. The format was seen as too
mechanized. Matthew Arnold, who was a school inspector as well as a poet, thought the policy a disaster. Yet the Revised Code, and more generally what Theodore Porter calls "the strange English prejudice that a new field is best established by creating an examination," was motivated by the classical Liberal belief in "free trade in education" - that it was better to reform education through demand and competition between teachers and students. It was thought that the only impartial way to determine success in these competitions was by written exams.

Unfortunately this verification was indirect. If good teaching was implied simply by exam successes, and funding depended on these successes, then it was in a teacher's interest to do whatever it took to get his or her students to pass exams. One option was to use rote memorization - a term more popularly known as cramming. The metaphor weds gastronomy with epistemology: facts are food to be consumed, but which sometimes remain undigested. For his part Huxley complained of boys being "stood up in rows and crammed like turkeys", or "how those dogs of examinees return to their vomit"; replacing the "folly" of Proverbs 26:11 with an incorrect or misunderstood point regurgitated in its entirety back onto an examination booklet. Teaching and learning by cramming was a rational, and rationalized, response to a rationalized exam-system.

More specifically, cramming was a problem in science: the Rugby science teacher James Wilson remarked in 1867 that fields such as geology and chemistry were "frightfully crammable." Books discussing science in a question-and-answer format abounded, such as Ebenezer Brewer's catechetical *Guide to the Scientific Knowledge of Things Familiar* (1841). Passing written science exams by rote memorization undermined Huxley's oft-stated belief that science was a mental habit, even an ethical stance, instilled by practice and direct observation. Huxley always thought that books alone could not teach science, and he especially disliked Brewer's *Guide*.

Huxley's distaste for cramming was a major reason behind his 1869 development of laboratory teaching methods at South Kensington. Not only were his classes supposed to show science teachers how to better teach their subject - they were also supposed to get them to stop teaching through rote memorization. Exams came first, then Huxley's teaching laboratory and Normal School of Science. The point is exemplified by the career of H.G. Wells, arguably the most famous product of Huxley's lab: Wells only got to South Kensington because he was so successful in D.S.A. exams, and he wrote many to earn money for an entrepreneurial grammar school teacher. Indeed as an exam coach for the University Correspondence College, Wells would later teach students effective ways to pass the University of London biology exams. His cram-course, which he called an "examiner defeating mechanism", was so successful that he condensed it
into an 1893 biology text - his first book. Wells thus probably learned more about science from the exam process than he ever did from Huxley's laboratory. Moreover there is a wonderful irony in Huxley's dislike of cramming and book-learning. For Huxley was placed in the position of having thousands of people every year riding on his every word: not those published in journals or newspapers, but those appearing in his syllabus. Teachers' livelihoods and students' future ambitions depended upon how closely they paid attention to Huxley's examinable topics. And what were the subjects he wanted them to study? Many could not be learned inductively or with trained common sense, because they required prior naturalistic or even materialistic metaphysical commitments. Huxley's September 1863 syllabus, for instance, announces that examinable topics included "the general properties of living matter", "the living body considered as a machine," and "Hereditary transmission, and the modification of physical and mental characters by education, as the basis of a rational belief in the possibility of human progress". Such principles cannot really be learned in a laboratory, no matter how well equipped. This point supports a later criticism made by Henry Edward Armstrong, the chemist who pushed for educational reforms in science teaching: contrary to the popular image of Huxley "as a master of education", Huxley was an overly didactic teacher who assumed that learning about science would automatically be followed by an embrace of its methods. While other examinable topics did not require metaphysical commitments, it was far easier to learn them from books, not experiments. For example, Huxley's February 1870 syllabus requires that students know the meaning of various anatomical terms, the chemical composition of air, water, ammonia, protein and fat, the quantity of "dry solid and gaseous aliments" needed daily by an adult, and the composition of sweat, urine or blood. Such information could quickly be looked up in texts such as Huxley's own Lessons in Elementary Physiology. In a second edition, published by Macmillan in 1868, some of the topics in the February 1870 syllabus are covered in Lesson's new "Table of Physiological Constants".
In the same year that Huxley's *Lessons* appeared, Macmillan (probably seeing a market opportunity) also published a companion book, *Questions on Huxley's Lessons in Elementary Physiology*. As the juxtaposition above shows, *Questions* follows Huxley's format extremely closely, with the physiological constants being the authoritative text to be memorized. To be fair to Huxley, this is why he idealized the practical teaching of biology: initially used to teach religious principles, catechetical instruction—which often led to cramming—was a difficult format to do away with.

Unlike religious catechisms, however, the correct answers to Huxley's questions were those with naturalistic or materialist underpinnings. It is thus not surprising why Huxley described the D.S.A.'s exams as some of the most important measures ever taken to reduce "Parsonic influence" in schools. He worked with what was at hand. The 3,705 candidates of his 1870 physiology exam—the ones who passed, anyway—had not only learned about physiology. They had also learned to associate scientific knowledge with a commitment to naturalism. Knowing this fact may have made Huxley's examining burden a little easier to bear; perhaps his sigh that May 1870 morning was followed by a slight smile.
Illustrations:
Caption:
Figure 1: Huxley's "Table of Physiological Constants".
Figure 2: Alcock's questions to be answered by referring to Huxley's table.

Bibliographic information:

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1 This combines the statistics of the Department of Science and Art's *Eighteenth Report* (London: Eyre and Spottiswoode, 1871), 49, 57, with the examination procedures outlined in Huxley's testimony for the Devonshire Commission, p. 19: Spencer Compton Cavendish, 8th Duke of Devonshire, *Royal Commission on Scientific Instruction and Advancement of Science: First and Second Report, Minutes of Evidence, Appendices* (1872). Unfortunately the precise date in May of Huxley's physiology exam has not been located.

2 Department of Science and Art, *Directory* (London: Eyre and Spottiswoode, 1870), iii; *D.S.A. Eighteenth Report* (1871), 49. In addition to the physiology exams, Huxley had to mark 114 in zoology.


4 The exception here, which does recognize the Victorian tendency to subordinate teaching to exams, is of course the collection of essays in Roy M. Macleod (ed), *Days of Judgement: Science, Examinations, and the Organization of Knowledge in Late Victorian England* (Driffield: Studies in Education, 1982).


this paper does not overtly discuss credentialism and the sciences, it is strongly informed by this perspective.

7 Teachers could not examine because of the inherent conflict of interest in assessing their own performance in the classroom. For this separation being "taken for granted," see for instance Robert Lowe, *Primary and Classical Education* (Edinburgh: Edmonston and Douglas, 1867), 5. Lowe was the politician on whose watch were created the 'payment by results' exams of the both the Department of Science and Art (1858) and primary schools (1862's Revised Code). Karl Pearson's desire to reform the University of London in the early 1890s seems to be grounded in a rejection of the assumed split between examining and teaching. This would be in keeping with his idealization of all things German. See Theodore Porter, *Karl Pearson : The Scientific Life in a Statistical Age* (Princeton: Princeton University Press, 2004), 217-220.

8 Note that this focuses on England, and not Scotland or Ireland, although exams began to draw in non-English jurisdictions for comparison. For instance the Scottish universities, with their wider-ranging Arts degrees, were generally deemed superior to the English ones until the results of the new India Civil Service exams appeared in 1856; candidates taught at English universities did much better on these exams, illustrating the view that exams were unproblematic indicators of educational merit. See Michael Sanderson, *The Universities in the Nineteenth Century* (London: Routledge and Kegan Paul, 1975), 99.


16 *Second Statement by the Council of the University of London* (London: John Murray, 1828), 26-7.


21' Rationalization' denotes here the transformation of a system along certain principles so that more actions can be done with fewer inputs (labour, materials, or time). One kind of rationalization analyzes: breaking down complicated tasks into multiple independent and simpler ones, which facilitates specialization at each simpler task. Another form of rationalization standardizes: making diverse parts and tasks uniform, allowing substitution or repetition. The Oxford Local Examinations, as was the entire shift to written exams, were cases of rationalization by analysis and standardization. This point is informed by Elihu Gerson's "Reach, Bracket, and the Limits of Rationalized Coordination," in Resources, Co-Evolution and Artifacts: Theory in CSCW, ed. M.S. Ackerman, et al. (Springer, 2008), 9-10.


24 This poem is from the Cambridge Review, November 28, 1895. The target of the poem must have enjoyed it, as a copy can be found in John Neville Keynes's “Common-place book,” Papers of Dr. J.N. Keynes, Cambridge Assessment Archives, PP/JNK/1/3. Keynes (father of John Maynard) was then-head of the Cambridge Examinations Syndicate.


27 John Tyndall to Thomas Archer Hirst, January 8, 1858, Royal Institution MS JT/1/HTYP/507.

28 Papers Used at the Examinations for Direct Commissions, and for Admission to the Royal Military College, in July 1858 (London: Harrison, 1858), 13-16. The decline in salary is taken from John Tyndall's letter to Lyon Playfair [nd], 1859, Royal Institution MS JT/1/TYP/3/986.

29 Tyndall, "Journals," VIIIa. December 9, 1859, 1166; December 1, 1860, 1193, Royal Institution.

30 Tyndall, "Journals," VIIIa, December 20, 1859, 1167; January 1861, 1198; March 11 and 13, 1861, 1203, Royal Institution.

31 Jarrell, "Visionary or Bureaucrat?", 227.


33 Desmond, Huxley, 28, 33-35, 37.


35 William B. Carpenter to Thomas Henry Huxley, [Summer] 1856, Huxley Papers, College Archives, Imperial College London, 12.92-3. The four other candidates for the position were Hugh Carlile, Thomas Spencer Cobbold, Croker King and Thomas Williams. University of London, Minutes of the Senate 1855-1858, vol. 4 (London: Taylor and Francis, 1855-1858), 47-8. The figure of £125 of 1856 is inferred by taking the 1865 examiner's wage of £150 then removing the £25 raise added when the B.Sc. began in 1859: "Duties and Remuneration of
Examiners [1866]." University of London Archive, Senate House Library, University of London
RC 40/21; University of London, Minutes of Committees 1853-1866, 86-88.
36 Scholastic Directory for 1861 (London: John Crockford, 1861), 8; D.S.A. Directory (1869), 3;
D.S.A. Directory (1870), iii.
37 Harry Butterworth, "The Science and Art Department Examinations: Origins and
Achievements," in Days of Judgement, ed. Roy M. MacLeod (Driffield: Studies in Education,
1982), 28. The "Industrial Classes" were defined as people not earning enough to pay income
tax, those supporting themselves by manual labour, and the children of people in these two
38 Asher Tropp, The School Teachers: The Growth of the Teaching Profession in England and
Wales from 1800 to the Present Day (Westport, Conn.: Greenwood Press, 1977), 18-19;
Elizabeth Bonython and Anthony Burton, The Great Exhibitor: The Life and Work of Henry
Cole (London: V&A Publications, 2003), 198
39 Harry Butterworth, "The Science and Art Department 1853-1900" (Ph.D. Thesis, University of
Sheffield, 1968), 33; Cavendish, Devonshire Report, xix-xx. The phrase "free trade in education"
can be found in many documents of the period, sometimes used supportively, sometimes used
critically. One disapproving example is in "The London University Calendar for 1857,"
Quarterly Review 9 (1857), 20.
40 This is to follow Ted Porter's point in his Trust in Numbers: The Pursuit of Objectivity in
42 Lyon Playfair to John Tyndall, January 7, 1857, Royal Institution MS JT/TYP/3/982-983.
43 Bonython and Burton, Henry Cole, 185; Margaret Reeks, Register of the Associates and Old
Students of the Royal School of Mines (London: Royal School of Mines (Old Students')
Butterworth notes that Cole was thinking about payment by results as early as 1857; Playfair's
letter shows that he too was considering a similar kind of policy at about the same time.
44 Bernhard Samuelson, Report from the Select Committee on Scientific Instruction (London:
HMSO, 1868), 4; Butterworth, "The Science and Art Department Examinations," 32; Devonshire
Report, xix-xx.
45 100-200 papers: Huxley testimony in Samuelson, Report from the Select Committee on
Scientific Instruction, 401. 1863: D.S.A. Tenth Report (London: Eyre and Spottiswoode, 1863),
10.
46 It was policy to preserve only a few of the best exam papers and a few of the average once
marking was completed, and even these papers didn't last long - all were discarded after a year.
Devonshire Report, 16.
47 Age range: Huxley testimony, Devonshire Report, 25. Female examinees: see Margaret A.I.
Macomish on the register (rated as one of the two best students in Huxley's 1871 biology course
48 D.S.A. Directory (1870), 75, 81, 82-83, 99-103.
49 Jarrell, "Visionary or Bureaucrat?", 232.
50 The rationale for the high wages was that they kept the best possible examiners performing a
job "of a very laborious and repulsive nature". Devonshire Report Appendix, 8.
51 Devonshire Report, xxv-xxvi, Appendix, 6-8; H.S. Roscoe to Thomas Henry Huxley, October
15 1871, Huxley Papers, College Archives, Imperial College London, 25.269.
Allusions to fraud are taken from William Miller's questioning of Henry Cole, Jun 14, 1870; Miller himself mentioned this "considerable difficulty" about exam security. *Devonshire Report*, 15-16, 19. As a professor of chemistry at King's College and as a University of London Senate member, Miller may have been referring to leaks of medical exam proofs.

The D.S.A. exams were held in the evening as many of the science classes were already held at this time; the evening writings also made it easier for the volunteer members of the Local Committee to attend and supervise the exam.

In 1870 teachers were qualified to earn D.S.A. monies in a subject by passing a special teachers' exam (before 1867), gaining a first or second class mark in the advanced paper of that subject, or graduating from any UK university. *D.S.A. Eighteenth Report (1871)*, x-xi; *Devonshire Report*, xxii-xxiii, 3; *D.S.A. Directory* (1870), 8, 38-40.


*B.S.A. Directory* (London: Eyre and Spottiswoode, 1863), 40.

Armstrong, "Our Need to Honour Huxley's Will," 70.
